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IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

IMPERIAL COLLEGE COMPUTER CENTRE

A RATIONALE AND DESIGN
OF A
MICROCOMPUTER SYSTEM FOR SCHOOLS AND COLLEGES

by

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ABSTRACT

This dissertation reflects the results of a two year study between June 1977 and June 1979 into the impact and importance of microcomputer systems for secondary level education. More specifically, it discusses the rationale for proposing a microcomputer system for schools and colleges, in particular, for those two hundred schools participating in the Imperial College 'Computing in Schools Project'; it evaluates two available systems specifically orientated towards secondary education; and, it looks at the possible future re-organisation of school life in the areas of administration, Computer Studies syllabi and examinations, and other disciplines.

The resulting investigation forms a systems analysis of the uses to which a microcomputer can be put and of the needs of the average teacher as a user of a microcomputer system and not of the needs of the machine level enthusiast. This high level approach was a serious deliberation in relation to this study and is reflected in the emphasis placed on the requirements for readable manufacturers' documentation, the development of a microcomputer appreciation course for teachers, as well as the presentation of a set of guidelines based upon both a personal experiment and a study of existing material up to June 1979.

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NOTE ON ASSISTANCE RECEIVED FROM OTHERS

The developments within microprocessors are such that no one person can hope to keep pace with its spectular growth. Therefore, although this dissertation is presented under my name, I acknowledge the assistance received from others and without which this project could not have been completed in time. Mr. K. Palmer and Mr. H.Elgindi provided technical assistance for the Computer Workshop M6800 microcomputer system. But in particular I owe my supervisor, Mr. E. B.James, a great deal who, in our many discussions throughout the investigation and during the development of microprocessor courses for internal students at Imperial College, provoked many of the ideas contained in this dissertation.

ACRONYM LIST

The following acronyms are listed here for convenience:

AUCBE (CEAU) - Advisory Unit for Computer Based Education

CAL - computer assisted learning

CDC - Control Data Corporation

CEE - certificate of extended education

CEG - Computer Education Group

CET - Council for Educational Technology

DES - Department of Education and Science

DuMP - Durham Microcomputer Project

GAPE - Geographical Association of Package Exchange

IC - Imperial College, London

ICCC - Imperial College Computer Centre

ICSP - Imperial College Schools Project

J.M.B. - Joint Matriculation Board

LSI - Large scale integration

MSI - Midwest Scientific Instruments

MUSE - Minicomputer and Microcomputer Users in Secondary Education

NDPCAL - National Development Programme in Computer Assisted Learning

SCP - Schools Council Project

VLSI - Very large scale integration

RAM - random access memory

ROM - read only memory

PROM - programmable read only memory

EPROM - erazable programmable read only memory

1. INTRODUCTION

It seems to me inevitable that in one or two decades, perhaps more, but certainly within the lifetime of our children, decisions of immense economic and political implication will be based on information produced by computers. The important matter here is not what the computer produces but that no one person or group of persons will have the ability to challenge that information. One major contributing factor to this situation is the development of the microprocessor. It is, therefore, vital that the inheritors of this society begin to learn about microcomputers now. The most effective method is to have one on-site, to use it and thereby come to terms with its potential and its limitations.

The importance of microprocesscr education based on this philosophy has implications for the mid-1980s. But this project is concerned with the situation as it was in the middle of 1979.It is, therefore, based on a more pragmatical approach. By June, 1977, the Imperial College Schools Project (ICSP) was feeling the effects of a traditional computing centre which had offered a service to schools for over a decade. The economical cutbacks of previous years had taken their toll and the staff engaged on the project had dropped in number from six to one-and-a-third. This affected the quality of the service and pointed towards a time in the not too distant future when the service may well have to cease altogether. In any case, in the light of the importance of microcomputer awareness by society in general, it is debateable whether a project of this kind which encourages the traditional approach at the expense of forcing individual schools and government to find their own solution via microcomputers, should not deliberately set out to emancipate those schools from its maternal protection.

In either case, it seemed that the general euphoria of the computer weeklies, conference speakers and the like would engender in schools a realisation that they should and could purchase their own microcomputers. In June,1977, then, it seemed to me that within a year or two, schools in our own project would be seriously considering the use of microcomputers. Then the questions would pour in and advise sought. Consequently, the ICSP had to become involved and the sooner the better. The most sensible approach was to buy a machine and to see what evolved.

This pragmatic approach could best be realised by conducting a systems analysis covering four broad areas:

1. the acquirement of personal experience with microcomputers;
2. the viability of microcomputers within secondary education;
3. the recommendation, if feasible, of a reliable microcomputer system;
4. provision of course material for teachers converting from a centralised system to a personal system.

This dissertation reflects the investigation of the two year study period.

Section 2: outlines the nature of the ICSP as it had existed since 1967, reflecting on the need for an alternative computing facility for schools.

3: presents the case for the introduction of a microcomputer in schools not for the long term issues but for the immediate issues.

4: looks at previous study in this area.

5: discusses the original design aims of the project.

6: evaluates our experience with our first microcomputer system.

7: evaluates our experience with what became our recommended system.

8: presents the fruits of the two year study in the form of 'guidelines' for schools participating in the ICSP.

9: presents the additional support required by teachers converting from centralised to personal computer systems.

10: discusses critically the achievements of the project within the time scale.

11: identifies future study areas.

12: draws together the various conclusions.

13: a post-script on some developments since June 1979.

2. *THE IMPERIAL COLLEGE 'COMPUTING IN SCHOOLS PROJECT'*

The study of the possible impact on secondary education of the recent technological advances in microelectronics arises out of the increasing curtailments imposed upon the service offered by the ICSP. It is necessary, therefore, to provide a brief history of the Schools Project to enable the urgency of this study to be fully appreciated and to be able to highlight those areas where the microcomputer could be of future benefit to schools.

2.1. A Brief History of the Schools Project:

2.1.1. History and Purpose:

In November 1967, a small meeting was held at the Centre for Computing and Automation at Imperial College to discuss the teaching of computer science in schools. As a direct result, use of the computing facilities at the College was offered to three schools: Dover Grammar School for Boys, Christ's Hospital and Sir William Borlases' School, Marlow.

The useful work these schools quickly accomplished prompted the idea of a full-scale Schools Computing Project. In an effort to promote this, a one-day seminar was held at Imperial College in June 1968. Invitations were sent to a large number of schools throughout the country, and to local education authorities known to be interested in the future of computer education in schools.

The purpose of the seminar was two-fold: to make a case for the need for computing in schools, and to advertise the service which the College was prepared to offer in running programs on the IBM 7094 computer. A substantial number of schools was convinced that a start ought to be made, even if the method by which the subject should be approached remained uncertain.

Since this beginning, a remarkable growth in the number of schools involved in computer education has been witnessed together with a considerable expansion in computer usage. Computer education has achieved a significant status in schools and, at the same time, the College's role in supporting school users broadened. The provision of computing facilities became only a part of the overall service. Equally valuable work was undertaken in developing courses and teaching materials, in setting up and coordinating working party activities, and in disseminating a growing fund of information.

The Computer Centre at Imperial College of Science and Technology first became involved in providing a service for schools on a general basis at a time when it was difficult for schools to obtain facilities of any sort. Schools from all over the U.K. joined the Project and this resulted in the ICSP providing a nationwide service.

Today, computing is respectable. Instruction is given at all levels of secondary education, and examination type courses are steadily gaining in favour. However, despite this general acceptability and despite the upsurge in activities, the provision of supporting facilities remains inadequate for many schools. It is true that a few local education authorities have had the foresight to provide almost near adequate computer access. But these are the exceptions.

2.1.2. The Computer Systems:

From the beginning of the Project until March 1974, the schools' work was run on the College's IBM 7094 installation. The limitations of the 7094 dictated the use of batch processing using off-line spooling. The configuration included a 1401 computer and a 1460 computer, each with a 1402 card reader/punch and a 1403 chain line printer attached. The 7094 computer was backed by a 1301 disc file, and there were ten 729 magnetic tape decks. Magnetic tape based input was prepared for the 7094 by one or both of the smaller computers. Output from the 7094 was written to tape and, converted to line printer output by the 1401 or 1460.

From March 1974, the Computer Centre's Control Data computers, the CDC 6400 and CYBER 173 processed schools' work. For the past few years the computer complex comprises a CDC 6500 and CYBER 174. The latter has 131,000 60-bit words of memory and the 6500 has 98,000. They share 250,000 words of extended core storage and 4,500 megabytes of disc storage for permanent files. The computers under the Telex subsystem can service up to 320 teletypes or VDUs operating at speeds of up to 300 bits per second.

PUFFT (Purdue University Fast Fortran Translator) was devised and written at Purdue University for running small student jobs written in Fortran on the IBM 7094. In concept it was similar to the WATFOR load/go compiler designed for the IBM 360 series. PUFFT reduced compilation times roughly by a factor of ten and since it was intended for student usage, the diagnostics were excellent. Such a system, which incorporated high speed performance with excellently clear trace facilities, was ideal for schools. It was the availability of this system which enabled the College to extend the service to so many users.

The CDC system offers the MNF (Minnesota Fortran) compiler which is comparable to PUFFT and WATFOR, but in addition was also able to offer Basic and the City & Guilds assembly code to those schools wishing to use a low level language.

2.1.3. Methods of Access:

To appreciate fully the path which the Project has taken it is important to understand three conditions under which it was possible to set up a service based on a university computer centre. Foremost there could be no disruption to the service offered to the university. It followed that the school user had to fit neatly into an existing system, and then be prepared to change with it. This immediately imposed limitations, but the advantage of gaining access to a powerful installation and to the expertise which surrounded it outweighed any such limitations. Secondly, to avoid conflict, the service had to have little impact on computing resources. Fortunately for the Project a large system, designed to cater for the needs and demands of graduates and research workers, makes short shift of school programs. Finally, there were financial constraints. A Project of this type attached to a university is only made possible through outside financial support (section 2.1.5).

2.1.3.1. A Batch Service:

The schools' link with Imperial College was principally based on the postal service, although some users in the London area organised their own courier service. By its very nature a postal link provided a means of access for schools in remote areas or without suitable computing facilities in their own locality. Distance was no criterion; users of the IC scheme were scattered throughout the length and breadth of the U.K. Links established with Edinburgh, Carlisle, Enniskillen, the Isle of Man, Hull, Truro and London illustrate this point.

Program decks of punched cards, prepared at the schools, were submitted to the

College for processing. Preparing decks in the classroom involved the pupils directly with the computing process, an important contact when school users were so remote from the system.

Variation in turnaround times depends on the effectiveness of lines of communication with SW7. To an individual school, if the time is relatively constant then this becomes the significant factor as far as teachers are concerned. It is relatively easy for teachers to arrange activities around a regular time cycle. Given that no other means of access is available and that turnaround times fall within a week, then a postal type service can play an important role.

School programs arrived by post daily at the Centre ready for immediate processing. Batches of jobs were run during off-peak periods as part of the policy of non-interference with the internal work load. Under these conditions it was possible to turn the work round completely within twenty-four hours.

Provided that all users conformed rigidly to the procedures laid down, the handling of the work, around 1500 programs a week at peak periods, was relatively simple. It was sensible to post card boxes and output separately. For ease of handling and for protection use was made of transit boxes, whilst line printer paper, containing listings and results, was despatched by letter post to speed its return.

Data preparation was the schools' responsibility. This arrangement was essential to the service. It was not practical to punch cards at the Centre, firstly, because it would lengthen the turnaround time beyond the acceptable twenty-four hours, and, secondly, additional staff would be required in the punch room. It was realised that if a punch service had been offered then the service would have been limited to a few schools. In any case, accuracy in data preparation is an important lesson which ought to be learned at some point in the computing process.

Until 1976, 84% of schools performed data preparation using IBM port-a-punch cards. When the Centre obtained a mark sense card reader, schools gradually moved over to mark sense cards, so that by 1977, only one school remained with port-a-punch cards.

2.1.3.2. A Time-Sharing Service:

A positive result of changing from the IBM 7094 system to the CDC system was that schools could be offered a time-sharing service. One line was provided for six schools on an experimental basis in 1976. As a result of the success of this venture, the service was extended and has grown considerably. By July 1977, it became possible to provide three links to the CDC system. One link had fifteen lines operating at 110 bits per second; a second link had, again, fifteen lines but operating at 300 b.p.s; a third link had one dedicated line which was offered on a timetable basis.

2.1.4. Supporting Activities:

Undoubtedly, the program running service was the cornerstone of the Project. To provide a practical service for schools and colleges engaged in programming and yet one which remained consistently reliable over the years must be recognised as an achievement in its own right even to those with a minimum of exposure to computing. However, there were additional supporting roles which the Project set out to provide.

Documentation in support of the program running service became a major preoccupation. This information had to be aimed at the right level and this was not the level of the conventional manufacturers' manual. It was to be used by the teacher who needed to be instructed precisely as he had little time to discover things for himself. We found that a users' guide, documentation to support the growing program library, and detailed manuals for the programming languages in use were necessary. A newsletter with over three hundred and fifty on its mailing list was prepared each term. This formed the principal communication link between the Centre and the user. A bulletin box, printed as part of the banner page of output, enabled us to relay messages of immediate significance direct to those who were actually using the system.

Computer Centre Open Days were held once a term to encourage pupils and teachers to visit the installation which processed their school's work. These still take place on Saturdays when the Computer Centre can be opened up entirely for the benefit of schools. Over one-hundred and fifty pupils attend each session. The day begins with a talk and the CDC film of 'Computing in College'; tours of the installation are organised; programs are run via the "instant turnaround" facility, the mark sense program service and the time-sharing facility; the Tektronix high-speed interactive graphics terminals as well as the Kingmatic flat-bed plotter are in operation.

Experience of computer education at the secondary level gained and collated over the years was available for distribution, for example, the experience of running a schools' computing service; advice on audio/visual aids; available and suitable books at a variety of levels and held in the Schools Project library; relative merits of computer examinations; etc.

Visits to schools were encouraged and were of benefit not only to the schools but also to Project staff. In a user-service environment, personal contact has an impact which although difficult to assess, is undoubtedly extremely valuable. Through direct and continual contact the Project remained practical and up-to-date as well as sensitive to changes and problems faced by schools.

The Project offered a range of library routines especially designed for school use. Various working parties consisting of teachers from within the ICSP developed packages which from their own teaching experience were of value in the classroom. These were held permanently in a Schools Library and could be referenced by a Fortran CALL statement and by the use of the so-called 'C-procedural' card. This card automatically invoked a system routine to call in Fortran, Basic or City & Guilds compilers and assemblers, load the program for execution and call in the Schools Library when necessary, without the teacher having to learn the JCL for our system. One delightful set of routines (POP76) collectively called the POPEYE package was designed to accompany an appreciation course for schools. Collaboration with the NDPCAL via GAPE led to several Fortran and Basic packages being available in the Schools Library, (GAPE76).

Apart from activity within the ICSP, involvement by members in various other computer education committees kept the Project in contact with what was happening elsewhere; e.g. the BCS Schools Committee, the ILEA Computer Advisory Panel, the Educational Film Library, Oxford Local Delegacy for 'O' level Computer Studies, the London branch of CEG.

One of the most outstanding achievements have been the five annual conferences held at Imperial College between 1971 and 1975. The first of these events was organised to provide a meeting point and forum for teachers from schools participating in the ICSP. The success of the first venture led to the idea of an annual conference organised on a national basis for all those involved and interested in computer education at secondary level. The event grew in stature over the years and became recognised as a major conference of its type held in the U.K. The themes of the conference are given in the Reference section - (IC7175).

Various in-service courses were developed and presented to teachers in Fortran, Basic, City & Guilds code, programming concepts and the use of the CDC time-sharing system, as well as an appreciation course in computing. This latter was eventually presented for publication (CC75) and is discussed in detail in (DIC74).

2.1.5. Financial and Personnel Support:

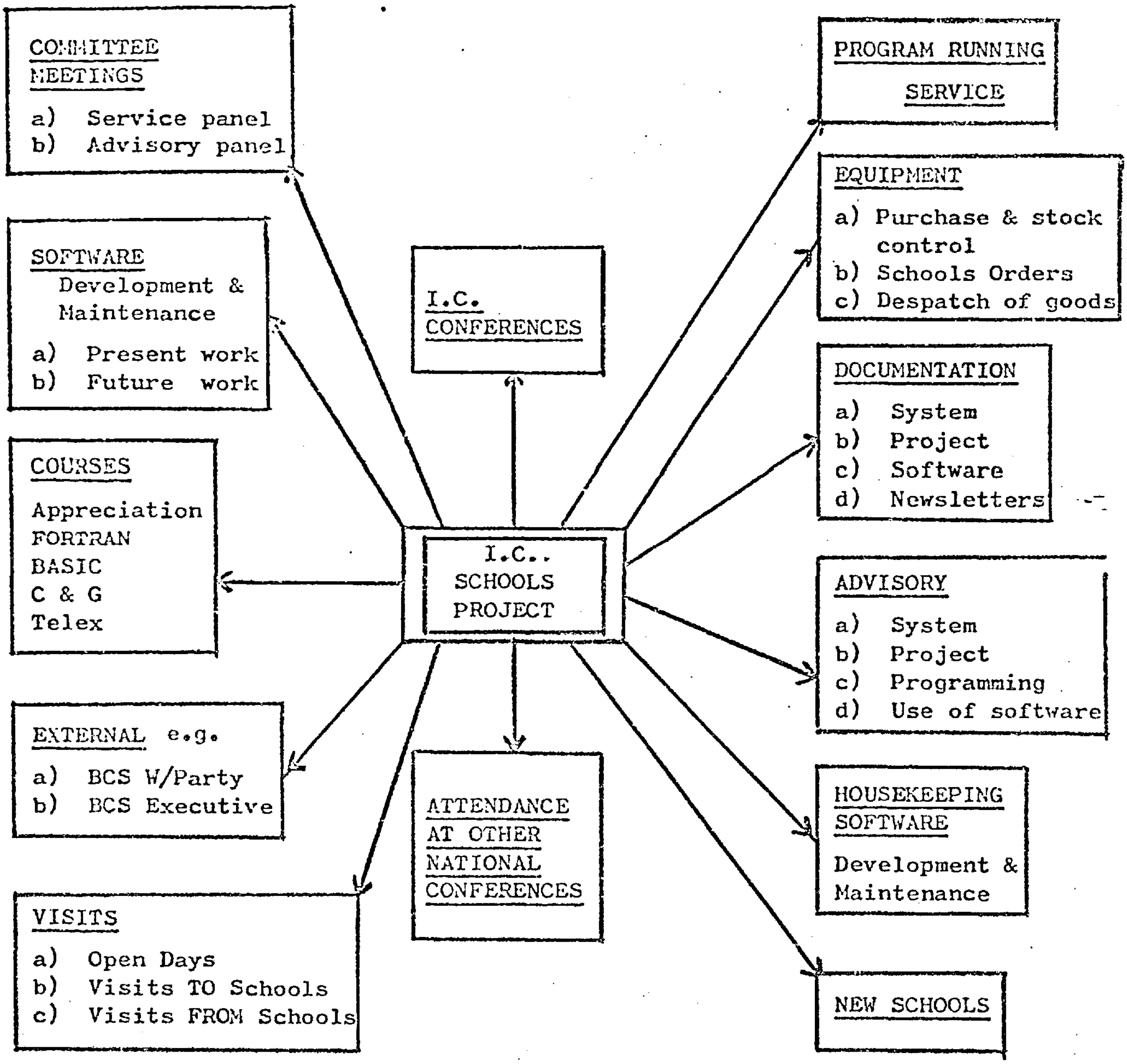
A Project as described and illustrated in diagram 1, obviously required a great deal of financial and personnel support. By 1975 the ICSP staff included:

Project Manager:	also involved in ICCC work for $\frac{1}{3}$ of his time
2 School Liaison Officers:	full time
2 Receptionists/operators:	full time
Schools Project Assistant:	part time

Assistance from ICCC staff

Operations/Services Manager in maintaining equipment and stocks
Systems programmers in support of system software for Schools
Accounts personnel to handle all monies involved in the ICSP
Typing assistance when required for documentation, letters, etc.

From its inception and until April 1976 the ICSP was funded by a benefaction from IBM U.K. Ltd. At the height of its activities this amounted to £17,000 per annum. Finance can often be a sensitive area and no details are provided in this dissertation but may be found in (ICR76). For one year after the cessation of the IBM benefaction the Project was funded by the College whilst applying for financial assistance from Control Data. This was successful in April 1977 but was restricted to a limited period of one year. Since then the Computer Centre has provided the financial support. For this reason a small charge is currently levied for users and ranges from £10 to £60 per annum depending on the amount of usage.



ACTIVITIES OF THE I.C.C.C SCHOOLS PROJECT 75/76

DIAGRAM 1

Until this time the Project was entirely free with schools having to pay for postage to the College or telephone charges and the supply of stocks required.

2.1.6. A Decade of Developments:

Although in 1975 there were two-hundred and fourteen schools participating in the ICSP, this did not mean that they were all engaged in programming activities. There were various degrees of involvement. Some were avid users of the system; others found the flow of information and ideas generated by the scheme sufficient in itself to maintain a link.

A complete cross-section of schools was represented, both from the private and the state sectors. A host of courses of one type or another were under way. Essentially they fell (as they still do) into three categories; computer appreciation, computer programming as an adjunct to mathematics, and computer science as an examination topic. In contrast, the activity is also run as a club in out-of-school hours.

According to the 1976 questionnaire, 65% of our schools ran courses with both appreciation and programming content, whilst only 28% were concerned with programming alone. In as many as 83%, computing was a timetabled activity. 44%, an encouragingly high proportion, generated sufficient interest for a club activity to thrive, and for 12% this was the only outlet. In 3% computing as a subject had departmental status, (ICQ76).

The age range at which schools tackled computing spread from nine to eighteen and, perhaps more significantly, right across the ability range.

2.2. Comparison with other Projects:

To the best of our knowledge there is no computing centre in this country which provides such a service to schools as the ICSP. Therefore, it is not possible to carry out any comparison. Developments in schools computing in the U.S.A have been watched for several years but the situation is clearly not comparable with that obtaining in the U.K. The massive hardware support for the projects involving terminal use for selected schools have demonstrated little else except the difficulty of the problem. In Scotland six centres were established as part of a National Policy dating back to 1967. Despite massive funding for this involvement the results have been somewhat disappointing in the areas of CAL and computer appreciation. It has been suggested that the reason for this is a lack of "driving force" in the schools themselves "in the form of at least one teacher whose major committment is to computer education. They are now actively seeking to establish computer studies as a curriculum subject." (PRV78). It would appear that in spite of the absence of a national policy computer education in the U.K.has certainly developed in a useful direction.

2.2.1. Similar Work on a Regional Basis:

In this country there are several projects concerned with schools computing. The LEA in the Dover region provides a service for a small number of schools via the computing system at the Medway and Maidstone College of Technology. ILEA with over two-hundred secondary schools runs a service for many of its schools based upon the City of London Polytechnic computer centre. In Hertfordshire, over thirty schools have access to the Hatfield DEC computer system, the work being co-ordinated by Dr. W.Tagg of the CEAU; in Birminham, a similar scheme is run via the University computer centre under the guidance of Mr.D.Tinsley. The point about these projects is that they are all based upon a given region where local control over policy and the provision of hardware and courses can be defined to the advantage of all concerned. Below, I discuss some of these projects to provide a balance to the work of the ICSP.

2.2.1. 1. ILEA

Within the Inner London Education Authority, (ILEA), there are about 210 secondary schools almost all of which are engaged in some form of computing activity. The Computer Centre for schools and colleges is based at the City of London Polytechic and comprises a variety of equipment based on Hewlet Packard and other machines. One of the causes of conflict over the past two years between 1977 and 1979 is that only a limited, probably twenty or so users can dial into the system at any one time. However, a batch service also operates with couriers collecting programs from the various schools and returning output when processed. In 1979, the rate of the couriers' pay has caused problems, resulting in a certain downgrading of this service.

Micros have also been placed in certain schools based on the RML 380Z machine in both cassette and disc based systems. A strong feature is that school teachers can attend many of the computing courses which have been established for all levels of GCE and CSE computer examinations. Under the control of the District Inspector, teachers have fewer problems in trying to find time-off from school duties to attend these in-service courses.

Private enterprise in the form of ideas and experiments may be stiffled as a result of a policy for a given Authority. This would apply to the material developed at schools, experimenting with other systems, freedom to generate one's own class material. On the other hand, a fixed approach to computing can bring the subject into being and careful nurturing by a common policy has many advantages.

2.2.1.2. Birmingham Schools Computing

The computer centre here is based upon the University centre, although more recently, since 1978, has been moved to another centre. Again, schools are drawn from a local population whereby a cohesion of ideas can be nurtured. With the advent of micros, a system based upon a network, linked to a centre which stores common files is in use. This has the distinct advantage of being able to pool a wide variety of programs for eventual dissemination. The main problem here is that in the event of the main system crashing, the satellite users are prevented from performing class work or whatever. The Birmingham system appears to me to encourage the use of stand alone microcomputers as intelligent terminals with all the inherent dangers of such an attitude.

2.2.1.3. Merseyside Schools Computing Project

In 1972, many schools in Merseyside belonged to the ICSP but have subsequently belonged to the Merseyside Schools Computing Project. The project is now based at the Polytechnic. As the computing needs of local schools increased so did the work of the Polytechnic. Initially, much of the work was based upon a batch system using port-a-punch cards (a legacy from the ICSP). One of the most important contributions from this project, apart from maintaining a service to many local schools was the development of an 'O' level GCE Computer Studies examination based upon and in conjunction with the J.M.B.

2.2.1.4. The Hertfordshire AUCBE

Based upon a County policy established some ten to twelve years ago, the AUCBE is centred around the Hatfield Polytechnic. The computer system is based on a DEC 10 system (formerly a PDP-10 system) and later a PDP 11/70 system. It aims to service all schools within Hertfordshire (state schools) on a batch/time-sharing system with courier facilities. The AUCBE has had the disticnt advantages of a county backing and a supply of a strong team of enthusiastic staff members (eight in number) as a supporting administrative and software contribution, with the ability of calling upon teachers seconded from schools when necessary.

Over the years, three aspects have predominated. First, is the provision of computer access by a variety of means, batch, time-sharing and more latterly microcomputers. The second is the establishment of teacher training, an issue of great importance. Finally, the steady development and maintenance of a comprehensive set of CAL-type programs and packages (see AUCBE80 for a list of the more popular programs numbering twenty-four), and, a steady output of supplementary documentation on package usage, system usage including languages at both high and low level, as well as a stream of other forms of documentation on guides to the computer centre, and various hardware guides. In addition, teachers from Hertfordshire have had access to the educational material not only in computing but also associated with any large scale polytechnic.

2.2.1.5. Durham Project

Since 1976, the County Computer Advisory Committee has been concerned with the use of microcomputers in secondary schools. As a result, the Durham Microcomputer Project (DUMP) was set-up to investigate the usefullness and suitability of schools microcomputers. In response, two schools out of twenty strong within a Computer Studies group were selected to participate in the project. A report (DUMP1) describes the findings in detail. It is of interest to note that its conclusions on the Computer Workshop M6800 system coincides with my own conclusions and that eventually, they recommended a RML 380Z system.

The broad aims of the project in conjunction with Darlington College of Technology providing hardware expertise and back-up, were: to identify areas of schools curriculum and administration suitable for micro application; to create appropriate software; to evaluate this software; and, to evaluate the microcomputer as a suitable and viable item of school equipment.

This project is somewhat different to the others mentioned here since like my own project it concentrates on microcomputers at secondary level. However, the main point of interest for me, is the fact that the conclusions of DUMP are almost identical to those contained in this dissertation.

2.2.1.6. Conclusions on Regional Centres

In many ways the AUCBE is the ideal vehicle for promoting computing in all its aspects for both teachers and pupils. It has, on the other hand, very much of a parochical nature which is good if you are fortunate to be within the 'parish'. I would like to see, however, much more co-operation between'parishes' such as ILEA, Birmingham and Hatfield, etc, under some DES sponsored committee so that these separate areas could pool experiences and software with the intention of producing some form of national computing policy for the whole country. Of course, committees can frequently destroy the enthusiasm of even the most adherent members, therefore, such a committee, in my view, would have no 'executive powers' to influence the spontaneous ideas and experiments of any centre. Where it would be useful, would be in sifting through the work and material from various centres and to be in the position to disseminate to others the best of these and, hopefully, to influence computing developments elsewhere in the country at Inspectorate, Teacher Advisor, LEA directors of Education levels. This is the type of engagment which the BCS Schools Committee should be involved with but seems unable to do so. With the advent of the microcomputer and the publicly avowed policies of both Tory and Labour governments, the climate has never seemed more ripe to attempt this task.

2.2.2. Single Institutions:

Some individual schools such as Oundle (OUN78) and the Manchester Grammar School have organised their own internal computing requirements based upon on-site facilities in the form of minicomputers and/or micro systems. Other schools not so fortunate as to possess their own computer have access to a local College of Technology or County Hall computer. Others manage to liaise with neighbouring commercial companies or indeed with bureaux. Schools in this latter category without on-site computers frequently have to accept a poor service since their priority is low in relation to other work processed at these centres. Certain schools in Plymouth, for example, have complained about a four or even six week turnaround from their local college.

2.2.3. The Unique Position of the ICSP:

The ICSP is unique amongst the projects mentioned above in that it provides a national service. This feature has necessitated reliance upon a postal-batch service since the time-sharing service can only be taken up by those schools living within the inner and outer London areas. Because of the distances between our schools, it has never been possible to shepherd their teachers in the way that regional centres such as ILEA and Hatfield have been able.

The ICSP on the other hand has been able to offer an independent service. We had no masters to serve, except those within the College, and consequently we have been able to offer any school a means of access to a computer. In the main, our schools have been those who wanted to experiment with computing before committing themselves to expensive hardware or those who without our help would not have been able to contemplate computer activity of any sort.

2.3. The ICSP during 1977 to 1979:

Economies in educational institutions since 1976 have been felt at Imperial College at elsewhere. In practice, this has meant that staff who have left or who have been up-graded have not been replaced. We are now reduced to one full-time member, the schools receptionist and a part-time manager who has a full-time committment to the ICCC as Courses Manager. As a result, the termley Newsletter has ceased, a total cessation of software development, no visits to schools (both as a financial and time point of view) and fewer Open Days.

Five years ago it was possible for schools in Dover to achieve two complete turnaround times within a week, at a fraction of the postal cost since 1979. Today, in June 1979, they are lucky to have one complete turnaround in a week.

2.4. Conclusions:

Imperial College has offered its computing facilities to many schools since 1967. In this sense the Project remains unique and can claim a special position within the broad aspect of secondary education at the private and state levels. Without the Project, many schools would never have had the opportunity of establishing an entrée in Computer Studies. It must always remain a proud boast that without the ICSP, computer education in the U.K. would be far behind its present status since many schools active today, albeit with other centres, may still have been wondering whether to become involved or not.

This nationwide structure of the ICSP has been both its strength and its weakness. It was sufficient to provide an initial introduction to computing for many schools and teachers but not sufficiently geographically placed to influence computer education by encouraging more intimate exchange of software, teacher training, and individual guidance.

With the increasing dependence of our society upon the computer, especially since the advent of the microcomputer, it is likely that by the year 2000 AD, all children will be taught the fundamentals of computing as today they are taught the fundamentals of mathematics and English. Provision of adequate computing facilities will, therefore, become a national issue. It is arguable that the ICSP should voluntary step aside so that the DES, for example, can see and be made to feel the real need for such facilities.

In any case, it seems clear that the ICSP cannot endure in its present state for much longer. While it does, its main consideration is on the provision of some alternative means for schools currently, in June 1979, relying upon our postal service. The advent of the microcomputer seemed in 1977 to present such a viable alternative bringing the power of the computer within the grasp of all schools.

3. A RATIONALE FOR A MICROCOMPUTER SYSTEM FOR SCHOOLS

Many schools in 1977 were obliged to use a centralised computing system. Section 2 discussed the ICSP in detail and concluded that for ecomonic reasons, it became necessary to reduce the service which has been the main form of access to computing facilities for many schools over the past twelve years. Since 1977, microcomputer systems have been in the news and must seem to many as the viable alternative.

The availability of cheap, personal systems has opened up many possibilities. This section discusses the rationale of microcomputer systems for secondary education in general as well as for those schools within the ICSP. We begin by looking at what has been available on traditional computer system and, then, discuss the classes of personal computers and what is meant by 'cheap'.

3.1. Availability of Cheap & Personal Systems:

3.1.1. The Components of the Traditional Computing System:

Most schools involved in computer education have contact with some form of conventional and centralised computing system either by a postal/batch service or by a terminal device. Such systems comprise seven major components. Three of these constitute the traditional central processing unit consisting of the arithmetic and logic unit, the control unit and some fixed size of main memory. Input and output devices combine to transfer everyday information between the outside world and the internal world of the CPU. A sixth component is the auxiliary storage device(s) consisting, currently, of magnetic tapes and discs in which an unlimited amount of information can be stored. These six components form the so-called hardware of a computer but for these to function usefully computer system programs and computer application programs are required and form the seventh component. It is possible to mention an eighth component for this conventional computing system and this may broadly be referred to manpower, i.e. the operators, reception staff, system programmers, education/information personnel and a management structure to organise and combine the different sections. Diagram 2 illustrates a typical staffing structure which at the ICCC consists of eighty members. Although individual

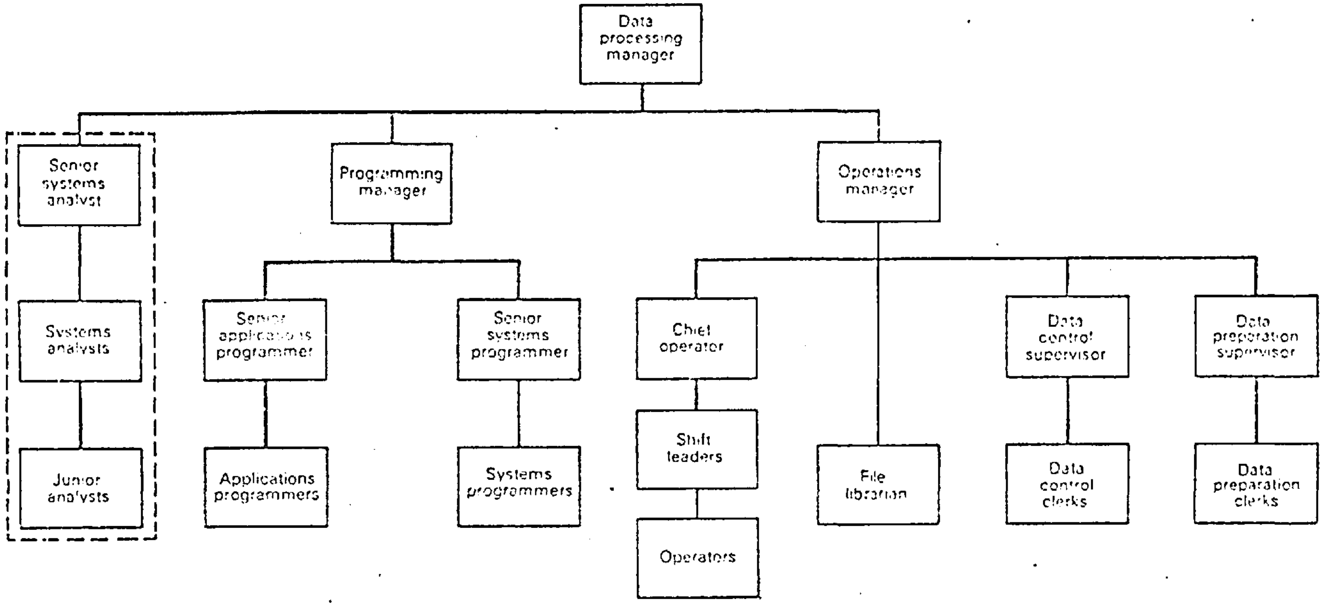


DIAGRAM 2: A typical staffing structure for a Computer Centre

details will vary between installations, the basic outline applies to all large mainframe centres. It is important to mention this manpower component because it affects the discussion of microcomputing for the individual.

The typical school user in 1977, would have little difficulty in recognising the above eight components at his disposal and would also recogise the batch-orientated nature of this computing activity where pupils' work is queued to a central system, processed to completion and results returned by post, courier or perhaps by personal collection. Even terminal users must admit that their access is merely a variety of a batch system since very few terminal users ever achieve genuine interaction with the computer system. The terminal is simply the means of input into a system which is essentially batch-orientated. The time-sharing aspect is just another way by which the computer handles many jobs and from the users' point of view differs little from multiprogramming as an end result. Execution of programs and return of results are in real-time via the telephone rather than by human intervention in the form of the postman or courier. Essentially, then, schools are 'batch-orientated' or in the case of terminal users 'remote batch orientated'.

3.1.2. What is Available :

From the excitment generated between 1976-78 by the press, conference speakers and over enthusiastic micro 'aficiandos', one might expect the microcomputer to be some totally new and different type of computer. In fact, on closer examination, it is found to be quite similar. It is true that the micro is smaller and cheaper, and based upon LSI technology. But size in itself is of no great significance except that the micro can be more easily housed and transported and that special air-conditioned rooms are no longer required. Clearly, this is an attractive convenience but little else. If size really had to be evaluated then rather than a positive advantage, the current micro is more limited in power compared to its larger brethren. Effective challenge to the larger computer must yet await further developments in LSI (or VLSI) technology possibly by 1985 according to (Elect.M).

It is the cost of microcomputers that is the real interest. In 1978, a significant general purpose microcomputer system could be purchased for about £4000 whereas the equivalent computing power some five or seven years ago would have been nearer £40,000. However, it is necessary to be absolutely clear as to what is cheap in a microcomputer system and we discuss this separately in section 3.1.3. The point we make here is that for users who require a modest computer facility, the cost is well within their budget. People will buy microcomputers simply because they can afford to do so. We have already seen this in the case of pocket calculators and it is true in 1979 for microcomputers.

In my opinion, this is the true impact of microcomputers and the reason for the urgency of this project. What is available is the very availability of micros. Because many have the choice of buying, then the need for guidance, advice and experience becomes important, especially in the short-term.

Apart from availability, the computing process remains unchanged except that with micros performance is somewhat slower. This may well change in the forseeable future as micro performances improve. Program instructions are still stored in central memory via input devices, the ALU and CU essentially perform arithmetic upon stored data, results are displayed via some output device. In the future, with a team of microprocessors the method of computing may well change, with each microprocessor looking after different parts of a 'computation'. But that is a future development.

3.1.3. What has become Cheap:

Until LSI technology and advances in the manufacturing process reached today's sophistication, the CPU of the traditional computer was assembled from discrete components by hand. The labour this entailed was expensive. Now many thousands of logic circuits which comprise the CPU can be built onto silicon chips using LSI and photolithographic techniques resulting in a reduction of cost by a factor of one-hundred. It is destined to fall further as the mass production of chips increase.

If we look at the cost factors of realising a given overall computer application we see that these include not only the cost of the CPU but also the peripheral units for input and output and auxiliary storage, operations and maintenance costs (including personnel), the cost of the computer system software and, finally, the application program itself.

But in the case of microcomputers, it is only the cost of the CPU which has dropped, the peripheral units, manpower and software costs remain the same. It is true that as a result of microprocessors the input, output and storage devices will become cheaper, but in no way as dramatically as that for the CPU. The relevance of this is brought out more strongly in section 8.

It is understandable that the newcomer to microcomputers is led to believe that they are cheap. But for the teacher responsible for managing the micro system, an awareness of what is exactly cheap is important. He must be aware that apart from the hardware costs of the CPU and the chip memories, the rest of the computing process remains the same. On the other hand, it is precisely this drop in hardware that has brought computing power within everyone's grasp.

3.1.4. The Classes of Microcomputers:

It is necessary to distinguish between the types or classes of microcomputers so as to be clear as to the type which this project discusses. Currently, we can identify three broad classes. First, there is the 'chip' level which involves using the microprocessor as the main computer component. The microprocessor consists of the arithmetic logic unit and the control facilities required to execute a program. These two units can be packed onto one silicon chip called the 'microprocessor'. Other chips may be added to provide for a limited storage of data and programs. The type of program which can be executed on such a basic microcomputer would have to be in machine code and, in practice, would be limited to very small programs involving one hundred instructions. Obviously, the main intent of such primitive computers is essentially in the control of simple laboratory equipment, domestic appliances, pocket calculators, etc. Other chips would be necessary to provide an interface to the input and output devices.

This type of microprocessor costing between £5 and £50 may have obvious benefits in a school's Physics and Electronics departments but is really of little use elsewhere.

A second class is the 'board level' computer where the microprocessor, the input and output interface chips, auxiliary storage and the timing clock are all mounted on a single board. Pre-written programs stored in read only memory (ROM) may also be supplied to act as a very primitive monitor operating system capable of reading in programs into successive locations and, perhaps, also providing input/output control enabling users to 'plug in' paper-tape devices and primitive printers to the 'system'. Such computers may vary in price, between £100 and £500. They will undoubtedly be of value in an 'A' level Computer Science course but are not designed for general purpose use in schools. Even the novice soon outgrows this system.

A third level is called the 'microcomputer system' - as used in the title of this dissertation. It consists of a microprocessor at board level together with input,output components (albeit of a primitive nature) and immediate access memory. Auxiliary storage can be in the form of either cassette tape or floppy disc systems. From the hardware alone, this system mirrors the familiar conventional computing system and will use a teletype or VDU as the input/output device. It will have an operating system which will enable the hardware units to function as well as a text editor, language translators for both assembly and high level languages, and, a fairly simple monitor program usually concerned with a mono-programming environment.

These systems will cost up to £4000 and rival the more modest minicomputers of yesterday. It is these systems which can be used by schools for general purpose computing since 1977 and upon which we concentrate in this Project.

When the requirements of the average user of the traditional computing systems are taken into consideration, it is found that in order to develop and process programs it is only this third class of microcomputer which can offer the necessary resources. Either of the two other levels would not be sufficient. The chip level micro would be unable to permit development of programs, whereas the board level micro would have to be increased until it had become a microcomputing system.

3.1.5. Implications and Conclusions:

The ideal schools' computing requirements would be met by a minicomputer with batch facilities, possibly using mark-sense cards, so that a class of twenty or more pupils could develop programs at one time. Some schools have such facilities but for the vast majority the initial outlay not to mention maintenance costs and dedicated personnel will rule this out. However, LSI technology and mass production techniques have combined to produce cheap microprocessors so that a general purpose microcomputer system is within the reach of every school.

The pressures on schools to buy their own micro system is too great to be resisted especially when they are reliant upon traditional computer centres, like the

ICSP, which are currently finding it difficult to maintain a reliable service or where the telephone costs to support a terminal based system become more expensive than the purchase of a microcomputer. Indeed, ILEA, in 1979 was finding it difficult to rely upon the underpaid services of their couriers. Certain LEAs are offering to pay part of the cost of a micro if the schools will find the remainder. In one case schools are asked to find only £300 for a £1500 cassette based system with the LEA paying for the difference.

Schools, therefore, will buy micro systems, indeed, many have done so already. The real question at issue, then, is who can advise schools to buy wisely, to make the correct choice of system, to offer guidance and advice once the machines are installed? Teachers themselves have little enough experience of traditional computing methods let alone of microcomputers and their potential. LEA computer advisors, where they exist, have little more to offer. It was this situation which in 1977 was even more pronounced that inspired this project, essentially for those schools participating in the ICSP.

3.2. The Microprocessor Revolution within Society:

The trade slogan for Texas Instruments claims to have put computing power within the reach of everyone. This is true of the microprocessor industry as a whole and not merely the preserve of one manufacturer. The implications of this for society as a whole and not simply for schools may begin to be appreciated when we consider that a computer comparable to the power of ENIAC was available several years ago in the guise of the Fairchild F8 microprocessor, for a few pounds.

Governments, both Socialist and Conservative, since 1977 have encouraged investigation into microelectronics (Finniston). Trade unions have become greatly concerned, typically one faction calling for an immediate cessation whilst another is calling for further examination of their potential. Educational bodies such as the DES and CET (section 3.4) are actively promoting research into the uses of microcomputers in secondary education and encouraging a range of courses for teachers. It seems that industrial societies have little choice but to convert to micro technology. A whole new range of applications areas to which computing can be applied but which was previously not cost-effective will gradually invade our technological society. Since it is the whole of society which will become affected, it follows that some awareness of micro-technology must be presented to the inheritors of the computerised society, our own children, and is a sufficient apologia for this project.

3.3. Microcomputers within Secondary Education:

3.3.1. Within Computer Studies:

The main purpose of any computing facilities is to enable programs to be executed. Within Computer Studies (at Alternate Ordinary level, Ordinary level and the Certificate of Secondary Education) and Computer Science (at Advanced level) computer facilities must exist in order that pupils may gain an understanding of programming in some high level language, develop their programming skills and create and process programs. Most examination bodies require evidence of practical programming by pupils which involves the successful completion of a programming project.

We have already discussed the problems arising from traditional computing facilities and have indicated that the only solution to the perennial problem of processing schools work is for schools to acquire their own on-site facilities. With the growth of examination candidates (see table 1.) for CSE and, latterly, O level, the demand by schools for computing facilities is increasing.

If we accept, then, that more and more schools will have on-site microcomputing systems expressly for the purpose of processing programming project work, we can begin to indicate other areas of benefit.

Children will be able to grasp the idea of a computer 'installation' and to see the hardware (equipment) at first hand. This is obviously better than having the installation at the end of a telephone line or a postal service which at best might be visited once during the course of study. It will still be important to be able to visit larger installations where magnetic tape and disc drives, fast card readers and line printers, possibly high speed interactive graphics terminals, etc, may be examined more closely. But the use and handling of cassette tapes and floppy discs will allow for a much more immediate appreciation of these mediums as storage systems. The whole concept of files and the nature of sequential and random access, the need for an operating system to control the use of these mediums can all be brought together in a more orderly manner.

YEAR	CES	GCE O level	GCE AO level	GCE A level	CEE	TOTAL
1974	5487	400		1000		6887
1975	8785	1335		1340		11460
1976	13181	3217	116	1512		18026
1977	15218	6091	109	1764		23182
1978	15489	8417	511	1769	233	26419
1979	16210	11635	765	2323	591	31524

TABLE 1: Examination Entries for Computer Studies/Science

The idea of starting up a system becomes more readily obvious and the concept of a system, i.e. both the hardware and the driving software. The purpose of system commands will be appreciated more fully together with their inherent limitations in structure which at the present time could be thought to be the whim of a given computer centre rather than a limitation on the part of the manufacturer to sympathise with the needs of the user. The idea of the need for additional software, for example Basic/Fortran compilers must become more apparent, and, indeed, perhaps the differences between compilers and interpreters (not yet a requirement at CSE/O level). An on-site micro system will enable a real appreciation of the differences between high and low level languages; the need for the security of files. Here the concept of ancestral files may be better appreciated because the pupils will be exposed to the needs more directly. Currently, in 1979, users of a computer centre are protected from these concepts.

It should be noted that we are not stating that all these features should be part of a CSE/O level syllabus. But by the mere fact of owning one's on-site system, these features are forced upon the users and a natural appreciation of the concepts must follow.

3.3.2. Within Computer Science:

All the above advantages exist for the A level student of Computer Science. But in addition they will be able to gain more immediate experience with low level languages and the more detailed concepts of computing machinery.

The cheaper board level computers are equally valuable within Computer Science since greater understanding of machine level concepts can be presented more easily and more directly. One model, the MMD1, mentioned in section 8.3.1., cost, in 1978, £400 and is an excellent teaching vehicle for such concepts as registers, RAM memory, ROM memory, address and data buses, LEDs for output in binary, octal or hexadecimal, input and output control, and, machine code programming.

These low level boards allow little in the way of examination type programming projects but allow for a very full exploration of machine level concepts and lend themselves to control of laboratory equipment. Perhaps more important, they provide a means for a future generation to be readily conversant with the real limitations and applications of microelectronics.

3.3.3. Within Subjects other than Computer Studies/Science:

Clearly, the implications of the board level microcomputer within Physics and Electronics is obvious. But to return to the full development microcomputer system we can see its implications within subjects other than Computer Studies and Computer Science. Schools are moving away from theory to a more pragmatical approach, towards real life situations. There is a need for models of the real world especially in subjects such as Social Science, Geography and Economics. Computer Assisted Learning (CAL) packages will help to provide such models. But at the present time very few truly portable and easy to use packages exist such that a substantial part of a course can be built around them. However, now that the hardware is at least attainable there will be less chance for computer educationalists to make excuses for not developing software.

The use of the term CAL in this project requires some explanation. CAL and CML (CAI and CMI in the North American continent) are two common terms. According to the Final Report of the Director (CET77) of the National Development Programme in Computer Assisted Learning (NDPCAL), Richard Hooper, CML 'tends to have a fairly consistent meaning. CML applications involve the computer in helping the teacher to manage, rather than provide, learning opportunities..... In CAL, the computer provides 'individualised instruction' ... acting as a kind of machine tutor.' In another class of definition, Hooper sees CAL in the light of 'the requirements and nature of the subject matter' so that the computer acts as a 'learning resource'.

In this project, CAL is used in a much broader sense encompassing any aspect of teaching involving the use of a computer as tutor. The past history of CAL, in this context, has not encouraged me to become enthusiastic. It is ten years ago (in 1969) since I first became acquainted with CAL in the terms stated above. During the past ten years not a great deal of suitable material can honestly be said to have accumulated. I am not condemning teachers for this but merely passing a comment that the traditional use of teachers as suppliers of CAL software has produced little. A few outstanding examples can be pointed to, such as the 'DIET' (DIET) package produced by John Lewis, the accumulation of material at the AUCBE at Hatfield widely available to schools within Hertfordshire (AUCBE1), and, the Chelsea Science Simulation (Chel).

It must be accepted that to produce worthwhile CAL packages a great deal of time and capital investment is required. To think that this can be invested by teachers already in full-time employment is, in my opinion foolish. To substantiate this we need only look at what has been produced over the past ten years. The CEDAR project which is an on-going offshoot of the NDPCAL which received £2 million by the then Secretary of State, Mrs Margaret Thatcher in January 1973, promulgates the efforts of those involved. To-date, very little can be offered to secondary schools in the way of CAL packages. In January 1979, the CEDAR project financed by the CET and housed within Imperial College, London, could offer the following in the disciplines of Chemistry, Business Management, History, Geography, Engineering(CEDAR 78). Two packages are available at secondary level for History, tweleve in Geography, none at Engineering, two at Chemistry, none specified at Business & Management Studies. Yet, according to the Schools Council Project (SCP) various packages do exist in Biology (7), Physics, (7), Economics (9), Chemistry (7), Geography (7) and Home Heating (1). To be fair, many more exist for undergraduate and graduate levels. Certainly, a wide variety of sources exist where 'packages' are obtainable, for example, the Schools Council 'Computers in the Curriculum', Chelsea Science Simulation Project, GAPE, Central Program Exchange (formerly Physical Sciences Program Exchange), MUSE Program Exchange, LEA Educational Computer Centres (the Hatfield AUCBE with Query, Route, Survey, to mention just a few is an exception in that a fairly comprehensive amount of material is available for their schools), Open University Program Library, various individual attempts especially by development projects, Amateur Computing Club, microcomputer magazines, microcomputer user groups, microcomputer suppliers and private enterprises discussed from time to time in the computing trade newspapers.

This is an impressive list of possible sources of CAL material, but I believe that any future worthwhile development of learning via the teaching ability of the computer must come from the commercial world which when it senses a profit can provide the capital and manpower investment. I am talking here about a national scale where every school can possess and use suitable material for many disciplines and material which will enable an entire course to be centred around the packages. Certain areas of the country, in particular Hertfordshire, have already gone a long way towards this aim. But in the main the material is confined to those schools fortunate enough to be within that county. Voluntary teachers, unpaid for their effort, cannot be expected to supply the whole of the country with what is after all an enormous task for secondary software.

I do not wish to appear to discount the tremendous effort put into CAL material by a few enterprising teachers and LEAs. Indeed, many useful routines do exist but can only be used on a given system and, in the main, for but a tiny part of a given discipline. For the majority of non-computing teachers, what is actually available does not encourage them to think seriously about altering their existing teaching methods and course material in exchange for CAL material. Hertfordshire can point to what could be possible for everyone. But my own belief is that the real impact of CAL for the country as a whole is still some years away, hopefully not more than five or ten years, and, that the main impetus will come from the commercial world rather than from teachers or indeed LEAs. This may seem a pessimistic approach and somewhat harsh but my case rests purely on what the average non-computing teacher can in practice be offered, and that is very little despite ten years of CAL activity. Another reason for placing the real impact of CAL material in the future is that the availability of graphics has much to do with suitable material. A discussion on graphics is left to section 11.5 under Future Developments.

3.3.4. Within Remedial Training:

The microcomputer as an educational tool can make a vast impact in the area of remedial training. By this term we mean individual practice or coaching for weaker students or indeed for students who through illness have missed some classes. I have seen several examples demonstrated especially in the field of mathematics where a remedial program provided additional tuition for individuals to practice, for example, division and multiplication using fractions. What was most evident was the enthusiasm of the pupils to learn through this medium, whereas practice set in the form of additional 'homework questions' would be treated with the expected indifference. It is the immediate response which is part of the attraction especially if any mistakes can be pointed out by the program. To try and get the answers correct presents a challenge, rather like trying 'to beat the machine'. Also, the impersonal nature of the machine rather than a response from a tired or frustrated teacher is equally valuable. All these considerations combine to provide a positive incentive for children to learn, surely, a most welcome change for many teachers.

Such programs are becoming commonplace where individual teachers are willing to expend a few hours of effort. Once written, of course, the pupil has a tolerant 'teacher' for individual tuition.

In the case of specialist teaching for handicapped children where the teacher-pupil ratio must be in the order of 1 to 2 or 3, the possibilities of the micro system as an aid is even more encouraging. In 1978, an Apple micro with tone generation was helping the deaf to talk. The child utters his or her sound for a given word and via voice recognition input the micro is able to show how near or otherwise to the accepted sound, the child's attempt has been. This can be displayed via the graphics capability of the Apple. But perhaps of more value to the handicapped child is the point that on a future occasion the micro is still able to recognise the utterance for an attempted word. Whereas a human teacher not equipped with a memory bank for a child's sounds may not be able to remember the word which the child is trying to say. Hence, via the micro much frustration on the part of the child can be removed.

The idea of the need for microcomputers as an educational need for specialist teaching can be extended, for example, Vietnamese refugees requiring a crash course in English. Perhaps in ten years time, voice synthesis will be improved to the extent that a micro system could teach a language. The basics at least could be grasped via the machine freeing the teacher to concentrate on the more idiomatic aspects of the language and to be able to spread his expertise over a larger number of individuals.

Whatever will happen depends on the amount of research into this area of specialist uses for microcomputers. The point being made here is that this area should not be forgotten.

3.3.5. Within Schools Administration:

The uses of a microcomputer system for school administration are not difficult to imagine. Indeed, many schools currently in possession of a micro have already made use of them to produce multiple copies of class lists in any desired order, house lists, parents address lables, reminders for immunisation, sports lists, etc. A large proportion of the school timetable can be processed by the computer, leaving only the clashes to be searched for by the timetabler.

With developments in word (text) processing, many more of the secretarial duties can be performed. Here a disc based system is necessary (section 8.3) together with a comparatively expensive character printer.

3.4. Official Attitudes:

"A consultative paper (DES79) issued by the Department of Education and Science outlines a development programme to help schools and colleges to become fully aware of microelectronics and to make the best use of the opportunities it offers." This was the comment from a Press Notice dated 6th March, 1979. The actual paper had the following to say: (part II Scope of Programme)

> "The Government intends that the programme should be developed by a central agency and should focus on the need for teachers, pupils and students to understand the potential of microelectronics, to be aware of its wider implications and to make the best use of the opportunities it offers. It will complement Government policies to improve standards of literacy and numeracy by helping to extend young people's powers of communication and access to information. .... Microprocessors, used in microcomputers and educational technology, will make new approaches to teaching and learning possible across the curriculum. "

The five year development programme is to cost an estimated £12 million.

The School Technology Forum (STF79) stated that

"In addition to the need for people to be aware of the impact of new technologies on themselves and on society and the need for people to be prepared to retrain and seek changes of direction in their careers, there is the need also for the country to have available the quality and quantity of manpower which can assume a more active role in taking full advantage of the opportunities presented by new technologies."

The Council for Educational Technology (CET78) believes that

"There will be a need to give young people a balanced understanding of

- microelectronics and computer-related activities
- what such devices can and cannot do
- the difference between what is theoretically conceivable and what is currently attainable

so that their attitude to these developments is as realistic as, for example, our current attitude to the telephone or television."

These statements and the rest of the papers from which they come are really delightfully vauge. They offer no concrete solutions, details or solid advice. This is obviously a matter for those working in the field. Nevertheless, to have official recognition is better than to have none at all and we should credit the Government(s) with being aware of the importance of microelectronics.

Although there was relatively little coverage in the British press it is of interest to note the French plans for developing micro computing in schools (NS79). The French micro programme was agreed by the Government on 6th December, 1978, and is to be sponsored nationally by the Ministry for Industry with funds of £240 million with the long term goal of developing the national microcomputing industry. The suggestions are that 10,000 micros will be installed in schools including all 7,350 secondary schools. The first phase of the project is user orientated, to ascertain the effective role of the microcomputer in schools. During the programme different kinds of microcomputers will be investigated.

How much of this ambitious programme will actually come to fruition is debatable. A national programme for CAL only achieved 20% of its original intention. Nevertheless, it is most encouraging to receive recognition both at home and abroad.

3.5. Overall Conclusions:

We have seen in this section that a great deal of interest is currently being engendered in the microelectronic revolution which at a cursory glance seems to be a purely technical development. On closer examination it is revealed that the traditional computing system (i.e. the computational power and storage) can today be mass produced and made available to the man-in-the-street. Even when the traditional computer was available at much higher prices they were bought in their thousands. Now that anyone can buy computer power, many more applications, previously closed to computer solution on economic grounds, will spring up over the next decade. The inheritors of this society are currently at school. Their education must include some awareness of these devices since their working lives will be involved directly or indirectly with them.

However, the main reason why schools will buy microcomputers is a more practical one. The decline of the service offered by traditional computer centres is forcing schools to look elsewhere. In the absence of on-site minicomputers with batch facilities, the only answer is the microcomputer. We went on to discuss the various types available in 1978/79 concluding that the development system was suitable for general purpose computing as required by schools. These may cost up to £4000. These may be used not only in Computer Studies and Computer Science but also in other subjects via CAL packages as well as in remedial training and schools administration, and graphics (see section 11.5.).

Finally, official attitudes taken by various governments were quoted as being in favour of microcomputers in schools. Indeed, they stress the necessity of this for the future economic survival of our societies. I find this approach encouraging, although a teacher may have to resort to an examination course in order to introduce computing of <u>any</u> sort into the curriculum. I believe that micros will alter the face of our societies and for this reason alone I applaud any method whereby our future generations may begin to appreciate computing and microcomputers whilst still at school.

4. PREVIOUS WORK:

When this project first began in June, 1977, there was virtually no organisation, advisory body, relevant literature or course to which one could turn to seek advice about the use of microcomputers in secondary education. MUSE was one exception but it was a small group comprising teachers whose schools had on-site minicomputers - Minicomputer Users in Secondary Education. With the advent of microcomputers, the M changed to Mini and Microcomputer Users.

However, at the time in question, anyone proposing to investigate the possibility of using a microcomputer was almost on his own, a pioneer in this field.

Although MUSE was engaged in a great deal of pioneering work, it was not until a year or so later that the members had proved themselves sufficiently to become recognised as a group with something positive to offer.

4.1. M.U.S.E:

During the MUSE AGM in July, 1977, the decision was taken to expand into microcomputers. As a result, several conferences were organised at which individuals who were interested in and actively working with microcomputers came together to formulate a set of guidelines for teachers wishing to consider the possibilities of microcomputers in their schools. The guidelines were published in Computer Education (CED77) in November 1977 by Roy Atherton of Bulmershe College, Reading. Subsequent editions carried articles on microcomputers in schools and it is without doubt that MUSE has contributed a great deal towards microcomputer education over the past two years. Perhaps this can best be illustrated by the growth in membership.

Certain members of MUSE were in collaboration with SINTEL (later Research Machines Limited) to enhance their machine for secondary education. We shall note later just how successful this has been (section 7). More recently, several workshops and conferences have been hosted as well as a continual stream of written information via MUSE newsletters. In the first of these (MUSE77) Hugh Williams chairman of MUSE hoped that "by 1980 MUSE will have established itself as THE forum for those with computers in schools." The fulfillment of this aspiration can be measured by the increased sophistication in the presentation of their Newsletter. Earlier copies were despatched with loose sheets bound by paper clips and contents so faint as to be unreadable. In September 1979 they produced a most respectable journal (CIS79) re-named 'Computers in Schools' and published by the Longman Group Resources Unit.

4.2. The British Computer Society Schools Committee:

The BCS Schools Committee is a specialist group of the British Computer Society which aims to promote computer education in secondary schools in the UK. Various working parties are established each year to investigate various aspects of computer education. One such working party was called the 'Chips' working party and later became the 'New Technology' working party and began as early as March, 1976. Unlike the MUSE group, little has actually been produced apart from a short bibliography (BCSWP77), a list of terms (BCSWP78) and a useful though short discussion paper (BCSWPb77). Various draft papers have been promised from time to time, but in reality very little of substance has been produced.

4.3. Literature and Courses:

Since 1977 there has been the expected growth of microcomputer texts. In 1977 only a handful were available, four of which are discussed below but which seem representative of the majority at that time. I do not claim to have tried to even begin an exhaustive research of available texts, but those that I have seen were more appropriate to a low level design course than a high level introductory text despite their misleading titles.

It is perhaps timely to state that one of the prinicpal stands of this project is the 'high level' approach. I am not concerned with machine level concepts or in building my own machine out of a number of chips. I do not believe that such a prospect would be greeted with enthusiasm by the majority of teachers. My intention then, in June 1977, was to see whether a microcomputer could be bought by inexperienced laymen and be made to perform its work with the least possible machine involvement.

They might be capable of fitting a 13 amp plug to the microcomputer and expecting everything to flow smoothly from there. I would not expect them to become involved with soldering irons. This is the meaning of the high level approach. It is in the light of this principle that the following criticisms are made.

The text by Aspinall and Douglas 'Introduction to Microprocessors' (AD) was written for a course (which I attended) given at Swansea University for engineers. Its aim was to present low level language principles to those already familiar with hardware concepts. Although the course which I attended in July 1977 was called 'A microprocessor workshop for teachers', it was a re-presentation of the engineers course. What most teachers already appreciated was low level programming, what they needed was a simple introduction to microprocessors, at a high level.

Page ten of the text discusses the NAND gate implementation of four inputs which is regarded as 'the familiar circuit diagram of the logic designer'; but what of the Computer Studies teacher, he can surely be thought of as a logic designer, especially by page ten? Worse was to come on pages eleven and twelve. 'Thus, we see a direct correspondence between a familiar tool of the logic designer, a truth table, as an actual circuit implementation, a read only memory. We have removed all the placement and wiring problems implicit in the implementation of the earlier logic circuit, and can see this approach as a possible way to implement combinatorial logic.' Is this really an 'introduction to microprocessors' at page eleven of any text? The rest of the book concentrates on low level language principles. Chapter two, despite its heading 'Hardware',discusses flags, jumps, an instruction set and conditional jumps. Chapter four is devoted to addressing modes, and so on. The emphasis is clearly on low level languages for those already familiar with hardware.

Barna and Porat book (BP) differs but little from the above. It becomes very low level and control application orientated. Compare chapter two (page five) which discusses traffic controllers for street intersection. On page 6 and 7, registers B & P are discussed. Neither book could be classed as a high level text and could certainly not be offered to the novice teacher.

Both Glynn (G) and Healy (HM) have presented somewhat more appropriate texts but nevertheless are more suited to the undergraduate or post-graduate in Computer Science, Physics or Electronics, where a study of the relevance of microprocessors in control applications is necessary.

The latest text which I have examined (NCC79) entitled 'Introducing Microcomputers' is no better. The first sentence of the opening page states: "A microprocessor is a component of a microcomputer." To use two undefined terms in an opening sentence shows very little concern for the beginner. The remainder of the chapter (twenty pages and only two line diagrams) covers at breathtaking speed many of the micro 'buzzwords' but leaves little space for an adequate introductory explanation. Although the approach is nearer to a high level approach, it is not a book for the novice.

The course at Swansea has already been mentioned as a low level language course designed for engineers with a heavy accent on very detailed machine level concepts. I have looked at several other course syllabi and discussed material with course designers, not in any exhaustive sense, but it must be concluded that the majority of microcomputer courses are set at a low level. Even commercial training courses (ICS142) seem to be able to offer only a machine orientated course.

It is not being stated that such courses have no relevance, but they do not seem appropriate to school teachers embarking upon the use of a microcomputer for general purpose computing. This was the case in 1977 and still is the situation in the majority of courses some two years later.

5. DESIGN OBJECTIVES

In the absence of any previous experience the design objectives for a microcomputer were simple. The most important consideration was to find a system which would be easy to install and to use by someone with no technical expertise in electronics. At various conferences and courses one had heard how easy it was to build one's own system, indeed, certain MUSE members at the time were shaping a particular SINTEL machine to the requirements of secondary education. But these were people with an electronics background. The average teacher would not be and would not be in a position to call upon such expertise from other members of staff. What was required was a machine which could be purchased 'off the shelf' and be ready to use at once.

5.1. General Requirements from a System:

5.1.1. Primary System Requirements:

The machine should be easy to install, comparable, it was hoped, to that of 'installing' a domestic washing machine. It should be easy to maintain by the teacher who, in practice, would become totally responsible for the machine. Furthermore, the system should be easy to use through the availability of comprehensive documentation.

5.1.2. Primary System Uses:

The system should be capable of running Basic programs typical of CSE/O and A level students. Basic is the most popular language for Computer Studies and Computer Science but a system which could offer Fortran in addition would have been an advantage especially to those schools in the ICSP which prefer this latter language and for those who wished to become involved with CAL.

Programs submitted by pupils particularly during their learning phase are short and simple. Therefore, reasonable diagnostic aids from the interpreter/compiler would also be expected. Eventually, the system would need to cope with processing programming project work required by the various examination boards.

5.1.3. Software Compatibility:

An exchange of software between schools would be expected, for example, for school administration, inter-curricula CAL programs, remedial programs, etc. Consequently, software portability between a given system or systems would be an important consideration.

The idea behind software exchange is the prevention of wasted effort where each school re-invents the same or similar program. A library of useful software becomes necessary for microcomputer users since they no longer have access to a central system which, formerly, contained their library. It therefore becomes important for schools to be in a position to exchange and receive hard-earned software.

5.1.4. Maintenance:

After sales service also becomes an important aspect of any prospective system. Computer machinery does fail and in such an event a speedy and sympathetic approach by the manufacturer is clearly important. Teachers cannot afford to lose class sessions because the microcomputer is not functioning. This may not be such a worry to commercial or research personnel where, typically, they can pursue other activities until the system is working again. But this does not apply to the timetabled classes where once a lesson has been missed, it has gone for ever.

5.1.5. Summary:

These simple objectives are no different to those expected by the average consumer. If we buy a car, we expect it to work, to fulfill the stated performance of the manufacturer, and, in the event of failure, a speedy after sales service. Purchasing a microcomputer need not be and should not be any different.

5.2. Project Requirement from the System:

The decision to purchase a microcomputer in 1977 did not rest solely on involvement with secondary education. At ICCC we could not but be aware of the importance and potential of small, dispersed computer facilities for tertiary and research applications at the College. It so happened that secondary education has the same initial requirements and performance expectations as those of tertiary education and research projects. The ICSP provided a vehicle for an initial investigation but it was the overall project investigation which determined the hardware specification for the proposed system.

5.2.1. A System for Secondary Education:

A cassette based system would have been sufficient if the only requirements were for processing Basic and possibly Fortran programs. However, with the additional interests in school administration only a twin floppy disc system could be considered. Furthermore, our concern was to investigate the full potential of the microcomputer.

5.2.2. A System for Developing CAL:

Apart from secondary level uses, the ICCC was interested in the possibility of a microcomputer system for CAL within the College. A branch of the Education and Information Users Section (within which the ICSP resides) is responsible for CAL within Imperial College. For this work a twin floppy disc system would also be required. It was hoped by early 1980 to 'down load'

CAL packages resident in the CDC 6500/CYBER 174 complex to our own micro system as well as forging links with other centres. However, this latter area lies outside the scope of this project but has been mentioned here to explain additionally the reason for purchasing a disc system and to illustrate the scope of the overall project.

5.2.3. A System for University:

Within the ICCC we need to keep abreast of computer developments in order to be aware of possible changes and improvments for our users. With the advent of micro technology, we clearly had to investigate its impact upon our traditional computer centre accessed by many thousands of students, graduates and research workers. In June 1977, there were many questions relating to microcomputers which we could not answer. For example, would users benefit more from an on-site micro system in certain fields of computing activity than from our large system? Was this large system really necessary for the majority of our users? Could a departmental micro cope just as well? Would a complex of smaller systems be more beneficial? What is the future role of large computer centres in the face of dispersed computing facilities via microcomputers? What courses should we be providing to help our users adjust to the new technology? Could a microcomputer support a data base? Could a microcomputer be used to provide CAL within the Fortran programming and system courses run by the Centre?

These were some of the unanswered questions. Only by involving ourselves directly in micro systems could we begin to provide some answers.

5.3. Specific System Choice:

The first Computer Hobbyist shop in Britain opened at 174, Ifield Road, West London, in May 1976. It was called Computer Workshop. Gordon Ashbee (the founder) and his close associate John Burnett (C77) were the principal people involved. Originally, it aimed at the ameteur market along the lines of many USA hobbyist shops. Later, it offered a complete microcomputer system for schools, based on the Motorola 6800.

Since this was the currently available off-the-shelf system designed, so it was claimed, for the secondary market and one which teachers would be most likely to buy, the ICSP bought this model in favour of any other. It was available, based in London, apparently 'assembled' and ready for use and promised a multi-user system which schools would think desirable. We began discussions in June 1977 for the purchase of this micro system.

6. EVALUATION OF THE COMPUTER WORKSHOP M 6800

In June 1977, a visit to Computer Workshop quickly demonstrated how involved it had become in secondary education as well as in the ameteur market. According to their documentation, complete systems could be purchased as 'assembled' units. This suited our high level approach. Cassette systems were available but because of the other aspects of the ICCC involvement, we decided upon their twin floppy disc system as well as their four terminal multi-user Basic system because of its obvious interest to schools. However, the idea of turning a personal system into a time-sharing system seems to go against the very nature of microcomputers.

6.1. Specification of System:

6.1.1. Hardware:

An order was placed in July 1977 for a four terminal multi-user Basic time-sharing system. A system although not immediately available would comprise the following hardware:

1 x MP-68 with 4k

4 x CT-64 terminals

4 x MOD 1 modulators

3 x MP8 8k memory boards

4 x MP-S additional serial interface

1 x TS1 Time-share board

1 x twin FD8

1 x AC-30

Full details can be found in (CW78) the Computer Workshop catalogue. Our high level approach precludes any low level appraisal of the hardware. Two points mentioned in the introductory documentation are worth quoting since if they were true would have fitted in with our simple design objectives. The first stated: "In addition to the outstanding hardware system, the 6800 has without

> question the most complete set of documentation yet made available for a microprocessor system."

The second quote referred to : " plug together construction making construction and testing very easy." We comment on these two statements later.

MP-68 : This consists of the MP-A board , the primary logic board for the system. It contained the 6800 microprocessor chip, the 6830 ROM which stores the mini-operating system and the 6810 128byte scratch pad memory for ROM. There was a crystal controlled processor clock driver and baud rate generator providing serial interface baud rates. The board also contained a power up/ manual reset circuit which loaded the operating system when activated. Full I/O buffering and a +5volt power supplied by a regulator.

The rest of the MP-68 comprised a mother board with interface address decoding circuits; the memory board with 4096 words of static memory, expandable to 24k by plugging in additional boards; a serial control interface card; and, a cabinet and power supply. The entire system was packaged by Southwest Technical Products Corporation (SWTP).

CT-64: This terminal permitted sixteen lines per screen with 64 or 32 characters per line; upper and lower case characters; 128 character ASCII set; scrolling or page mode operation; and, control characters with 32 combinations. A matching 9 inch monitor could be purchased separately, alternatively, a domestic TV set could be used via a UHF modulator for £4.50. It was anticipated that the availability of cheap TV sets would be more appealing than £140 monitors. Thus, we set out to purchase our own TV sets.

FD-8: As our auxiliary storage device we opted for the twin floppy disc which was marketed by Midwest Scientific Instruments (MSI). Each diskette (hard sectored) contained 77 tracks, each track 16 sectors, each sector 256 bytes, i.e. 308k data bytes per diskette.

AC-30: Audio-cassette interface using Kansas City recording standard was required since the bootstrap program was held on cassette tape.

6.1.2. Software:

The MSI FDOS operating system permits a small microcomputer system to be programmed in assembly or the Basic high level language rivalling many of the smaller minicomputers. System features comprise a disc based Basic, a co-resident assembler editor and FDOS. In order to bring FDOS and other disc driver routines into the system a small (512 byte) Bootstrap had to be located on tape and loaded into the system. This exercise took approximately 3 minutes. Later we purchased the PRR-68 PROM/RAM board and excluded the need for tape cassettes as well as being able to locate the routines directly on the PROM chip.

DOS permitted the user to perform CATALOGUE(or FILES), CREATE, SAVE, PURGE, INIT(ialise), COPY, RENAME, LOAD, RUN, PACK, LIST, CORES and BASIC - all of which are familiar to users of a large computer system. Our Basic occupied 12k of memory and permitted most features of Basic, certainly enough for typical project type programs for CSE/O and A level.

6.2. Experience With System:

6.2.1. ICSP Project Experience:

At the time when our order was placed, on July 11th, 1977, no one person had been appointed to administer the order. Several people were involved from the ICSP project, the Education section, the Applications section, all from the Users Support of the ICCC, and, finally, from financial considerations the order was placed via the Communications section. As a result, no one section took any real responsibility for chasing up the delay in receiving the equipment. This was our mistake entirely and the lesson was taken to heart as an example of real experience which could later be passed on to our schools.

The outcome was that by January 1978, the entire order had still not been delivered. The odd component began to arrive from October 1977, but no one knew exactly what remained of the original order. It was only when MSc students from the Computing and Control department began to announce their interest in the microcomputer with a view to completing their MSc projects that something more positive was done. I was appointed in April 1978 to take over the general administration of the project. Within the month, all components were checked and it remained to plug them together into a functioning system.

This task was given to Ken Palmer, chief technician for the ICCC, who was experienced in electronics and was responsible for the connections of terminals within the College to our CDC system. In other words, a person who should have found little difficulty with the interconnections of the various hardware units. Haman Elgindi on secondment to the ICCC was to become responsible for testing the software performance of the system. However, it was not until August, 1978, some four months later that the system was near completion. A report (ICCCJS78) describes some of the intervening problems.

"Over the past four months the following has been achieved. All units of hardware and software have been checked and seen to work as a unit. This was not without considerable assistance from K. Palmer and H.Elgindi.

The first problems encountered resulted from the deplorable state of the documentation supplied by the manufacturer - Southwest Technical Products Corporation - Computer Workshop being a distributing Agency in the U.K. Although K.Palmer is an experienced technician he, nevertheless, had to wade through far too much irrelevant documentation in order to discover where and how various units had to be assembled. The point of interest here is that we insisted on buying only 'assembled' units to make construction as easy as possible. But like Humpty-Dumpty in "Through the Looking Glass", manufacturers tend to use words and attach their own meaning to them, independent of their common usage. 'Assembled' to Computer Workshop does not have the meaning which is accepted in everyday parlance.

An 'assembled' system involved the services of an experienced technician for over six-weeks (part-time). It was only by delving into documentation on 'kit construction' that any sense could be made of the 'assembled' version of the documentation. This is beyond the scope of most school teachers. Schools which did own a microcomputer in 1978 also had access to an electronics expert or hobbyist willing to spend many hours assembling the units into a working system.

Nevertheless, after several weeks, the hardware units have been connected successfully and the software tested so that finally we have a usable system.

An associated hardware problem was the type of CRT screen to use. The documentation suggested an alternative to the video monitor, namely, a domestic TV set, at a much lower cost. Clearly schools would be attracted by this. Originally, we had considered buying four different types and sizes of TV sets to permit some evaluation. Caution however dictated that one set should be purchased first. Tempo Discount Stores offered a 'bargain' PYE 12" black and white, lightweight model for half the price of the Computer Workshop monitor. However, once connected to the system characters were blurred and the tuner needed to be adjusted every minute or two. After contacting PYE to see whether the signal could be improved and, by modifying the set according to their technicians, a slightly better quality was obtained. A second TV set was ordered in July 1978 from SONY. This was of better quality than the Pye as a television set but, in practice, hardly improved on the overall quality as a microcomputer monitor. It was then decided that two video monitors should be purchased as our third and fourth screens instead of further television sets. One was the Computer Workshop model, the other an Hitachi monitor. Both of these proved to be highly superior and in our view justified the higher cost.

Later on, a trolley was constructed making the microcomputer portable so that demonstrations can be given anywhere in the College."

Apart from portability, when the components are bolted onto the trolley, some degree of security is offered.

In July, 1978, it was decided to buy the PROM based bootstrap in order to speed up use of the system. Although this was just one year after the initial order had been placed and only six months after all the components had arrived, Computer Workshop were no longer supporting MSI discs and were promoting the SWTP mini disc system. It was necessary for us to look elsewhere for assistance, namely, to Strumech Engineering Limited from now on for any matters related to our disc.

6.2.2. Pupil Experience:

In September 1978, several schools were invited to test our system. This offer could only be extended to those schools fairly near the College since it was expected that pupils would visit the College on a regular basis. The International School in London sent three students on a weekly basis for two terms. These were boys aged between 16 and 17.

An interesting point here was that after only a one-hour demonstration and armed with a simple guide on 'how to use the microcomputer', these boys were confident enough to begin to explore the system by themselves with very little overseeing on my part.

The simple type of documentation (appendix 1) was sufficient to enable them to begin to use the system commands almost straightaway. For the first few weeks it was necessary for me to be available to answer any queries, but after that I was confident enough to leave them alone. They very quickly began to write simple Basic programs, save them on disc and later retrieve them, modify them, etc. In a matter of weeks, they had progressed from the simple documentation to the Basic reference manual supplied by MSI. This is not too surprising and any computing teacher can agree that pupils are far more capable than the teacher of exploring a system to its full potential.

6.3. Conclusions:

6.3.1. Specific Conclusions on the CW M6800:

6.3.1.1. Technical Expertise Required:

The technical expertise required to construct even an 'assembled' system would be beyond the scope of most schools unless they had ready access to an electronics teacher who would be willing to spend many hours of his own time in constructing the system. Even when this experience may be present, there is still the problem of what happens if this teacher decides to leave the school. This situation was not uncommon when terminals were first installed in schools.

The testing of the software once the hardware was assembled, engaged one of our members of staff at ICCC for several weeks. The average teacher could not be expected to find this time nor the sufficient motivation or the general know-how to cope with this M6800 system. At one conference, a speaker suggested as a general rule that a school wishing to base a CSE or O level course on a microcomputer should allow one year from the order date to the beginning of the course. This was certainly my own hard earned experience. At this time, my advice for teachers was to wait for a year to see how the market would settle down. New systems would be available which would be easier to construct and, hopefully, more readily available.

6.3.1.2. Documentation:

Computer Workshop had advertised their documentation as being the most complete for any micro system. Complete it may have been, readable it was not. We have mentioned already that it became necessary to read the 'kit' documentation in order to understand how to construct the assembled components. But even when this was achieved, it was difficult to find out how to use the system since the odd reference was scattered here and there throughout the 714 pages, with one reference throwing the reader onto some other incomprehensible section.

It became necessary for the software tester, H. Elgindi, to become the documentation editor as well. I was able to identify two levels of documentation at this stage. The first level was a simple introduction by which, and with the minimum of effort, a new user could create, save and run Basic programs on the system. This is not a trivial conclusion. Much time can be wasted by beginners who are forced to wade through irrelevant details when all they want is to run a simple program. It is a pity that so often when motivation is especially high beginners are frustrated by the lack of a very simple level of documentation.

The second level is the more advanced documentation which a user will require once he is familiar with the simple steps. Without both levels not only does the pupil waste time but also the teacher who will be asked the questions.

6.3.1.3. Transportability:

One requirement from a micro system was that it should be portable so that demonstrations could be given in different parts of the College. Frequently, this proved to be a problem. After moving it from one point to another, even on the same floor level, the micro system would not function. To resolve this, one had to accept that possibly one of the boards had shaken loose, and, consequently, all the PCBs would have to be pressed down to secure contact with the pins. This may be quite an obvious matter to an engineer, but not to the average Computer Studies teacher. After one knows what the cause of the trouble may be, it is a simple if annoying way of correcting the fault, but how does the non-engineer discover the fault in the first place? Secondly, why should we have to put up with such inferior microcomputer designs. If we had paid £4000 for a car, we should not expect the engine to die suddenly while driving along the M1, and certainly, not be satisfied to find that the cure is to push it into the hard shoulder, shake the engine around and then restart. Why do we accept anything less for a microcomputer costing £5000?

6.3.1.4. As A Stand-Alone System:

Despite the problems above, once a user had come to terms with its quirks the M6800 functioned quite well as a stand-alone system. The multi-user system ordered in July 1977 did not come until April 1979. This was after many telephone calls, personal visits to the London office, etc. When it eventually came we had become involved with another microcomputer which proved more reliable.

In 1977, Computer Workshop was obviously in a very strong position to capture the secondary education market and was regarded as a promising light. But it could not provide the right after-sales care that schools need. Doubtless, the various changes in management exacerbated the situation. Users were promised that everything would be all right once the new factory in Peterborough was opened. But this was not to be. Two out of our five terminals developed faults. We suspected capacitor failure and, as requested, sent them off to Peterborough by Red Star (at £6.00 each). Two weeks later, they were sent off to the London office, untouched. Two weeks after this and several telephone calls on my part and serious criticisms of their 'after-sales-service', they began to service the two terminals. They were eventually returned some six weeks after the costly packaging to Peterborough.

We could only conclude that they were not suitable for schools in general. Equipment sold in a previous year and involving over half the budget was not supported one year later; promised software arrived two years later; enhancements such as the 80 character per line printer was promised but never materialised; the documentation proved unreadable and was not improved. As an agency, it could not be recommended for secondary level education.

6.3.2. General Conclusions on Micro Systems for Schools:

6.3.2.1. Administrative Leader:

Although in retrospect it may seem an obvious matter to have appointed an administrative organiser especially since several different sections within ICCC were interested in the microcomputer, nevertheless it was a lesson which had to be learned. I must conclude that one person be responsible for the purchasing of the system, receiving the items, checking up on any delayed component. This does involve a great deal of time and in fairness to the administrator he should be allowed sufficient time to attend to this work.

6.3.2.2. Manufacturers' Documentation:

Manufacturers' documentation is notoriously poor. We should expect the same if not worse from microcomputer manufacturers in view of the continual changes in technological developments. What is written for today will be out-of-date by tomorrow, therefore, why pay much attention to today's documentation. This is their argument. However, poor documentation results in a great deal of confusion and waste of time for the user. If a user is to make proper use of a system, he does need readable documentation. Some compromise should be made between the user requirements and the amount of effort a manufacturer can be expected to spend. User groups can provide the necessary voice to the manufacturer and perhaps even demonstrate the type of documentation that they require.

However, at the present time, it is the teacher who has to prepare the two levels of documentation.

6.3.2.3. Management of the System:

The idea of having one's own computer on-site is attractive for many schools since programs can be developed and processed at will and no longer at the whim of some computer centre manager. However, there is a price to pay for this freedom. The owner must now become totally responsible for the entire management of his system. He must become responsible for organising an hourly (or so) timetable for the use of the system; provide instructions on how to use the system; diagnose and possibly correct system failures or call out the service engineer; he becomes responsible for maintenance contracts, returning faulty equipment, oversee the system and provide for security arrangements. Other aspects are discussed in section 8.

Hitherto, responsibility for these aspects were assumed by the manager of the centralised centre. Now they fall totally to the teacher, who additionally must have the time to carry out these duties as well as his teaching work. Often head teachers have no realisation of the effort such management entails but, often,neither does the teacher until he assumes the role.

6.3.2.4. Hardware Considerations:

Apart from the choice of microprocessor, other hardware components have to be considered. Our initial experience taught us that the domestic television set **is no substitute for video monitors. Children will accept the poor quality, but I can see no justification for the use of TV sets at the expense of potential damage to children's eyes. Furthermore, in my own experience, I have learned that cassette tapes are much more inferior to floppy discettes. In a** classroom situation where the system has failed,a wait of five to ten minutes to re-load the bootstrap and Basic cannot but undermine the teacher's authority, and the implications of the microprocessor. As an ideal, only disc based systems can be recommended, but we do appreciate that it is only by purchasing cassette systems that microcomputers can get into a school. Hopefully, the teacher will see this as a short term system until more money becomes available for a disc system.

6.3.2.5. Accomodation and Mobility

Microcomputers come in various shapes and sizes. The simpler PETs are self-contained units comprising keyboard, MPU, screen and cassette unit. The Tandy on the other hand has four separate units. The same is true for the RM 380Z. Accomodation and mobility around the school have to be seriously considered. The physical structure of the school may well affect the mobility if split levels and different buildings are common. There are two approaches.

The first is to have the micro system on a trolley and to move the entire system at one go. This is possible provided that the school does not have split levels or several buildings. Snow and ice (even very heavy rain) can present impassable obstacles confining the micro system to one building just when it is required somewhere else. If lifts are available then transportation from one level to another presents no problem (until the lift fails). A trolley should have large rubber wheels so as to lessen un-necessary jolting. If bolted onto the trolley, a degree of security is maintained.

The alternative, apart from employing a team of pupils to man-handle equipment and thereby losing class time, is to house the system in a separate room. Private schools may be better off for room space than many state schools. Clearly, in-school politics will be roused in order to gain valuable and scarce room space. What is not suitable accomodation, although all-too-common, is the typical cupboard room where only a small handful of pupils can ever get to the microcomputer. The disadvantage of having a separate room, even the ideal as shown in figure 3 , is that teachers and pupils will have to move to the room. Some teachers especially from disciplines other than Computer Studies will be reluctant to use the equipment under this condition.

However, if a room is made available then an ideal arrangement could follow the plan of figure 3 . Of the two choices, I prefer the separate room to moving individual units in relays or even the entire system on a trolley. If the material to be used on the micro system is good, then even the most reluctant teacher will eventually be persuaded to 'go to the micro laboratory'. For serious CAL material, TV monitors are required. Another useful point is to have a small room which can be locked, adjoining the laboratory so as to secure the equipment when not in use. It is fully appreciated that this is an ideal arrangement. Usually, the schools which I have visited have only the small lock-up room with teacher and a few pupils crammed into the small area.

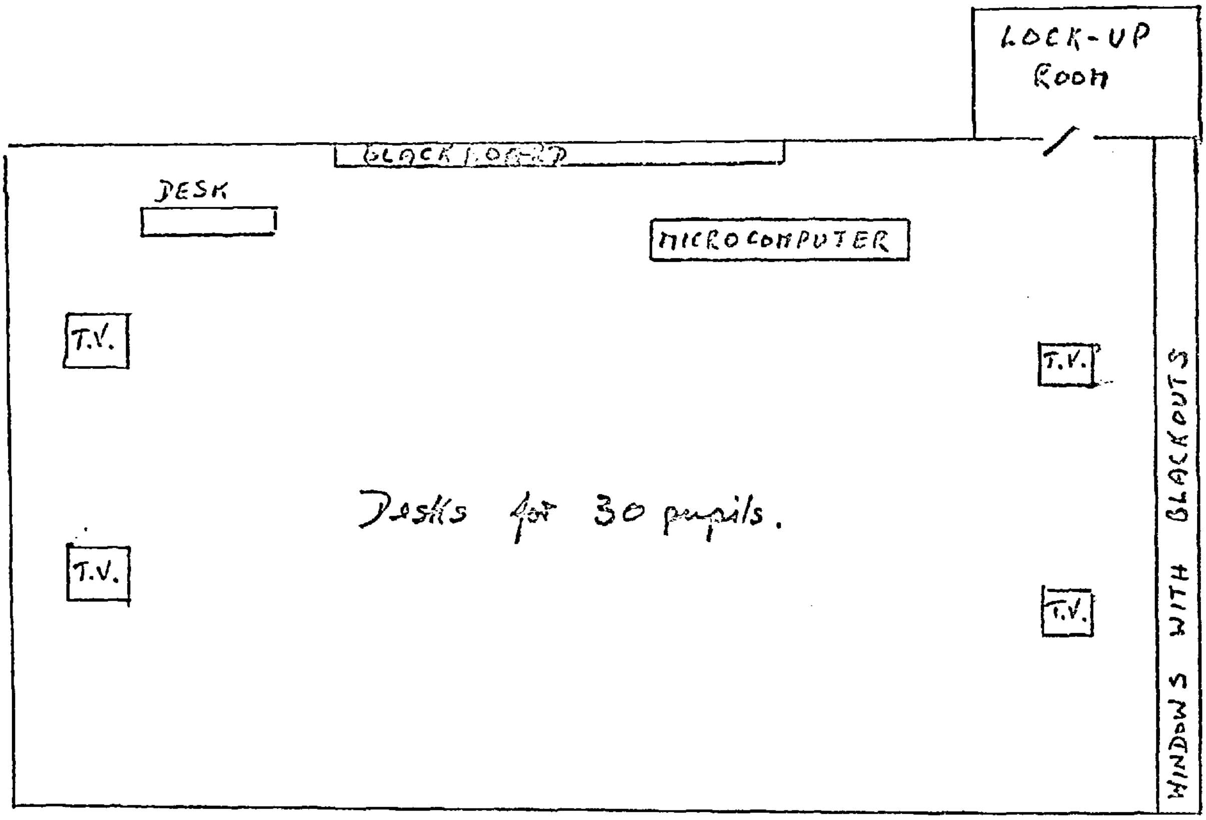


DIAGRAM 3: Ideal layout for microcomputer laboratory

6.3.2.6 Software Maintenance

Software is the living power of computers, without software computers would be useless machines. The development of software whether by a manufacturer as part of the operating system of the microcomputer, or by professionals for teaching material or schools administration, or, by individual teachers and pupils is a time-consuming and highly expensive task. Once the software has been purchased or written, it is not something to treat lightly. It will need to be maintained. Maintenance will involve two main considerations. The first after the programs/data files so that they do not become lost or destroyed; the second is the tailoring of existing software to meet the special needs of oneself or one's institution.

It will be useful in the following discussion to divide schools into two broad categories; those which have some back-up supplier of software,e.g. in the form of a link to an LEA computer centre; and those schools which are entirely on their own. Below the term 'systems software' refers to any software for the operation of the microsystem,e.g. language translators (both for high and low levels), text editors, monitors, even home produced assembly routines to create some special technique, such as 'down-loading' files from a mainframe to a micro. 'Library routines' refer to any application program in CAL, schools administration, pupil examination projects, any teacher/pupil program of any value or significance.

6.3.2.6.1 Individual Users

Private schools are typical examples of this category. Having no access to LEA computer centre's, they need to be entirely self-sufficient. When software is purchased they need to ensure that in the event of any mal-function by the system or carelessness on the part of an individual there is always a second or even third copy available. This applies to both system and library programs. Micro manufacturers supply system software on discette or cassette with the machine. This should immediately be copied onto one or more other tapes or discettes, reserving the manufacturer supplied version as the master copy. Should anything happen to one of the two working copies, the master copy can be used to re-generate further copies. This should apply to any library routine of any significance or length. Short teacher/pupil programs, less than 50 statements, could be listed with only one copy of the program preserved listing acting as a master copy. But CAL and school admin programs require several copies. With CAL programs the master should reside with the micro manager but the individual teachers whether or not from the computing department should be responsible for maintaining copies since it is their material. The school admin programs will have ever changing data files. However, it is my strong belief that school admin and school teaching should be two distinct units, although the same person may have management responsibilities for both. The supervisor/manager of the school admin will assume the normal duties of any Data Processing manager, maintaining ancestral files for data, security of sensitive data, master files and transaction files and the archiving problems related.

As for maintaining copies of the teaching programs, the manager will have to organise how the basic medium (tapes or discettes) are to be distributed amongst both staff and students. Cassettes are relatively cheap, £3, but discs are more expensive, £10 or more.

The individual school has to be more careful about archiving, copying and general maintenance than the school which can rely upon the services of a computer centre staff. Purchasing new copies or re-writing the entire program is the alternative to careful husbandry. However, in exchange for their extra diligence, they can amend any suitable program for their own requirements. This may not be so simple a task for LEA centre schools who have to rely on a more general program to cover needs for a group of schools.

The individual school will also have to keep in touch with many sources in order to keep abreast of any developments in either hardware or software.

6.3.2.6.2 The Group Schools

Schools linked into some LEA computer centre have distinct advantages over individual institutions. By 'link' I mean any form of access, physical movement, via newsletters, or, indeed, via a telecommunication link. The centre can gather material from many sources including the schools within the scheme; disseminate material; in some instances, even generate material. This material could be system enhancements, CAL or school admin programs, even ideas for examination projects or PTA demonstration programs.

Master copies will be held at the centre and therefore, individual schools need not be so involved in copying, archiving and maintaining programs. All these problems will have to be shouldered by the computer centre. Someone or group at the centre will become responsible for the problems of copying files, for example, ensuring that the information copied is accurate in the first place before being sent off to schools; any updates or enhancements to the file (data or program) made at the centre will have to be tested and all schools notified of the updates, and new versions sent off or at least advertised perhaps via a newsletter. Of great importance is adequately documented versions. Anyone taking on the supply of material must also shoulder the responsibility for producing good quality documentation. Archiving files will become another important aspect to be shouldered by the centre especially if telecommunication links exist between centre and school, e.g. the number of copies, the version, whether to maintain older versions, etc.

Indeed, any computer centre taking on the responsibility for this work should have adequate staff numbers as well as a guarantee of continunity in the future. Finally, I introduce the problem of several schools accessing an interactive program simultaneously. This is of particular relevance if the master program generates other files to the system Files' Manager in the course of its execution. These files may have to be organised for individual schools so that correct versions can be 'queued' to batch printers or stored in the system for later transmission. This is no trivial problem and requires the support of programmers familiar with a given system. It appears to me that such situations will have to rely on the services of traditional computer centres until technology reaches the ideal of enabling all schools to individually own their entire suite of packages. This is not the case in June 1979, but could well be so in five years time.

7. EVALUATION OF RESEARCH MACHINES OF OXFORD

In August, 1978, the ICSP began discussions with Research Machines of Oxford (formerly SINTEL) about the suitability of their 380Z system for secondary education and for College use. Our previous experience with the Computer Workshop M6800 system proved useful in the initial discussions.

Although other systems such as the Commodore PET, Tandy and Apple were known to us, apart from the other 148 models as listed in (ED78), They were dismissed from any serious investigation. The PET machine was too restrictive for general purpose computing. At the time, the PET's architectural philosophy allowed only stand alone mode. Two or more PETs could not be used simultaneously in a multi-user environment since each PET was designed to be in complete control thus causing conflict with any other machine being used. The Basic language and memory extension were limited and the fact that ASCII code only was accepted meant that software developed on any other system could not be loaded into a PET. However, its very competitive price would be especially attractive to many schools.

Apple was, in our opinion only suitable for games playing and not capable of tackling serious development work as desired by the total IC micro project, for example in CAL and administration. Apple II in 1979 is being used for colour graphics and speech laboratory work and, as pointed out earlier (in 3.3.4), is of great interest and value for aurally handicapped children.

7.1. Specification of System:

7.1.1. Hardware:

The hardware consisted of the following:

380Z microprocessor (with keyborad) and 56k of memory (RAM)

FDS-2 dual floppy disc system

RS232 serial interface

PIO board - an interface development board

an Hitachi video monitor

Further details of the hardware and software can be found in (RML78 and PCW78), however, for the purpose of our high level specification the following points are of interest. The CPU of the 380Z uses the Zilog Z80 A microprocessor with a 4MHz clock. We decided to purchase the largest memory available, namely 56k of bytes, so that the full potential of this system could be investigated. Future administration uses dictated a dual floppy disc and the use of 8" standard diskettes, soft-sectored dual sided, with a maximum of 1 megabytes on-line (eventually two megabytes with the promised IBM 3740 dual density standard). The alternative is the mini-floppy disc system. A single mini-floppy system needs to hold the 9k disc Basic, the disc operating system, the text editor, peripheral interchange program and disc status program, realising only 49k bytes for user files. A second mini-floppy drive will increase this user file space by 75k bytes. Each minidisc is capable of holding 82k bytes of information. Although, the standard 8" disc system is clearly better for on-line files, the minidisc system is perfectly adequate for processing typical schools' programs. My previous experience with cassettes showed how time consuming and tedious they were in comparison with discs. Any serious work must justify the cost of a disc system.

7.1.2. Software:

The extended disc Basic (XDB) interpreter and the Fortran - 80 (Microsoft) were chosen as the two high level languages. We had thought about Pascal but its subsequent unavailability as well as its decline in popularity has meant that it has been put to one side for the time being.

The disc operating system ran under the popular CP/M. We opted for the RML text editor, an interactive character-orientated editor which, it was claimed, could be used for program preparation, 'word processing' and data manipulation.

7.2. Experience with System:

7.2.1. Project Experience:

One of my first impressions of the RML 380Z is that it is much more elegant in style than the Computer Workshop M6800. Only three 13amp plugs are visible and very few interconnecting wires in evidence. However, the disc drives are noisy and despite various attempts to quieten them down these have not succeeded. The system sits comfortably on a trolley and is easy to transport around the College for demonstrations and seminars. To date, the system has always worked after being transported and in this sense alone is much more reliable than the CW M6800. The various components arrived within three weeks of the delivery date and were constructed on one afternoon.

Documentation proved to be better than that of many other manufacturers but it is still well below what is required. The constant reference to the cassette operating system (COS) as owners of a disc system causes unnecessary confusion. The attempt to introduce the system to a new owner was certainly a vast improvement. However it did go too much in one direction. The author assumed that the beginner would do everything incorrectly and hence the beginner was introduced initially to all possible mistakes. A single correct guide should first be introduced, followed by an explanation of what happens when the correct steps are not followed.

The documentation does need improving but a most encouraging aspect of my talks with the manufacturer is their obvious sympathy with the needs of users and their own admission that all was not perfect. They appear to be genuinely concerned about correcting and improving any faults in documentation, hardware and software.

Much of the material has has to be re-written and the material produced in folders and in the form of 'menu' sheets for beginners. This does appear to be one of the penalties of owning one's own system.

The only major doubt that we had in 1978 was whether RML could continue to function as a company. It was a small company, working in very crowded conditions in Oxford with an alarmingly growing order book. However, this is the sort of gamble which has to be taken with almost any young company, especially today in this new field of microprocessors. By Dec. 1979, they seemed to have shown they could cope.

As a hardware system, the RML 380Z proved to be very reliable and potentially a most powerful system. It has become our recommended system for both schools within the ICSP and for research departments within IC. A series of courses and seminars have been developed around the 380Z, e.g. two seminars, 'Personal Computer Systems' and 'Criteria for Microcomputer Selection', and, 'Introduction to Microprocessors', Introduction to Microprocessor Organisation' and 'Advanced Microcomputer Engineering' (EH79/80).

Turning now to the software, one of the most useful pieces is the CP/M which is fast becoming the microcomputer system international standard floppy disc operating system. It was developed by Digital Research in the U.S.A and a new version will extend its usefulness to those who wish to expand their systems beyond the two megabyte storage facilities possible with diskette systems to the 128 megabyte available with the coming eight inch 'hard' disc drives.

The basic monitor is available automatically when switching on and for those who wish to use and experiment with machine code programming, there is a delightful software front panel allowing users to display on the monitor screen and to modify the contents of all the registers and any storage location. There is also a single -stepping mode and continuous stepping-mode which can be most useful in a teaching situation. This panel clearly makes redundant the use of specialised and more expensive logical analysers. As a result of using the text editor, it is a comparable, even a superior text processing facility to those available on most large mainframes.

7.2.2. As a Secondary Level System:

RML are concerned with secondary education with 25% of their sales being directed at this market. We would certainly recommend those schools which can afford to do so to buy a full disc system. However, the cassette version is also a highly prised system which can easily be upgraded to a disc system when finances permit.

The languages available are certainly appropriate even for A level project work, for example, the XDB and the promised Basic Plus which is said to contain Pascal features. Fortran is also available and is preferred by certain schools.

The software front panel is clearly extremely valuable in A level Computer Science. The recent formation of a 380Z Users Group will provide all schools with such a machine to exchange software and documentation aids as well as providing a pressure group to maintain close and profitable relations with the company.

Our own experience and those of several other schools has shown the after sales service to be at worst sympathetic. In practice, I have found that any faulty equipment is either repaired in a reasonable time or else a replacement found.

7.3. Conclusions:

1. Orders were met within three weeks of the delivery date.

2. The RML was easy to install but the documentation could be improved. It is a simple and neat system which has proved easy to maintain. The formation of the

Users Group could benefit individual schools not only in the exchange of software but also in the exchange of more suitable documentation.

3. The system can cope with the primary educational requirements of Computer Studies and Computer Science candidates.

4. Software compatibility for disc based systems is guarenteed with the use of CP/M so that packages generated by the Users Group can be readily exchanged.

5. It is easy to transport and works first time after transportation.

6. After sales service has proved to be reasonable.

7. What is valuable is that people who already have the RML system remain enthusiastic about their system. A claim I have not heard with any other model.

The system meets the simple design objectives in section five and can be recommended for use by schools in the ICSP.

8. SELECTION CRITERIA AND REQUIREMENTS FOR A SECONDARY LEVEL MICROCOMPUTER SYSTEM

The following abstracts part of the independent investigation carried out by the ICSP by presenting a set of criteria for the selection of a microcomputing system for use in secondary level institutions, and a summary of the requirements of such a system.

8.1. The Purpose of a Microcomputer System:

Before selecting a given microcomputer one should be clear as to the purpose for which it will be used. We can identify the following six broad categories which will be referred to in some of the following sections.

a) processing programming projects for CSE, Ordinary and Advanced level examinations

b) introducing machine level concepts for Advanced level Computer Science

c) for use within schools' administration

d) for use of CAL packages within Computer Studies, Computer Science and other disciplines

e) for remedial work, i.e. additional practice for weaker students or for those who have missed certain lessons

f) specialised systems for handicapped children or for those with particular learning problems.

Because of the special problems relating to category (f), we do not pursue this classification further although its importance is fully appreciated.

8.2. Language Requirements:

Basic is one of the most popular languages for microcomputer systems and is available on all development systems. Fortran is perhaps one of the most commonest languages known to research, teaching and scientific personnel. It is available on many microcomputers. Other languages such as Cobol, Algol and Pascal also exist but are not so generally available as Basic and Fortran. For the first five classifications given in section 8.1, we can suggest the following languages.

a) High level languages such as Pascal and Cobol are not serious consideration for the majority of school pupils, particularly in June 1979. This is not a comment on their suitability as languages but on the difficuluty of their implementation on microcomputer, their future support and the development of packages for these languages. For example, Pascal in June 1979 required 56k of memory to run successfully on a RML 380Z; Computer Analysts and Programmers (CAP), the designers of microCobol were in financial straits in 1979 mainly as a result of their high capital investment in the microCobol project. In my opinion, most children have enough difficulty learning even the simple BASIC language let alone the more esoteric aspects of Pascal. Furthermore, how are the teachers to learn Pascal.? So, teachers are left with the choice of either Basic and Fortran, which is not a bad one, especially since many already know Fortran and since Basic has become the almost universal language for schools and microcomputer systems.

b) In order to introduce machine level concepts, the particular machine language of the microcomputer can be used, although in practice, the teacher will have to create a working sub-set since a full set would be too complex for most secondary level use.

c) For school administration, either Fortran or Basic (extended) would be suitable. Indeed, Basic is fast becoming the more suitable choice with its relatively easy I/O and string handling facilities and on many interpreters and compilers has better diagnostic facilities. Certainly, the RML Micro-soft Fortran has inferior error facilities than the Basic translators.

d) For CAL packages both Fortran and Basic will be necessary since these packages are written mainly in both these languages.

e) Remedial programs can be written in whatever language the teacher has at his disposal, since pupils will typically be concerned only with the input of data.

Basic is clearly the most sensible language for secondary level education with Fortran being a good second language. For CSE and Ordinary level programming projects a typical 9k Basic is sufficient. This will require a minimum of 16k RAM for either a cassette or disc system. However, such a sub-set of Basic will not be suitable for administration programs or for developing CAL packages. For these a typical 12k Basic which permits such features as MID$, auto line numbering, PRINT USING, hexadecimal constants, substring search, etc, will be required. In general, a microcomputer user is always advised to get the largest version of Basic which will run on his system and which will permit enough memory for the development of large programs. The cost of a typical 9k Basic is approximately £25 whereas a 12k Basic will cost £80. Fortran may cost up to £300.

8.3. Minimum System Requirements:

8.3.1. Hardware Specification:

a) To run project programs only a development microcomputer system can be recommended. Anything less than this will have to be converted into such a system, requiring a great deal of specialised knowledge and time. Any development system will run Basic programs, but if one is considering possible use of programs developed by others then one will have to be more selective in the choice of system. The RML 380Z is rapidly becoming the standard educational microcomputer system and this is the one machine which we would recommend.

A cassette based system is only a second best. If money is not available for a disc based system, then one has little alternative. Cassettes are slow and tedious compared with discs and if the system mal-functions during the development or execution of a program, then re-loading of system files and language translators can take up to 10 or even 15 minutes. Even the short bootstrap program loaded from cassette on the M6800 system became unacceptable within a few weeks.

Consequently, only a disc based system can be seriously recommended but one must also take into account that for project work hardcopy facilities must be available either in the form of a character printer or a teletype device.

b) Board micros vary a great deal, especially in price. But for a teaching environment the more a student can see of the various chips and connecting wires, the easier it is to appreciate what is happening. The Mini-Micro Designer (MMD-1) has been developed by E&L Instruments, Incorporated and is obtainable from E&L Instruments UK, 62, Queen Anne Street, W1M 9LA. It is remarkably good in that the various chips are not only visible but are also labelled clearly and the various interconnections between the chips are placed on top of the board as opposed to being wired underneath. Output is displayed via LEDs which are more useful at this level than character display since the fact that computers do use pulses and work in binary, octal and hexadecimal can be appreciated more immediately.

c) In administration, a cassette system could only be used to produce very simple and trivial tasks of a highly serial nature, e.g. the production of mailing lists. Any serious work will involve copying files and random access. It is here that the inherent limitations of the cassette can be seen. Copying files must be performed within seconds and minutes, not in hours. The only satisfactory medium is the twin disc system which will also permit random records to be selected.

But should one choose a mini-disc (5¼) or the standard discette (8") system? Part of the discettes will be taken up with system software such as the text editor and language translators thereby reducing the amount of available user space.

Certainly, the mini-disc system is cheaper. A twin mini system will cost approximately £900, whereas a twin standard system will cost £1700. The individual diskettes are also cheaper for the mini system. Ten can be bought for £35, whereas a pack of ten single sided standard diskettes cost £40 but the dual sided cost £80. Furthermore, to upgrade the disc controller to a dual density standard will involve an additional £300.

However, in my experience, the standard floppy discette system is mechanically more reliable than its smaller counterpart despite the fact that the mini system switches itself off when not transferring data, thus reducing wear and tear on the mechanism. A final consideration is that with the smaller discs the task of copying files to a second diskette for security purposes is simpler and obviously takes less time. This may be a desirable feature when only comparatively small files are in use. But in general, I must advise that the larger system should only be considered for administrative purposes.

d) In the area of CAL packages, only a disc based system and the standard disc, to boot, is the only practical system.

e) Remedial work can be carried out adequately on a cassette system although the penalty here is slower loading of programs. However, I have seen an excellent remedial system at St. Clement Danes School, Hertfordshire, for multiplication and fractions used within the mathematics class and based upon a cassette system. Programs typical to this kind of remedial work are never very long and the loading time does not create too much of a problem.

8.3.2. Additional Software Facilities:

Before recommending sample microcomputer configurations based on the RML 380Z, mention should be made about additional software and features available with this system, namely, the text editor, VDU graphics and the 24 volumes of the CP/M Users Library Software.

Since 1978, the text editor is recognised as an essential part of the overall system software. It is now generally used to prepare programs as well as text. RML's Text Editor is an interactive character-orientated editor which can be used for program preparation, text processing and data manipulation. Text may be entered into a text-buffer and via the optional 'window display' the operator may see the effects of his activity at a glance. The upper part of the VDU, twenty lines, becomes a 'window' into the text buffer. When present, the user can enter an 'immediate mode' whereby he can visually control the text and the text pointer. This, in effect, turns the VDU into an 'electronic typewriter' and yet enables the user to move around the page and to insert and delete lines at will. Certainly, this is a distinct advantage for schools administration.

The VDU can be used to display not only alphanumeric characters but also a limited graphics set. This can be used to display simple graphs and present tables of information. The 9k version of Basic contains extensions which allow the plotting of symbols, characters and numbers with the 380Z graphics (see section 11.5).

Every microcomputer system manufacturer has various volumes of library software. RML via the CP/M User's Club can provide 24 such volumes at £7.50 per volume. These are not meant to be taken seriously but they may provide instant programs to demonstrate the working system. Perhaps a more useful idea is the purchase of the "101 BASIC Games" published by D.E.C for £6.00. The importance of the CP/M disc operating system has already been stated in section 7.2.1.

8.3.3. Recommended Sample Configurations at June 1979:

Any school should aim at the disc based system since there is no inherent advantage in owning a cassette system. However, the latter is less expensive and since finances are of considerable importance we begin with a cassette version.

A recommended minimum cassette based system should comprise:

an RM 380Z with 16k of RAM

2 x cassette recorders

dual cassette controller

RS232 serial interface

RML 9k Basic, interactive text editor and RML Z80 assembler.

Additionally, a video monitor would be required but the system above would cost approximately £1200. This would enable programming projects for all three levels, CSE, O and A to be processed; data files to be stored on cassette tapes and edited with the text editor as well as allowing assembly level programming for Computer Science A level. Remedial packages could be developed and a few limited, serial type administration programs.

A comparable mini-disc system will cost £2200 but will provide the speed associated with discs, approximately 125k bytes of on-line storage and 32k RAM. A twin mini-disc system is my recommendation for the additional benefit of school administration tasks.

However, the ideal system recommended would comprise:

an RM 380Z with 48k RAM

FDS-2 dual drive (double sided) full floppy disc system

RS232 serial interface

DISC RML interactive text editor, with RML extended disc Basic and RML Z80 assembler.

This system could be expanded to the full 56k RAM for an additional £150. Additional compilers would cost approximately £300 for Fortran, £100 for CP/M RML Algol and £400 for Cobol. Currently, this system permits one megabyte of on-line storage. It is, therefore, an ideal system for data processing, program development, CAL packages and all forms of Computer Studies and Computer Science teaching. In fact, it can be said to lie at the bottom end of the professional range rather than top end of the 'fun' or 'hobbies' market such as Pet and Tandy systems.

In all the above cases, a video monitor is required or a domestic television set. But as previously suggested, I advise the use of video monitors mainly on health grounds. An additional piece of equipment will be some form of hardcopy device. This will be necessary for any system in which a permanent record is required, as for example, in project programming work and school administration. One has the choice of a simple teletype or some form of printing device. A teletype can be bought for £500 or so. But for school administration a better quality printer may be more desirable, for example, the CENTRONICS 779 (appromixately £900) which is an 80 column dot matrix device capable of achieving 30 characters per second, or, the CENTRONICS 701 (approximately £1400) which is a 132 column dot matrix device reaching 60 characters per second.

For much higher quality comparable to the IBM golf-ball typewriters, the Diabolo or the Anderson Jacobson may be considered. However, they do cost approximately £2500. They are terminals in their own right with exchangeable plastic or metal daisy wheels permitting a range of fonts to be selected.

All hardcopy devices will involve some form of maintenance contract or at least two to three service visits per year and the paper and ribbon costs will not be insignificant in themselves.

8.4. Requirements of an Administrator:

It has already been stated that someone should become responsible for ordering equipment, chasing up delays and handling any queries related to non-delivery of components or faulty equipment. This administrator may well be the same person who will take responsibilty for managing the system (section 8.5) and possibly even the teaching of pupils in the use of the system. In other words someone who is already acquainted with computing and certain computing jargon. On the other hand, in many secondary schools it may fall to the bursar, the head teacher or the head of the Mathematics department to take responsibility for orders. If so, it is equally possible that they know very little about computers and even less about microcomputers.

Such people should be given the opportunity to attend a one day orientation course on the appreciation of microcomputers so that they may become more familiar with the purpose and uses of microcomputers and also with the jargon which surrounds the technology. The alternative is for these people to merely oversee the production of order slips and, possibly, to become hopelessly confused with strange jargon. It does seem sensible to suppose that the administrator ought to be aware of the importance of the equipment which he is responsible for ordering and from his own professional standpoint to be at least aware of why such an order has been placed. A head of school or bursar coerced into ordering a microcomputer for fear of being thought 'out-of-date' does not make a suitable administrator. But someone who has even a high level understanding of these machines retains his own professional standing. A second point that is worth mentioning is that sufficient time should be set aside to enable the administrator to perform his work. Chasing orders when delays occur can be extremely time consuming.

8.5. Management of the System:

Users familar with the traditional computer centre may have little idea of what is involved when they become responsible for their own on-site microcomputer system. Certainly, they now have the ability to do their own work at any time and in any place and may tailor the hardware to suit their own particular requirements. On the other hand, for this new found freedom, they must do everything necessary to make the system work.

In the case of a centralised system, the choice of hardware and software has been made for the user. He may not be totally satisfied but at least he has not had to become involved with any management decisions. However, as a potential owner he must become involved in many aspects. We look at some of these below, and then discuss them in more detail.

a) whether to buy a personal system in the first place - discussions about funding such a venture;

b) what type of system to buy and what hardware is necessary for my particular requirements;

c) what software is necessary and can they be upgraded easily when required;

d) is the existing documentation supplied by the manufacturer readable enough to enable me to construct the components; what levels of documentation is required by the potential users of the system?

e) how is the system to be supervised and what security arrangements will be required?

f) whether to opt for a full maintenance contract or regular services - discussions again with financial controller?

g) is a 'users group' organised?

Previously these decisions at centralised centres were taken by management with the assistance of many staff members. For example, the ICCC involves a staff of eighty or more persons. Admittedly, the computer system is much larger with approximately 5000 users. Nevertheless, these decisions have still to be made whether the system is small or large.

Whether to buy a personal system

The first requirement before deciding whether to buy a system or not is to identify in some detail the purpose of an on-site system. This will involve a certain degree of systems analysis so that the financial controller has concrete facts to work from. The analysis will of course cover many of the aspects mentioned below so that any doubts or misgivings about the venture can be clarified at this early stage.

Hardware

We have already discussed the types of microcomputers which are available and have suggested that only a full development system is practical for secondary education. However, from the brief summary presented in section 8.3.3 where three sample configurations were discussed out of a possible eight for one manufacturer alone, it is possible to forsee the problems involved in the selection of a particular configuration. There is also the additonal work of selecting a hardcopy device.

There is always the possibility that some 'experienced' electronics enthusiast in the school will try to persuade the administrator and/or manager that he can build the system for a fraction of the cost by buying all the individual chips at board level and contructing the development system from these.

However, a 'do-it-yourself' system, although cheaper and possibly even successful, has decided disadvantages. The enthusiast must still spend time on assembling the board level components into a working development system. This time factor may frequently impinge upon his working time at school. As soon as this happens, the cost of'people time' far outweighs any difference in hardware costs between the chip level and a fully packaged development system. Furthermore, any mal-function of this DIY system can only be referred to the 'manufacturer', in this case the enthusiast himself. Should he decide to leave the school or to become involved in other and more pressing engagements, then what? The conclusion is obvious.

Any administrator or manager is strongly advised to deal only with recommended manufacturers. Such a supplier should offer a suitable after sales service as well as software support; these cannot be offered by the enthusiastic hobbyist.

Software

Since microcomputer systems are beginning to invade many areas of commerce, industry and education, it does not make sense to buy a system which does not support an easy-to-use operating system which has been produced by professionals. The RML monitor for example is ready when the machine is switched on, furthermore, it makes use of the disc operating system, CP/M, which has become the international standard which will allow software developed on any other system under CP/M to be available to any other system with the same disc operating system.

Users will spend enough of their time grappling with the use of the system without creating future problems when trying to load and use a package developed under some system different to their own.

Finally, any software purchased now should be compatible with any expected future upgrade of the current hardware. For example, the RML cassette based system can be upgraded to a disc based system with very little user involvement.

Documentation

When buying a microcomputer system (or indeed a car or domestic appliance) which costs up to £4000, it is not unreasonable to expect an easy to read introduction to what one has bought, how to assemble it and how to make use of it as quickly as possible. This 'quick guide' should also be backed up by a more detailed guide for the more experienced user.

In practice, documentation from microcomputer suppliers is never like this. A complete mass of documentation frequently accompanies the components and it is left to the purchaser to sort through this documentation in order to find out how to assemble and use the machine.

In a secondary education environment it will be the manager who will have to work through this documentation and effectively re-write it to suit the various levels of his users, e.g. those who will be using the system for the very first time and typically will have no idea of where the switches are on the various components, to those who can prepare, execute and save programs but who now wish to extend the potential of the microcomputer system.

For the foreseeable future, it is unlikely that manufacturers will produce the ideal documentation. Here the user group via voluble irritation with current documentation and by supplying samples of what should be produced, can persuade the manufacturers to produce better material. Also these samples can be freely distributed to other users, thereby saving time and effort for individual owners.

It is clear that manufacturers are not aware of at least two levels of users, the absolute and naive beginner and the more experienced user. Being within the Users Section of the ICCC where we have to cater for 5000 users of the College's computer system, we are probably more aware than most of the requirements and distinctions between the two levels. Manufacturers are essentially hardware orientated and, therefore, seem to have little appreciation of users who are only concerned with the use of a system rather than with its machine level attributes.

Operations and Supervision

Yet another consideration for the manager is the practicalities of running and supervising the day-to-day operations of his system. Having to timetable its use from 9.00 am to 5.00 pm so that the machine will be available to everyone at the most appropriate times is no small matter. In addition arrangements for the safety of the equipment and for the security of files will have to be made. Should two or even three copies of a given file be made? Should some form of ancestral file system be brought into play? Who is to become a valid user and how will such arrangements be made? When shall orders for more cassettes or diskettes be placed, ribbons and paper for the printer, etc? Previously, it was the computer centre staff who had to think about these points both the important and the trivial ones. Now this responsibility falls to the computer manager.

Maintenance

Maintenance considerations will have to become the responsibilty of the manager. No longer is it cost-effective for the manufacturer to send out service engineers to customers on any regular, weekly or monthly basis, or, to provide on-site engineers except for large mainframe centres. Microcomputer components will mal-function and then it will be the manager who will have to diagnose the fault. Then the all important factor becomes 'how soon can the fault be rectified'. There are two considerations here. First, there is no point in having a most wonderful microcomputer system if the manufacturer cannot provide a very reasonable after sales service or if the spare parts are on the other side of the American continent. The manufacturer will have to be comparatively close at hand so that faulty parts can be sent back quickly and replacements returned with the minimum delay. In this respect, RML have proved to be reliable.

The second point is that educational users are in a different position to most research users and commercial or industrial users. In many cases, they can tolerate a longer delay for replacement parts since they can get on with other work (unless the microcomputer is preparing the weekly payroll). But once a class lesson has been missed, it has gone forever. The school timetable is not always capable of very much flexibility. In this respect, schools are very much in the forefront because of their vulnerabilty.

Again, a strong user group comprising school-users with a sufficient voice to make some impact is one way of ensuringthe continuing goodwill of the manufacturer.

User Groups

A user group strongly supported by the manufacturer is not only of value in the areas mentioned above but will also provide of means for exchange of suitable and tried documentation and software. The existence of a user group may well be the most critical criterion for microcomputer selection. The mere formation of such an organisation indicates that the manufacturer has been in existence for some time and that his products have been tested and found to be, at least, reasonable.

In Oct. 1979, RML formed a users' group at which 100 out of 1000 users attended the inaugural meeting. It has yet to prove its worth, but that largely depends on the users.

8.6. The ICSP Guidelines:

As a summary, we can present the following overall guidelines based upon the experince of the Computer Workshop M6800 and the Research Machine 380Z microcomputer systems.

1. First perform a systems analysis to define the purpose and the feasibilty of a microcomputer system in your institution and define any future requirements.

2. Appoint an overall adminstrator who should be sent on a one-day microcomputer orientation course if necessary.

3. Select a suitable manufacturer, e.g. RML of Oxford, with a solid & proved track record. Contact other users of the system to discuss the pros and contras of the system. Find out whether a User Group exists and the name and address of the secretary. Visit the manufacturer for a demonstration and test the system with one of your programs.

4. Select the hardware and software.

a) A disc based system is the only practical system to choose, but if money is not available for such a system then discover whether the cassette system is readily compatible with the disc system.

Is the CPU standard? There is little choice here between the main manufacturers of the microprocessor chips. Among the established ones, the Intel 8080, the Motorola M6800 and the Zilog Z80A lead the field. They are second sourced and therefore a safe design on which to base a system.

Random Access Memory - at least 16 kilobytes are required for a cassette system and 32 kilobytes for a useable disc system. One should make certain that RAM can be extended easily.

Floppy discs - 8" standard diskettes allow for greater on-line storage if double sided and have the dual density potential. A twin floppy will permit up to two megabytes of on-line storage in contrast to approximately 125 kilobytes for a minidisc system with twin drives. More important, however, is whether the disc system conforms to some standard such as the CP/M. The choice between the mini or the standard diskettes will depend upon whether the system will additionally be used for extensive CAL packages and schools administration. In either of these cases, the standard disc system is the only practical choice.

Keyboard - must be rugged

VDU - is it possible to attach a set of TV monitors for large class demonstrations?

Peripherals - Are printers, teletypes, etc easy to plug into the system, i.e. does the system have the RS232 interface?

b) Software

Monitor - is this available in ROM and, therefore, available when the machine is switched on?

Disc operating system - is it one of the industrial standards? If so, additional software developed on different systems may be used.

Text Editor - is this simple to use yet powerful enough to enable the preparation of programs and data files for text processing?

Language translators - has the translator been in use for at least one year and therefore really available and tested? Many manufacturers announce the 'availability' of compilers two years in advance.

Documentation - What is it like? Can I understand it? Does it really help me to assemble the components and to use it at a simple level straightaway?

5. Duties of the Manager

i. Select and advise on choice of manufacturer and choice of hardware, software.
ii. Assemble components.
iii. Test hardware and software.
iv. Insist on suitable room for housing system and which can be used as a work room by students.
v. Prepare suitable levels of documentation for the use of the system.
vi. Provide the documentation in a suitable reading area.
vii. Timetable the use of the system.
viii. Organise and oversee the operation of the system.
ix. Provide for the security and safe keeping of the equipment.
x. Provide for the security of files (2 or 3 copies).

xi. Join the User Group and attend the meetings.

xii. Contact the manufacturer when faults occur, this may involve returning the faulty components.

xiii. Keep up-to-date with manufacturer's enhancements.

xiv. Extend one's own system when possible.

xv. Order paper, ribbons, etc when stocks are low.

xvi. Will have to involve other members of staff in the microcomputer to avoid being considered 'a micro-ham'.

xvii. Prepare material for use in other disciplines.

xviii. Prepare programs for one's own use in remedial and other lessons.

xix. Be prepared to show the school secretary how to use the text processor.

xx. Learn to use the system oneself - not a trivial exercise.

xxi. Accomodation and mobility of the system.

Some questions which the manager should ask the manufacturer:

1. Does a User Group exist? What is the name and address of the chairman and secretary?
2. What are the arrangements when components mal-function?
3. Can replacements be sent out on a temporary basis if the correction of the fault takes too long?
4. What are the maintenance agreements?
5. What proportion of the total market sales are within education at the secondary level?

Advantages of a User Group:

Exchange of programs and packages

Exchange of introductory documentation

Exchange of ideas

Exchange of common problems and how they have been tackled successfully

Provides contact with local users.

Some advantages of standardisation:

Exchange of programs which will work immediately.

Saving time by not having to develop everything by oneself, including documentation.

Others experience can benefit my school.

Manufacturer more likely to adopt a commonly acceptable documentation for all new users.

To place oneself outside these two important considerations means working almost totally by oneself instead of being able to benefit from the experiences of others. We have tried to show that for the cheap hardware, the user now must pay the penalty of doing everything else for himself. Standardisation and user groups help to redress this imbalance.

9. REQUIREMENTS AND DESIGN OF A MICROCOMPUTER COURSE FOR TEACHERS

The fundamental importance of teacher training in computer appreciation was brought to our attention by CERI and IFIP (CERI70, IFIP71; see also DIC74) as early as 1970. If teacher training was necessary for the traditional computer users then the need today for microcomputer courses is even more urgent. Such is our belief in what has virtually become a truism, that the provision of some training package was seen to be an integral part of the overall project.

But in 1977, very few courses or even text books existed. Those which did were far too low level or machine level orientated to be, in my opinion, of much practical value to a user of a microcomputer system. In keeping with the basic philosophy of this project that a user or high level approach is what is really required by users, our own course reflects this philosophy. Although, conferences and workshops, such as those promoted by MUSE/CEG were valuable for exchanging ideas, they were not able to provide a training in the fundamentals of microcomputers. The ICSP micro course aimed to do this by providing for teachers with limited experience of computing an entrée into the recent developments in microprocessing and its potential impact on computing in schools.

9.1. ICSP Course Objectives:

9.1.1. Provision of a High Level Course:

There are various courses which can be identified for a teacher of Computer Studies who is contemplating using a microcomputer system as well as courses for administrators and managers of micro systems. The course outlined in this section is a general appreciation of microcomputers which sets out to discuss what microprocessors are, where they came from and their relationship to the traditional computer. It provides, furthermore, an understanding of certain jargon terms, the applications of microprocessors in general, the fabrication process and discusses the guidelines as developed through this project.

It is my aim in such courses to encourage attendees to feel that they have learned something positive and can feel confident in using jargon terms in their proper context. It is here that a course which presents the fundamental concepts differs from workshop courses where, typically, terms are heard but not always explained.

9.1.2. Hands-on Experience:

It is clearly desirable in such courses to be able to demonstrate equipment, to be able to show a floppy diskette, a floppy disc drive; to open up the microcomputer and to point to the various memory, microprocessor and ROM chips; to be able to demonstrate a program running a Basic and/or Fortran program and to show the visual impact of the software front panel (in the case of the RML). This enables the concepts discussed to become a reality.

Furthermore, the teachers ought to be given the opportunity of using a system, of overcoming any feelings of awe or prejudice concerning microcomputers and to be able to get some, albeit slight, feeling for the way a microcomputer system can work and its potential.

9.2. Design Considerations:

9.2.1. Practical Considerations:

Attendance was limited to thirty, not because the lecture theatre could not hold any more comfortably but because thirty is a reasonable number to handle when practical demonstrations and hands-on experience has to be considered.

Lecture notes were issued but being a first draft they were not seen to be in any way a final or even suitable version. From previous experience with a teachers appreciation course, between 1970 and 1975, a course has to be presented several times before the lecture material has the right emphasis. It is hoped that through future presentations, these notes can be improved and issued in some more permanent form.

The course did not begin until 10.30 am in order to allow teachers from more distant parts (e.g. from Yorkshire) to arrive in London. It was due to finish at 4.30 p.m. but those who wished to stay on to discuss matters in person or to gain more practical experience were encouraged to do so. A substantial lunch was arranged to sustain those who had some distance to travel and, of course, the inevitable tea and coffee breaks were included. That left five hours in which to cover the lecture material, open discussion period, look at a book exhibition and demonstrate various machines.

9.2.2. Questionnaire:

There are always two problems on any 'introductory' computing course. First, there are the different levels of computing experience which the attendees possess; some with no knowledge at all and some with varying degrees of previous experience. This makes it difficult for the lecturer to know at what level he should pitch his material. Secondly, and in the case of many raw beginners in particular, their expectations from the course differ enormously. However, because of their limited knowledge, they frequently have no means by which to judge what they need to be taught.

A very simple questionnaire was sent out those who wished to attend. Essentially it was designed to find out which attendees had previous experience and at what depth, and, what was the primary aim in attending this course. In practice, all of them had fairly substantial knowledge in that they had been teaching for at least one year. This meant that the development of microprocessors could be built upon this knowledge. Secondly, it meant that the teachers were in a position to define what their main expectations were. Because of their awareness of the potential of micros, they wanted to know whether these machines could be used in school, what a practical system comprised, costs, and uses. Several of the schools had already decided to buy a micro and had already begun to to raise funds and therefore any advice would be welcome.

As a result of the questionnaire, we were better prepared than usual to give the attendees what they were looking for. However, the course notes were designed to be of value to someone with no previous knowledge at all of computers.

9.3. Implementation of Course:

9.3.1. Lectures and Timing:

10.30 - 11.30 Lect: 1 The traditional computer system; microtechnology: what is available; the manufacturing process.

11.30 - 11.45 coffee

11.45 - 12.30 Lect: 2 Possibilities for schools.

12.30 - 13.30 lunch

13.30 - 14.15 Lect: 3 What is different when owning one's own system.

14.15 - 14.30 tea

14.30 - 15.15 Lect: 4 The new possibilities with on-site micros.

15.15 - 16.30 Open Discussion
Demonstrations of various equipment
Book exhibition

The following outlines the lecture contents whereas the full contents are provided in an appendix.

Lecture 1: Here the aim was to present the microcomputer within the context of a natural technological development of the traditional computer to show that it was not some totally new wonder which is frequently the impression given by the mass media. Consequently, the traditional computer architecture was presented along with the technological developments of the three generations. LSI technology was introduced within this general framework, leading to the ability to manufacture the small and labour free (therefore cheap) components which comprise the microprocessor.

The three broad classes of microcomputers were next introduced, the chip level, the board level and the development system level. For me, it is the size of the chip which comprise the microprocessor and the various memories that presents most of the fascination. To provide some insight into this aspect, a short survey of the fabrication of microprocessor and memory chips based on a set of twelve slides obtained from the National Semiconductor company was also included.

This lecture provides an introduction into many of the jargon terms such as ROMs,RAMs, EPROMS, UVEPROMS, LSI, VLSI, as well as the fundamental distinction between microprocessor and microcomputer.

Lecture 2: Here we discuss the various roles which the microcomputer can play in secondary education; its on-site processing ability for Computer Studies/ Computer Science courses; schools administration; remedial training; and, CAL.

Based on the knowledge of the first lecture, a discussion about the usefullness of the various classes of microcomputers can take place, concluding that the full development system is the most practical one for schools. This leads naturally to considerations concerning the relative merits of input and output devices and to cassette versus disc based storage systems.

An attempt to look to the future and to visualise some future possibilities is made via two electronic aids 'Dataman' and 'Speak and Spell' both of which are discussed in section 9.3.2. Finally, the value of joining MUSE is brought to the attention of the attendees.

Lecture 3: The purpose of this lecture is to bring home the differences between using a centralised computer centre and having one's own on-site facility. Cost is important and the freedom to make one's own decision about when to use the system. But against this it should be realised that cost relates only to the microprocessor and memories, all else in system's hardware remains the same or at best fractionally cheaper as a result of microtechnology.

From this arise all the problems of personal responsibility for one's system, problems associated with administration, management and maintenance as detailed in section 8.

Lecture 4: Here more realistic future possibilities are discussed such as text processing, CAL, close laboratory control and links between mainframes and microcomputers.

Finally, reference is made to the Research Machine 380Z as a prime example of a recommended system; other courses and texts; and, the advice which can be obtained from the ICCC.

9.3.2. Equipment:

The RML 380Z clearly formed the centre of the demonstration equipment of a full development microcomputer system. But there is a board level micro, the Mini-Micro Designer. This is very useful to show clearly the chip components and can bring home to teachers the various concepts discussed in the lecture. Furthermore, it is a useful microcomputer on which to demonstrate machine code programming, and, can be useful in providing teachers of Computer Science A level with some indication of power or limitations of this board level class.

Two electronic learning aids are shown, 'Dataman' and 'Speak and Spell'. These frequently provoke more interest than any other piece of equipment. They are used in lecture two not to promote them as serious learning aids, but rather to indicate something of what teachers may expect from microcomputer technology in the next five years or so. Dataman can be 'programmed' to accept in its 'memory bank' certain arithmetical problems. These can be set by parents (teachers in the future) or by the children themselves to try out problems on their friends. In this way, the device becomes not just a learning aid but also a device whereby children can learn to construct problems. But the real value of Dataman lies in its potential. In June, 1979, it is a sophisticated toy costing £20. Yet it has calculating ability, a 'library of programs' and a memory bank. To program a new set of tests, one simply invokes an existing program (at the press of a button) and inserts the test material without any involvement in tedious programming at any level.

With luck, this easy to 'program' approach may filter down to CAL proponents. Its documentation is superb. Within two minutes one can be happily and painlessly using the device to run some of its simpler programs. Perhaps this too could filter down to manufacturers of computer systems. Its switches are easy to read with such startling innovations as 'ON' and 'OFF' buttons, easily identifiable program buttons and not the common ones associated with much more expensive terminals such as 'power', 'reset' or 'CR'/'return'. If we can have all this today from a toy, its future progeny will prove very welcome devices.

'Speak and Spell', like Dataman from the stable of Texas Instruments, is even more surprising. It has character display and a computer voice output which sounds not like the staccato, mindless voice from much more expensive micro-controlled devices, but is true speech synthesis complete with voice inflections. This development entered into teaching devices will surely benefit blind people. Already some similar device exists complete with an English-French dictionary of substantial size which can perform a simple word-for-word translation. But what of the future? Possibly some device to teach English to foreign students, ones own pocket interpreter for journeys abroad, etc., and all possible within a decade.

These learning aids not only show what they may be like in future years, but also make us question certain fundamental approaches in computing which have been accepted for so long that we do not notice their inhibiting features for new users. Documentation is one area. But why should we put up with such poor documentation from manufacturers? Another is the difficulty many find when using a termnial or microcomputer system for the first time. Power switches hidden away, buttons with meaningless terms on them, etc. Why can not we try to make things more normal? Why cannot Basic be loaded into memory at the touch of the button with Basic written on it, or, Fortran with Fortran; the Mathematics program with Maths on it, etc.? Why do we have to go through such a prolonged procedure using the gobbledegook created by systems programmers? Why cannot programs be used which are as simple to use as the program in Dataman for setting new tests?

Finally, a set of slides were used which came from the National Semiconductor in Scotland. These can be used to open up another dimension for teachers. One can see the actual chips and part of their fabrication process. These help to realise the minute size of the chips which cannot be achieved merely by pointing to an already packaged chip.

9.4. Conclusions and Critique of Experimental Course:

It was stated that the primary aim of the course was to teach the fundamental concepts of microcomputers from the viewpoint of a potential user rather than a designer of microcomputer systems. Much of this was presented in the first lecture, whereas the rest of the day tended to become a series of seminars. This was a result of having only five hours in which to present both lecture topics and seminar topics. Also it was clear from the questionnaire that teachers wanted to be told how to use microcomputers in schools, the criteria for microcomputer selection, what a teacher needs to be aware of when owning his own system, etc.

What emerges then is that a teachers' course has two requirements; the first is the presentation of technical details, consistent with our high level approach; the second is the presentation of the seminar topics detailed above. In retrospect, these could be presented at two different times an approach which we may adopt next time. The technical material being presented as a series of lectures, the seminar topics on some following two or three afternoons. This has been successful for the microcomputing courses developed for internal students and staff at Imperial College.

At present the slides cover only a portion of the manufacturing process, namely, the production of the design and layout of the circuitry, the testing of individual wafer surfaces, the coating of silicon dioxide process, testing and probing individual chips of each wafer, the sectioning of the chips. The manufacture of the ingot, the photolithographic process and the packaging process are missing. However, it is difficult enough to get even a response from manufacturers let alone slides of their process. Hopefully, a full set will be obtained at some future date since they can make a unique contribution to such a course.

The lectures require more attention but this can only be gained by experience in future presentations. The seminars tend to be more of a discussion where some dialogue is expected. This naturally is difficult to present in written form except as a series of points or notes.

More suitable demonstration programs are necessary so as to show more fully the capabilities of the RML system, e.g. in graphics, text processing, CAL and school administration. These are not programs which can be developed overnight. But in due course the material will gradually build up. Hands on experience is difficult to arrange in a one day course which has to cover both technical details and seminar topics. It seems more appropriate to provide such experience in smaller groups during the end, for example, of the seminar periods.

In conclusion, it was strongly felt that some provision for a suitable teachers course should be present and form part of the overall project. It does exist and can be given quite readily at any time. Experience from one presentation is already being used to improve on a future course.

10. CRITICAL ANALYSIS

10.1. Objectives:

In June 1977, any legacy which could be passed on in the event of the demise of the ICSP and which could guarantee that our schools could continue with their computing courses was a major objective. The ICSP had sufficient resources to undertake this investigation rather than leave it to schools to discover their own experiences by some individual and heuristic method.

However, the main objectives of the project were:

a) to gain personal experience of microcomputers;

b) evaluate the feasibility of microcomputers for secondary use;

c) to determine upon a reliable system and identify areas of use;

d) to present a set of guidelines for teachers;

e) to experiment with a system in conjunction with pupils;

f) to present an introductory micro-course for teachers;

g) to undertake the above objectives at a 'high level', i.e. without consideration for machine level details.

10.2. Comments on Project Achievements within the Time-Scale:

The project need not have been conducted. The conclusions of others could have been awaited. However, by conducting this investigation, personal experience and confidence in one's own choice of system and awareness of the needs of secondary education have been acquired as well as the ability to pass an informed opinion about the conclusions of other projects.

As regards the two main areas of investigation, namely, to provide a rationale and design of a micro system for schools and colleges within the ICSP, it has been demonstrated that microcomputers can be of immense value to secondary schools and colleges in the areas of Computer Studies/Science courses, other subjects in relation to CAL especially with graphics facilities, in school administration, in remedial training, as well as in a general awareness of the nature of microcomputers for a future generation of employees. In addition, this project has been able to place sufficient confidence in one particular model, the RML, such that this system can be recommended to schools.

I believe that the adoption of the 'high level' approach led to a more single minded attitude and a more critical consideration of various systems by demanding from the manufacturers much more than they were prepared intially to offer.

It was not only an awareness of micro systems which has been gained but also an awareness of other closely related areas, for example, the need for readable documentation at various levels, a reliable after sales service, compatible and easy to add enhancements, and what is involved for the 'managers' responsible for on-site facilities. Finally, the presentation of a microcomputer conversion course for teachers already familiar with traditional computer centres has enabled the original notes to be extended and revised for future presentations.

Unlike other projects with access to more than one person, several areas of great interest and importance could not be investigated within the two year time-scale of this dissertation. Nevertheless, an important contribution of this work has been to identify areas of future development, and these are discussed more fully in a separate section (11.0). For example, during the investigation it became clear that the RML system had far more potential than originally expected. Here, I can mention just a few areas such as the powerful text processing ability, the potential for CAL on a disc based system, graphics capabilities and the link between the micro and the large CDC mainframe. These points have obvious importance and relevance to school users.

Due to the high level approach, no attempt has been made to investigate the philosophy of the basic machine construction at the chip level. Reference to (PCW78) will show how such considerations are only of interest to the electronic enthusiast. Such material relating to machine level details abounds and is easily accessible to those who are interested. My paramount concern was in the use and the reliability of microcomputers.

Although the development of CAL material and school administration software is of great importance, in view of the amount of time required to produce any worthwhile program, this project was not able to consider such development to be practical.

10.3. Comparison of Project with other Projects:

10.3.1. With LEAs:

The RML system has been chosen for reasons given in section 7 not simply for schools and colleges but also for more general use within universities and for Imperial College in particular both as a general purpose system and as a laboratory and teaching system. It is of interest to record that many LEAs, such as Birmingham, Hertford and the ILEA have also found this system to be of value to schools. Indeed, MUSE, individual schools such as Oundle and Douai, and a Durham project have also invested in this system. This gives credence to the work of this dissertation and personal satisfaction in the efforts between June 1977 and June 1979 to determine upon a reliable system.

10.3.2. Comparison between MUSE and ICSP guidelines:

10.3.2.1. MUSE Guidelines:

The MUSE guidelines were published in volume 28 of (CE78). They have been included in an appendix. They attempted to define a set of guidelines for teachers wishing to purchase microcomputer systems. Their main philosophy was that microcomputers should be small and in schools rather than large and in computer centres. The "starting point for MUSE's deliberation was a set of principles evolved by the Berkshire working party on microprocessors" devised earlier in March 1977 (CE77). The guidelines were set out under six main headings.

1. The closed box principle: the various plug in hardware modules should be commercially made and regarded as closed boxes which teachers would not need to modify.

2. The minimal system: keyboard, 16k bytes of memory, interface for TV

	screen, tape cassette recorder, Basic language, low level language and editor.
3. Expansion:	Standard modules should be available for expansion of minimum system, e.g. extra memory, hard-copy facilities, floppy discs, mark sense card reader and multi-user capabilities.
4. Safety & Security:	Modules should be robust, practical and safe. Unauthorised removal should be prevented by locks.
5. Maintenance:	Simple and inexpensive maintenance procedures should be arranged at the time of purchase.
6. Standardisation:	The benefits of standardisation are considerable to the development of teaching materials, development of the system and for maintenance.

10.3.2.2. Comparison with ICSP Guidelines:

The comparison between the MUSE guidelines of February 1978 (publication date) and the ICSP guidelines is not a comparison between the relative merits of either one, after all, there is a time gap of about eighteen months between them. The guidelines established by MUSE are still valid for today and certainly for the foreseeable future. What is more interesting is that since the year 1978, the manufacturers have had a chance to settle upon more stable systems; their equipment has been tested and tried by, in some cases, several hundreds of individuals and, therefore, the quality of the hardware and software, their documentation and their after sales service sampled. As a result the euphoria which greeted the advent of the microcomputer has quietened down somewhat, as it always does when reality itself arrives. By June 1979, people were asking practical and 'hard-headed' questions.

It is for this climate that the ICSP guidelines have been assembled. A definite manufacturer has been selected; a particular choice of hardware and software singled out and justified; a more detailed appraisal of input, output and secondary storage devices performed; and, the duties of the administrator and manager defined. These are the additional elements which the ICSP have been able to provide and to offer schools.

The 'closed box principle' (1) reflects our own high level approach. The 'minimal system' suggested was valid for 1977, although R.Atherton's private comment on (2) about provision for hardcopy facilities was an excellent addition. The idea of 'expansion' (3) to include extra memory, etc is clearly justifiable but the inclusion of mark sense card readers and multi-user facilities needs further comment. The notion that a mark sense card reader for a form of local batch system for a group of neighbouring schools reflects the psychological dependance of schools by 1977 on centralised batch systems rather than an true appreciation of the microcomputer as a unique and personal on-site device. Again, the attempt to turn the micro from a stand alone system into a mini version of centralised time sharing systems by multi-user facilities seems to me to go against the very nature of the personal microcomputer system. It so happens, that, to-date, the absence of multi-user facilities for the RML 380Z at Imperial College has denied us of the opportunity of investigating this aspect.

When it is remembered that a school class involving between ten and twenty pupils each requiring immediate and simultaneous access to a computer, perhaps some form of on-site batch system is inevitable. This implies that research into the use of microcomputers in secondary education must still continue in order to exploit their full potential in the future.

With regard to the remaining MUSE guidelines on safety, security, maintenance and standardisation, their importance and relevance meet with our own comments.

10.3.3. Comparison with DuMP:

The Durham Microcomputer Project (DuMP1) also began with a Computer Workshop M6800 and finally selected the RML system. It is of interest to note that our findings on both these machines coincides (DuMP p.15 f). Many of the objectives and conclusions of this dissertation have been mirrored by the Durham project with the exception that due to additional personnel and use of teachers the latter project has concentrated on software development. BASPIC - Basic interpreter with graphics extensions - is of particular relevance (see section 11.5).

11. FUTURE DEVELOPMENTS

My interest in microcomputers in secondary level education will not cease with the completion of this M.Phil dissertation. Many interesting aspects have been uncovered during the investigation which are of considerable future potential. It is these which are discussed below.

11.1. Further Hardware Investigation:

In Sept. 1979, the RML 380Z was linked to the ICCC mainframe, the CDC 6500/ CYBER 174/CDC 1700 complex. This means that stored data can be 'down loaded' onto the microcomputer's storage facilities. Immediately, a new dimension is opened up. Previous work which is stored in the CDC system will not have to be laboriously transcribed onto the microcomputer. It is also possible to 'up-line' data from the microcomputer to the storage facilities on the CDC mainframe. The software to achieve both aspects has recently been completed and tested. Perhaps, the main significance of this is for internal personnel at Imperial College. But, there is considerable scope to extend this potential for secondary schools within the ICSP project.

Recently, one school's mini-disc system was brought into College and linked to the RML microcomputer system. The purpose was to see whether 'down loading' and 'up-loading' could be achieved on the mini-disc as well as the standard disc system. The attempt was successful. The result was that it is now practically possible to make available to any school with an RML 380Z mini or standard disc system, the programs which have already been developed or will be in the future on the CDC system, and, at the price of the diskette itself. These are two practical advantages of standardisation.

Later, it may be possible to link various centres such as Imperial College, Hatfield, ILEA and Birmingham, via a network of microcomputers. Clearly, this is an area for more experimentation as well as careful study of library maintenance.

Multi-user systems needs further development. Although the Computer Workshop M6800 has this facility, the software took over two years to arrive, by which time the project had settled upon the RML 380Z and no further commitment to the former machine was expended. But clearly, this area must be looked at more closely.

It does seem to offer some solution to the problem of sharing one or more machines between many pupils (section 10.4.2).

11.2. Future Software Investigation:

11.2..1. Languages:

Currently, Basic is the most common high level language used by secondary level institutions. But in the very early days of learning to program, pupils have to master the craft of powering up a microcomputer system, bootstrapping, loading Basic translators, etc, all before they can write their first test program.

```
100  PRINT "my name"
110  END
```

It is a pity that the system becomes a problem at the same time that pupils have problems with learning the art of programming. Of course, teachers or more experienced pupils can always 'prepare' the system for the learner/beginner, but this involves time consuming effort on their part.

Much more effort ought to go into making the interface between user and system much easier, perhaps along the lines of the terminal system at the London Science Museum and developed at ICCC. Here a button with 'START' on it will activate the entire system and an easy to read and understand CAL type interface leads the user to interact with the computer system. Such a development is not only of value to schools but to any user of a terminal. Why should we first have to learn the gobbledegook and hieroglyphs so beloved by time sharing systems ? It is here that Dataman has excelled. Within seconds of reading the first page or two of the documentation, children (and parents !) can begin to make sensible use of the learning aid. The buttons are clearly marked 'ON', 'OFF' and program calls can be made at the touch of a button. Yet this costs only £20. Surely, our more expensive microcomputers could adopt a similar policy?

The Fortran compilers in use at Imperial College for student type programs have excellent diagnostic features comparable to PUFFT and WATFOR. Neither Basic nor Fortran-80 as supplied by RML and other manufacturers has anything comparable. Yet, these machines will be used in a large part within a learning environment where clear and useful diagnostics are paramount. Much work could be usefully centered on the production of an initial Basic (or Fortran) translator which would comprise a simple sub-set of the language but would also concentrate on clear diagnostic features. Beginners to Basic only require provision of about ten or so statements; LET, REM, PRINT, READ, DATA, INPUT, IF.....NEXT, GOTO, etc, but require a great deal of diagnostic assistance.

11.2.2. Packages:

Pre-written, documented and tested programs of value to others as much as to the originators will always be in demand. One of the weakest areas (next to teacher training) in educational computing is the absence of suitable CAL material. Bits exist here and there but nothing significant enough around which to build an entire course. As the microcomputer becomes more used within secondary schools , the effort required to produce CAL type programs of significance may be more forthcoming, especially when such programs can be developed and tested on large mainframes and down-loaded onto diskettes.

11.2.3. Text Processing:

The text editing feature of the RML 380Z appears to us to be highly significant. The current limitation to its general use amongst secretarial staff is the 40 column line screen. Attempts are underway to obtain an 80 column screen so that full pages of equivalent A4 size paper can be seen through the 'window display'. It is thought that current playback of text which folds over the second half of the 80 column line makes reading and typing far too difficult for the average non-computer person. Once this has been solved, the potential of the text editor is thought to be superior to the several editors on the larger mainframes. Here again we have to investigate the potential and to devise suitable documentation which can be readily understood by the average secretary.

11.3. Schools Administration:

It will be in schools administration that the microcomputer system will have a special attraction especially when used in conjunction with text processing. Some of the tasks which could be easily handled are 'flu jab reminders, mailing lists, class/school lists, timetabling (at least as an aid), library booking systems, and, the tuck shop stock control, etc. It is important that the computer studies teacher is not seen as a sort of micro-ham by other members of staff. Therefore, the sooner that microcomputers are used for a general purpose within schools the better. But this will centre upon how easy it is to use by non-computing personnel. If such personnel can, in fact, use the system easily and for useful purposes the battle will be won. Here CAL packages, schools administration packages, etc., will play an important role. No teacher will chance a dramatic change in approach until that new approach is seen to be of value. It will only be by proving the usefulness of microcomputers in subjects other than Computer Studies as well as within school administration that others have a chance to inspect this value.

One immediate future task within the ICCC section will be to develop a course booking package based upon the RML machine. Initially the booking system will be confined to the Fortran courses (of which six exist each year). Later this system will be extended to the other thirty or so courses presented by the User Support section (ED 80).

11.4. Impact of Microtechnology upon Computer Studies/Computer Science Syllabi:

For those of us involved permanently with computers, it has become almost a truism to state that a future society within industrial nations will become dependent upon computer technology not merely within a decade or two, but within a few short years, say by 1985. Without doubt our children MUST learn something about computers while still at school. Ten years ago, we could say that this was at best a most desirable aspect, but today, it must be recognised as a necessity. Our children must be prepared for the society which they will inherit. Part of the escalation of computer dependance is due to the microprocessor. Computer Studies then is one subject which can easily absorb microtechnology into itself. Existing syllabuses, however, do not reflect the importance of microtechnology and it seems that few syllabuses will reflect this technology in any depth until about 1985.

Currently, certain examination boards are trying to update their syllabi. This has happended with the AEB and Cambridge over the past month or two. In my own case, as Senior Examiner and Awarder for the Oxford Local Delegacy, we shall try to make concrete changes in a special meeting in 1981. One bonus of this M.Phil dissertation, is that I do not have to be persuaded that such changes in existing syllabi must take place. My only fear is that we, who are responsible for such changes, may not be able to react quickly enough. It is my intention to lay before the Oxford meeting a proposal for change. This will have to be backed up by reference, at the teacher level,initially,of suitable texts. Few exist. 'The Mighty Micro' by (MM79) is such a text. It is interesting to mention here that it is the only book which I have come across in almost ten years which does concentrate upon the social implications of computers. Many texts exist which by their title would seem to indicate that they deal with this important topic. But when reading them they seem to differ little from general appreciation books.

At the time of writing I have not seen the new syllabi proposed by AEB and Cambridge, therefore, I cannot pass a judgement. But, it does seem that their content cannot incorporate very much of the new technology since so few schools have access to microcomputers. What I propose is to look at the likely situation by 1985, and to try to propose a comprehensive syllabus to meet that date via Oxford, unless the new 'N' & 'F' prove to be too time consuming.

Any full scale pruning of Computer Studies/Computer Science syllabi must take place now so as to produce some effect by 1985.

11.5 Graphics

One of the most exciting possibilities with microcomputers is their graphics capability. When combined with existing CAL material the effect is greatly increased and opens up a whole new area of exploitation. As a previous section (3.3.3) stated, I believe that the future of CAL will be tied in with graphics. With new techniques including animated diagrams and images,and,diagram build-up, school pupils will no longer have to rely on crude graphs and histograms produced by line printers (although highly successful use of this medium has been demonstrated -POP2,POP6,POP9 - to produce maps of Great Britain and the sky at night as well as diagrams to illustrate Young's Slits).

Essentially, the VDU screen becomes a piece of graph paper without the division lines and one can plot a point using one of the graphics characters by quoting the X and Y co-ordinates. Clarity of the resulting diagram depends upon the fineness of the screen's division and this has given rise to the two terms 'high resolution' and 'low resolution'.

11.5.1 Low Resolution Graphics

Typically the screen is divided into a matrix of 80 x 72 with each plotting area for a graphics character forming a 3 x 2 matrix. With such low resolution the horizontal and vertical lines appear straight whereas the diagonal lines appear chunky and stepped since the plotting box or area meets only at the corners. This affect is seen readily on Ceefax and Oracle displays. Within this limitation, nevertheless some useful effects can be produced in certain contexts, such as histograms and simple diagrams within remedial spelling programmes. However, in other contexts such as geometry theorems, higher resolution is required.

11.5.2 High Resolution Graphics

With high resolution, the VDU can be divided into a matrix some 256 x 256 resulting in solid lines being plotted onto the screen and appearing almost smooth. According to Professor Negreponti (SemRCA) future systems will become available with matrices approaching 1000 x 1000 with a choice of fonts. Existing fonts, such as those seen on Prestel and Ceefax can become somewhat tiring after a few minutes.

11.5.3. Graphics Software

One problem with both high and low resolution graphics is the programming time and effort required to produce diagrams and images. This aspect will deter otherwise enthusiastic teachers from making use of graphics displays. However, for the RML 380Z a piece of software called BASPIC has been developed by Peter Grimshaw for the Durham Microcomputer Project (DUMP). It can be used with both high and low resolution graphics, and, so it is claimed, any teacher can begin to use BASPIC to draw and save images on either cassettes or discettes within a few minutes rather than the erstwhile laborious process and skills of the PLOT facility within other BASIC interpreters.

BASPIC is a standard BASIC interpreter which has been extended to permit easy graphic commands to create and save images, return them to the screen, modify and store the changed images. (PILOTPIC is a similar piece of software based on PILOT - DRAW is an Apple II version). The BASPIC commands can be learned very quickly, in under half-an-hour, even by teachers with no previous computing experience. BASPIC allows diagrams to be labelled a feature of the RML 380Z which is not matched by the APPLE II. However, the latter does permit colour graphics. At the present time, in June 1979 , colour cannot be seen to be anything more than a luxury but it does indicate the way future graphics systems for secondary schools will develop as hardware and software become cheaper. The inability of the APPLE II to mix diagrams and text is seen as a distinct disadvantage for schools.

The range of graphics characters vary from one system to another depending upon the type of 'chip' at the heart of the system. The RML 380Z has all its 256 symbols available, any of which can be plotted onto the screen, hence the ability to label diagrams. The CBM Pet can plot any symbol shown on the keyboard and, of interest, is the feature that symbols are plotted direct from the keyboard. In some cases this can be a distinct saving in time. Computer Workshop M6800 had no graphics facility at all in June 1978.

11.5.4. Additional Graphics Hardware:

Cost is the major factor which precludes many of the features below from becoming widespread over the next two years. Hopefully, within five years, hardware cost may fall sufficiently low so as to be within the reach of many schools.

It should be possible for users of graphics to perform a variety of erases such as points, lines and even large portions of the screen quickly. At a minimum any hardware system should permit the erasing to an end of line and to end of screen with the provision of moving the cursor to any position on the screen without erasing intervening displays. At a semin

At a seminar by Professor N.Negreponti at the Royal College of Art, he described touch panels. These are ideal for school children and eliminate the use of light pens which have proved to be unreliable in classroom use in the States. Amazingly, a finger has the ability to pinpoint accurately to 1/1000 of an inch when the ball of the finger is rotated. Plastic touch panels do not become dirty or greasy from constant touch unlike the more common glass panels of CRT screens.

A user defined character set proves most beneficial in certain subjects. The PLATO system allows such a feature and the genetics package on the breeding of fruit flies permits the various parts of flies to be user-defined as new characters. In this way a fly can be drawn using only a few characters instead of the more laborious graphics routines to plot points.

Ultimately, with vioce recognition and speech synthesis instead of keyboard input and screens (although they will still have a place in the future systems), a great step forward will be taken to bring computing systems nearer to our own method of human communication. What is relevant here is that such capability should belong to the terminal not to the microcomputer.

Colour and dual intensity black and white displays are also a desirable future consideration to emphasise selected areas of the screen. But the greatest future solution to the cost of these features is the video disc. Currently, in 1979, a video disc can hold 54,000 frames. In succession, these frames could be shown to mimick animation. Because the disc is a random access device, the frames can be selected in any order even in reverse, unlike the serial film strips which have to be stopped and reversed by switches. A complete library of frames could be accessed by any number of authors. Certainly, the area of graphics will become one of the most exciting over the next ten years, stretching the imagination of teachers far beyond anything they have at the present time.

11.6. A Course Text for Teachers:

Chris Evans' text by itself will not be able to effect any dramatic change upon syllabi within computer subjects at secondary level. Therefore, some additional text or texts is required for both teachers and pupils. It is hoped that an expansion of the proposed microcomputer course can be adapted for this purpose. Already one publisher has expressed interest and this avenue will be explored.

11.7. Special Systems for the Handicapped:

We have already mentioned that special systems such as the Apple II have been developed for aurally handicapped children and adults. The possibility shown by the 'Speak & Spell' learning aid shows the potential of speech synthesis for the blind and could be extended for illiterates. According to (COM78) an Australian father has taught his son Peter to overcome dyslexia. Other machines are of potential value to physically handicapped people as well. Unfortunately, it was not possible in this project to investigate such systems but it should be clear that there is a whole area of potential that should and must be looked at.

11.8. Teletext and Viewdata Systems:

Finally, the increase in teletext and viewdata systems could make a direct impact upon primary, secondary and tertiary education. Already the Open University is preparing to become an information provider for Prestel. It may be that a future role for large centralised computer centres will be to provide large databases and CAL packages which can be accessed by microcomputer systems over the telephone networks. But is this desirable in view of the fact that diskettes containing the same information can be posted direct to stand alone systems? Should large centres act merely as convenient development centres?

Viewdata systems will have the drawback of being potentially very expensive as are our current time-sharing systems using telephone communications. They have the advantage of two-way communication whereas teletext systems are constrained to one way communication, albeit 'free'. Again, there is a great deal of potential research into this aspect alone.

11.9. Author Languages:

Although I believe that the future of CAL depends to a large extent on the use of graphics and the involvement of commercial organisations, nevertheless the best people to write CAL programs are teachers. Many would be willing to move out of teaching and into the commercial world (perhaps alleviating the redundancy problem). Most teachers will know Basic and perhaps Fortran. But such high level languages are not suitable vehicles for writing CAL material. Even a casual knowledge of Fortran quickly proves why it is easier to suggest the following format for replies to questions: "If 'yes' type 1, if 'no' type 0". Although somewhat easier in Basic, many existing programs will only recognise a correct spelling of 'yes' and 'no' with anything else being totally unknown to the program. This involves a test and a loop back to the "type in yes or no" prompt. Unless one adds a count, this style of program will loop indefinitely. Far worse is that inexperienced users either become frightened of using computer programs or find such programs somewhat tiresome and unimaginative.

What is required is a special class of high level language in which it is easy to write CAL material. These are known as 'author languages'. One simple example from this class should establish how easy it is to accept a range of answers of the 'yes' variety.

```
M: yes%%!of course!sure!right!
```

The M is an instruction in the COMMON PILOT (CA80) author language to match an answer. The exclamation sign indicates an 'or' operation, the percentage sign matches a space or spaces or the end of an anwser. Case and space editing are automatic.

Features of these author languages should include alternate answers, space and case editing, multiple answers, tolerance with spelling errors, extraction of numbers from text, inclusion of graphics instructions, and easy to learn. I do not wish to discuss in any detail the features of COMMON PILOT, but a further example will illustrate how easy it is to match an answer despite incorrect spelling and at the same time point out that the test of a good author language is its abilty to cope <u>easily</u> with a variety of answers from a variety of abilities. Suppose the answer to a question is 'psychologist'. This can be spelled in many ways, but the following permits a wide range of answers in one simple statement. Imagine this had to be achieved in either Basic or Fortran and one immediately gets the feel of the power of these author languages.

M: psy&h&g&t

It is the & sign which acts as an 'and' operator. The only limit to the use of this feature is the imagination of the teachers writing the instructions.

As CAL material increases so will the demand for author languages. It is an area for much development. Currently, in 1979, COMMON PILOT which is a version of the original PILOT developed at the San Francisco Medical Centre has been implemented on a wide range of small machines, namely, the M6800 and M6809, the Z80 under CP/M, Helios, North Star DOS, TRS-80,TERAK,TERC, Alpha Microsystems, Perkin-Elmer, and on any system which runs standard Pascal. A number of additional implementations are also under way.

11.10. Conclusions:

A few of the future development areas have been mentioned briefly in this section to illustrate the point that a great deal of pioneering, research and development still remains. The primary aim of this project was to investigate the viability of microcomputers within secondary education and to determine upon a reliable system. This has been achieved but forms only a starting point. As far this study is concerned the original objectives have been achieved. It is to be hoped that now one can go onto some of these other areas. Whatever happens, though, the time ahead for those involved in microcomputers at the secondary level is sure to prove an exciting one.

12. CONCLUSIONS

12.1. Results of Investigation:

One of the best ways to learn about microcomputers and microprocessors is to buy one and use it. Through one's own experiments more will be learned. This was true for ICCC and for the ICSP in 1977 and it remains true for our future generations who are currently at school.

If microprocessor growth in both manufacture and applications is as exponential as suggested in (MM79) then this alone will justify the use of microcomputers in secondary education. Indeed, the degree of necessity in this matter is closely related to the degree of one's belief.

In this project, however, we did not base our rationale on the future implications of microprocessor to mankind, perhaps, we should have done so since it is arguable that this is the more important long term issue. However, my belief in the future role of microprocessors was not quite so shining in 1977 as it has become today. Thus, our rationale has been based upon the more pragmatical point of the necessity of passing on some legacy in the event of the demise of the ICSP.

Before leaving this rather intriguing question, let us return to one publication from 1970. Chris Evans says: (MM79b)

> "..computer technology is embarking upon a period of exponential growth.. The first person to spell this out was Alvin Toffler whose book 'Future Shock', published in 1970, warned that the world was moving into an era of change which would stretch existing institutions to their limits, and strain psychological concepts beyond breaking point. 'Future Shock' was criticised for being sensationalist, but it is clear when one re-reads it nine years later that Toffler himself under-estimated the rate at which things were going to move. His book....contains not one single reference to the most sensational instrument of change of all - the microprocessor - for the very good reason that when he wrote it the microprocessor did not exist."

One may be tempted to dismiss this as good material for TV programmes. But there are two points which can be raised which make us take this comment much more seriously. First, when I began just two years ago to talk about the future impact of microtechnology in lectures, I used the following sentence:

"Industrial and commercial companies which do not take advantage of microtechnology will not survive the 1980s."

Over the past two years, this idea,which is not my original thought, has become more deeply entrentched in my thinking, and, in that of many others. It has taken just seven years for the microprocessor to appear from nowhere to a position where it "threatens" the very survival of the world's largest companies in particular.

Secondly, when this project began, in June, 1977,only a handful of schools had become involved in microcomputers. Twenty would be a conservative estimate. By June, 1979, two years later this has risen by a factor of ten (again, conservative). Does this mean that 2000 schools will have microcomputers by 1981 ? Who can dispute this possibility? Perhaps we are in an exponential growth period and if so, this fact alone determines the necessity for microcomputer systems to be used in all schools so that the basic teething problems can have a chance to be ironed out before the mighty wave of microtechnology washes over our socities.

12.1.1. Rationale and Design:

In June, 1977, our approach was more pragmatical. We were thinking of the short term rather than a possible situation by the mid-1980s and wanted to present something concrete by 1979.

Such is the degree to which the microcomputer market has settled down that whereas in 1977 schools were encouraged to 'wait for while', in 1979 they can be encouraged to make a confident selection of microcomputer. Furthermore, they can be presented with guidelines from which a particular selection of equipment can be chosen. For example, the choice of a disc based system, the choice of video monitors rather than domestic television sets, standard diskettes rather than mini diskettes, etc. It is also of interest to note that exposure to VDUs does not cause damage to eyesight (VDT) according to a two year study sponsored by the International Research Association for Newspaper Technology. But it does show "that failure to apply ergonomic knowledge to the design, implementation or use of VDUs frequently results in unnecessary fatigue among the operators."

There can be no doubt about the value of having one's own on-site microcomputer system. Its primary use may well be for processing Computer Studies/Computer Science programming projects and for teaching a high and a low level language. But there are other areas of use namely, within remedial training, schools administration and CAL. However, the new found freedom from the constraints of another's centralised system has its own penalties for the manager of the system. When the expense involved in telephone costs each year for a time sharing system, or, indeed, the increasing costs of postal services, a microcomputer system could be expected to pay for itself over a number of years.

12.1.2. Guidelines for Teachers:

As a result of our personal involvement with a microcomputer system and the training of a group of pupils in using the system, it has been possible to provide a set of guidelines (section 8.6) comprising a set of system selection criteria (section 8 in toto) and the terms of reference for the administrator (section 8.4) and the manager (8.5) of the on-site micro.

It is essential for any teacher thinking of buying a microcomputer to be aware of what is involved both in the purchasing of a system and the degree of his or her involvement after its purchase, especially if the only exposure to computer management is merely as a user of someone else's centre.

12.1.3. Introductory Microprocessor Course for Teachers:

The guidelines by themselves could provide only a part of a more complete service to teachers within the ICSP. It was realised that a course should be developed which would present a basic awareness of what microprocessors are, from where they came,the classes of microcomputers, etc. In addition as a series of seminar topics was also proposed to discuss the uses of microcomputers within secondary education, the criteria for microprocessor selection and the duties and responsibilities of the administrator/manager, (section 9). Consequently, an experiemental one day course was offered in June 1979 which aimed to provide for teachers with limited previous experience of computing an entree into the recent developments in microprocessors and its potential impact on computing in schools (9.4).

12.1.4. Justification of the High Level Approach:

In 1977, and to a large extent today, a low level machine orientated approach is presented to users by manufacturers and texts, as well as courses, conferences and workshops. This project deliberately set out on a high level user orientated approach in the belief that this is what teachers required. Consequently, only 'ready made' microcomputer systems were considered (sections 6 & 7). This approach is also strongly reflected in the teachers' course.

The theory behind this approach has been justified since it has been possible to test various systems and to recommend a useable and reliable system without the need for any in-depth study of machine architecture. The ideal has not yet been achieved because the average teacher may not find it too easy to install, construct, test and use the RML 380Z. Nevertheless, recommendations to the manufacturer for the improvement of documentation for the new user especially via the User Group will hopefully overcome these problems in the near future. At least RML are engaging a technical writer and it is this sympathy and awareness on their part which is one of the most encouraging facets of this manufacturer. A User Group, if properly organised and supported by the manufacturer should be able to contribute a great deal to new members who, initially, require the most help.

12.1.5. Identification of Potential Study Areas:

Section 11 considered in some detail those areas which could benefit from further investigation, for example, future networks of microcomputers linked to large mainframe centres such as ICCC, Birmingham and Hatfield (the latter two are currently being linked together); easier user interfaces (11.2.); more development into a useful sub-set of Basic with better diagnostic aids aimed at the novice programmer (11.2.1.); CAL and schools administration packages (although this is more likely to come from commercial organisations in the mid-1980s than from the teachers themselves), (11.3.); definition of a core syllabus in microcomputers for Computer Studies/Computer Science (11.4.); potential use of teletext and viewdata systems(11.7.); and, specialised systems for the handicapped (11.6.).

Some of these areas will be offered to future IC students for MSc project work, some will be investigated by ICCC staff as resources (time, money, staff, equipment) become available. But what is certain is that microtechnology for secondary education will not remain static. The main problem will be to keep up with its progress. The future, then, promises to be full of excitement.

12.2. The Systems Analysis:

12.2.1. An Administrative Project:

This project approached the subject of the viability of a microcomputer system for schools and colleges from the stand point of a systems analyst. To clarify this we need to return to the situation facing schools in 1977 when, on the one hand, computer weeklies were full of euphoria over the advent of microprocessors, predicting wonderful possibilities; conference speakers predicting microcomputers in every school within five years or so. On the other hand, very little hard earned experience of a personal nature had been accumulated which could be offered to the majority of teachers advising them of the pros and contras of microcomputers in schools.

At this time, the ICSP was in the position of a systems consultant asked by an outside company whether a given computer would benefit the company. Consequently, the ICSP had to conduct a systems analysis before certain relevant questions could be answered. For example,

are microcomputers a feasible proposition for secondary schools ?

is it desirable to have on-site facilities?

what type of microcomputer should a school buy ?

what are the necessary hardware and software requirements ?

what are the hidden problems involved ?

in what ways can a microcomputer benefit schools ?

This project has been an attempt to provide answers to these and other questions.

12.2.2. Specific to ICSP:

The knowledge gained by personal involvement with this systems analysis and presented in this dissertation can now be applied to those schools within the

ICSP. It is hoped that such benefits can also be extended to other schools who have no County or LEA policy from which to gain much needed advice.

12.2.3. Specific to ICCC:

The project was encouraged and financed by ICCC which in 1977 had decided to explore the potential of microcomputers within a university centre. Some of the initial areas of interest were the choice of both manufacturer and system, the possibilities of data storage and their extent, linking to the CDC mainframes, CAL within tertiary education, types of microcomputers for internal students, research assistants amd members of staff.

Since some of these problem areas were similiar for those of secondary schools, the ICSP became the vehicle for the Centre's initial investigation. Clearly, many ICCC considerations, such as CAL and linking to mainframes, will be of eventual value to schools.

In the 1979/80 Education Handbook (EH79/80) a series of five courses and seminars are being offered as a first contribution to the ICCC's investment in this project. The courses and seminar topics are of a high level but one low level course 'Advanced Microcomputer Engineering' is also being presented for those with a need for more detailed machine level concepts. It is of interest to quote the following (ICCCb79) to underline the ICCC's interest in micros.

> "The year has seen the start of some very important developments in the role of the Computer Centre in providing training and advisory support for users of computing facilities in the College. The 'Microprocessor Revolution' has brought into question again many previously accepted ways of providing computing resources for research and teaching. The remarkable drop in the cost of certain hardware components has made it practical to dedicate a considerable amount of computing power to individual experiments. It also makes possible a considerable decentralistaion of more generalised facilities, apart from 'number crunching', so that a personal computing system becomes economically feasible for many members of staff with regular computing requirements. However, in order to exploit the new possibilities, a considerable increase in personal computing

expertise is required; a lack of training and consultancy in the effective use of small scale systems is likely to lead to a great deal of frustration and wasted resources.

The Centre has carried out a survey of personal computing systems and can now advise users both on systems for laboratory control and on more general computational support. In addition, we are preparing for the next academic year a range of introductory and advanced training courses in microcomputing, and plan to provide a user's room of personal computing systems to enable researchers to acclimatise themselves with these before making a purchasing decision, and as an essential backup for training courses. "

12.3. Teacher Training:

A conclusion drawn in 1974 in (DIC74)and by others before in connection with teacher training stressed the importance of some computer awareness course for every teacher at Colleges of Education. Five years later the same conclusion is drawn in relation to microcomputer awareness courses but, unhappily, little has been achieved in the meantime to promote such courses even at the computer awareness level. Of course, there are several reasons for this. The economic restrictions following 1975 affected staff commitment to new courses, and, the re-organisation of colleges of education meant that some were fighting for their very survival.

For the short term, in-service courses can be presented but is really needed for the long term benefits is a steady stream of young teachers with an awareness of the potential of microcomputers within education as a whole. What is most encouraging is that government financial aid has been promised for the development of courses in both these areas.

13. Post-script:

Between the completion of this project in June, 1979 and the submission of this dissertation in May 1980, several interesting developments have taken place. For example the DuMP project (DuMP) has produced its findings of a project similar in nature to this one. Many of the conclusions are the same as my own. The on-going development of microtechnology has produced the Sinclair ZX80 and the Sharp PC1210 micros for under £100. An Apple II printer can be purchased for under £600. The commercial world has begun to express interest in CAL material.

It would be very tempting to include all these points within the original text, however, to draw the dissertation to a close, it was preferred to present some comments as a post-script.

13.1. Some Hardware Changes:

For me the most significant change since December 1979 is the availability of the Sinclair ZX80. It is a machine which will run Basic programs for less than £100 - or £79 in kit form. Basic reserved words can be entered at the stroke of one key and the Basic interpreter is held in ROM (as in the case of the Apple II). In addition to the microcomputer a cassette recorder for storing programs and data, and, a TV set are required. These can be merely plugged into the basic set. We hope to have a kit version soon to test its reliability. It does seem to be a system which could well be used by schools in initial Basic programming classes. We shall have to look closely at its diagnostic features since this will be very important for this type of activity. It has a 1k RAM memory which could well rival many 3 or 4k RAMs due to the entry of single key strokes. Future modifications promise add on memory modules , graphics capability and real number arithmetic. At present the integer number system is only available and this may well be felt by many teachers to be too severe a limitation. However, with floating point arithmetic, certain mathematical functions are also promised.

The main concern will really be the ruggedness of this Sinclair machine. His previous products have not been reliable in the past hence the cryptic comment by Computer Weekly that its strong point was its size and weight so that it could be easily returned to the manufacturer!

But what is really important to me is that this product has marked the arrival of microcomputers at under £100. With such prices, micros could well become standard school equipment for first programming courses. The Japanese have also announced their Sharp PC1210 micro/calculator capable of being programmed in Basic. It runs on calculator batteries and measures a mere 10 x 20 cms complete with QWERTY keyboard. It runs 392 steps of Basic and has a Kansas City interface for VDU and printer. Cassettes can store programs ahd data. A more powerful PC 1211 has also been announced capable of 1424 program steps and 178 steps of memory. The PC 1210 is selling in Japan for £40 and the PC1211 could sell in the U.K. for under £100 rivalling the Sinclair ZX80 and the Nascom 1 (at £140). The Sharp machines can be used anywhere since they operate from batteries but the limitation of the display which is litlle better than a pocket calculator may well demand 'nearness' to a VDU and printer.

A printer for the Apple II capable of full A4 size printout on fan-fold or single paper is now available for £600. This will be of particular importance to schools. Again what must happen is that other printer manufacturers will have to bring their prices down in order to compete.

13.2. CAL:

Commercialism is already looking hard at CAL material. Edward Arnold publishers have brought out a series of publications under different subjects with CAL material (EA79). A high street radio/television retailer has opened a computer 'floor' in Watford selling systems (hopefully) to schools complete 'CAL' material. Several companies have recently advertised for any CAL type material which it is willing to sell and amend for more general distribution. One company 'Audiogenic' of Reading have the rights to sell software for the Commodore Pet. Another company set up by a lecturer from Hartlepool College of Further Education and called Linsac is to write software for the ZX80 Sinclair machine. Although this may not seem to add up to great deal, for me this is just the beginning of much interest in CAL. As stated earlier this together with easier to use graphics will be, in my opinion, the start of a new approach and enthusiasm in educational software.

13.3. Publication of Course Notes:

One publisher has taken an interest in the Microcomputer course notes, now extended into a more presentable and complete format. Hopefully, this will be available to a far wider audience than we could cope with via single courses presented at Imperial College.

13.4. Miscellaneous Points:

It has become clearer since June 1979, that in order to safeguard against 'down - time' due to repairs to the microcomputer hardware that a back-up facility of one or more modules, such as the disc drive, printer or VDU screen is a point to be seriously considered. This may not be adopted as yet considering the financial situation of May 1980, but certainly, if and when times improve, it is a point to take into account when budgeting for hardware.

The drawback of the 40-column line for RML text processing has been partially resolved with a later text editor version permitting extended lines to be folded over into two 40-column lines by the depression of an 'EL' command.

The recent newsletters produced by RML of Oxford provide invaluable material for the user. There are notes on upgrades, high resolution graphics or rather the lack of it, errors in various Basic interpreters and how to overcome them, etc. But the real point is that the user does have some regular contact with the firm. This newsletter confirms the sincerity of the company to help the user as far as it can.

Finally, mention should be made of the promised 10 million component chip by 1985. Today the Cray computer is the world's largest machine containing some 200,000 gates each containing some 30 circuits, i.e. 6 million circuits. If this can be placed on one chip and an additional 14 memory chips to supply 65 million bits of memory, what cannot the future hold for computers in schools? One must feel rather like the designers of ENIAC who would not have been able to comprehend their 500,000 dollar machine (1950 dollars) being sent through the mail for 10 dollars (1979 dollars) as a result of LSI technology. If one believes this possibility, then as much groundwork as possible needs to done now otherwise when the reality dawns teachers will have idea of how to use such computing power effectively for computer education.

In conclusion, these features indicate to a time ahead of greater activity in microcomputer usage at secondary level. Cheaper hardware will make micros more available, and this availability will itself increase interest in the many aspects outlined in sectioned 11 not just from computer teachers but from teachers of all disciplines, provided that the marriage of CAL material and graphics is taken seriously.

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APPENDIX 1: INITIAL DOCUMENTATION FOR CW M6800

HARDWARE NEEDED FOR SINGLE USER

MP-A Board (the microprocessor CPU board).

3×MP-8M2 Board (memory board) to be switched to make 24K of memory starting at location 0000 (HEX) and finishing at location 5FFF (HEX) using switches 2, 3 and 4.

1 keyboard connected to MP-C board (serial CONTROL interface).

1 MSI PROM/RAM board.

HARDWARE NEEDED FOR MULTI-USER

MP-A Board.

3×MP-8M2 Board (to be switched to start memory at 2000 (HEX) and finish at 7FFF (HEX), using switches 1, 2 and 3.

1 MP-M Board (4K of memory starting at 1000 (HEX) and finishing at 1FFF (HEX).

1 keyboard connected to MP-C board (serial CONTROL interface).

1-4 keyboard each connected to an MP-S (serial interface) starting from Port 2 onwards.

1 Cassette tape containing either 4 user Basic (4K) or 4 user Basic (8K).

1 MSI PROM/RAM board.

IMPORTANT

The 4 user BASIC does not support DISK usage.

SINGLE USER

1. LOG-IN PROCEDURE (USING THE BOOTSTRAP TAPE)

1. Turn ON power (i.e. the POWER switch on the 6800 computer system, the PWR switch on the AC-30 cassette interface, the POWER switch on the CT-64 terminal system and the POWER switch on the FD-8 disk memory). See Appendix A for location of switches.
2. Load the BOOTSTRAP tape in the recorder.
3. Press the RESET switch on the 6800 computer system. The system will respond with asterisk (*) on a new line.
4. Start reading the bootstrap tape (i.e. push the PLAY switch on the recorder) and immediately type the letter 'L' on the keyboard.
5. The bootstrap will be loaded and at the end there will be an asterisk (*) on a new line. Press STOP on cassette recorder.
6. Load the system diskette in the upper disk driver. Press the RESET switch (on 6800) and type the letter 'G'.
7. The disk operating system will be loaded into the memory and the system will respond with the message DOS READY.
8. Type the command DCORES followed by a carriage return (RETURN key on the keyboard).
9. The system will load the DCORES system and respond with the message READY.
10. Type the command DOS followed by RETURN key. The system will respond with the message DOS READY.
11. Type the command BASIC2C followed by the RETURN key. The BASIC interpreter will be loaded into the memory. The system will respond with the message MSI READY. (See section 3 for commands available)

NB: (a) If not in use, please keep the diskette out of the disk driver unit.

(b) Please remember to switch power OFF at the end of your work.

SINGLE USER

1. LOG-IN PROCEDURE (USING THE PROM BOOTSTRAP)

1. Turn ON power (i.e. the POWER switch on the 6800 computer system, the PWR switch on the AC-30 cassette interface, the POWER switch on the CT-64 terminal system and the POWER switch on the FD-8 Disk memory). See Appendix A for location of switches.

* 2. Press the RESET switch on the 6800 computer system. The system will respond with asterisk (*) on a new line.

3. Type the letter M. The terminal will insert a space after the M.

4. Enter the address A048 after the space. The terminal will print on the next line: *A048 XX (where XX is 2 hexadecimal characters).

5. Enter a space and C7 on the terminal. The terminal will print on the next line: *A049 XX (where XX is 2 hexadecimal characters).

6. Enter a space and B6 on the terminal.

7. Load the system diskette in the upper disk driver and lock the front panel.

8. Press the RESET switch on the 6800 computer system. The terminal will respond with * on a new line.

9. Type the letter G. The terminal will respond with DOS READY.

10. Type any of the available commands (see DOS commands). The command will be executed. E.g. Type BASIC2C followed by a return. The terminal will respond with MSI READY.

11. Now you can use the BASIC interpreter to create, save, load and run programs (see Section 3 for commands available).

NB: (a) If not in use, keep the diskette out of the disk driver because of the heat.

(b) At the end of your work switch OFF power (in the same manner as Step 1 above).

* In case there is any problem, try again from Step 2 above.

2. DOS COMMANDS

While under DOS, several commands are available for execution as described below:-

FILES or CATALOG:	Typing either of these commands causes the system to list on the terminal the various program files which are stored on diskette.
FILES1 or CATALOG1:	Same as above but uses the diskette or drive numbers 1 (i.e. the lower one).
SAVE:	While operating under DOS, all files which are saved must be machine code files. There are two types of machine code files: system files and user program files. Examples of system files are BASIC2C and the Coresident assembler/editor. When saving system files, precede the file name with a dollar sign ($), such as $BASIC2C, for example. Two dollar signs ($$) must be entered in response to the last (?) on the terminal.
SAVE1:	Same as above but uses drive 1.
LOAD:	In order to load system files one must simply type the file name, for example BASIC2C.
LOAD1:	Same as above but uses drive 1.
RUN:	Typing the RUN command, followed by the file name causes the file to be loaded and program execution begun.
RUN1:	Same as above but uses drive 1.
CREATE:	This command is used to allocate a fixed number of sectors of file space to be used later when saving a program.
CREATE1:	Same as above but uses drive 1.
INIT:	Typing this command causes the system to initialise a new diskette.
INIT1:	Same as above but uses drive 1.
	The initialise routine must be performed before utilising the diskette for saving or reloading programs.
COPY:	This command will allow the users to copy a system diskette onto a blank diskette.

PURGE:	This deletes a file name from the disk catalog.
PURGE1:	Same as above but uses drive 1.
RENAME:	This allows file names to be changed.
RENAME1:	Same as above but uses drive 1.
MIKBUG:	This command allows the user to jump to the MIKBUG monitor routines.
RECOVER:	This command allows a non-readable disk sector to be reread.
BASIC2C:	This command loads the BASIC interpreter from disk into memory and responds with the message: MSI READY #
DCORES:	Disk coresident assembler/editor which stores object code directly on diskette.
TCORES:	Disk coresident assembler/editor which stores object code on tape cassette via the system terminal and AC-30 cassette interface.
PACK:	Removes unused file space on a diskette by compressing all program and data files. Copy a diskette before performing PACK in order to have a backup.
MOVCAT:	Stores a copy of the diskette catalog on track 4C which is protected. If catalog should be lost from track 02 of a diskette, it can be restored by transferring track 4C to track 02 using MINIDOS.
COPYFILE:	Copies a system file from one diskette to another. Precede all file names with the appropriate drive number, even for drive 0. For example, 0BASIC2C.
PFILES:	Display disk catalog on terminal or printer with complete diskette address, (00 for drive 0 and 01 for drive 1).
PFILESP:	Same as PFILES except that catalogue passwords are also displayed.
MINIDOS:	Is a utility program which allows the user to read or write any desired sector to or from any desired section of memory. MINIDDS requires memory at $7000.

3. BASIC COMMANDS AND INSTRUCTIONS

When BASIC is ready to receive commands, the words

```
MSI READY
#
```

must be displayed on the terminal. After each entry the system will prompt the user with a # . Commands are typed on the terminal without using statement numbers. After the command has been executed,

```
MSI READY
#
```

will be displayed indicating that BASIC is ready to receive another command from the user.

COMMANDS:

LIST:	This command causes the statements of the current program to be displayed on the users terminal. For example, LIST Lists the entire program LIST30 Lists ONLY statement 30 LIST30,100 Lists statements 30 through 100
RUN:	Typing RUN, followed by a carriage return, causes the current program, which is residing in memory, to be executed beginning with the lowest statement number.
NEW or SCRATCH:	Either of these commands causes the user program area and all variables and pointers to be reset.
CONTROL C:	Typing a CONTROL C on the keyboard will cause BASIC to halt its current operation and to respond with MSI READY
CONT:	The continue command causes a program to be resumed after a stop instruction has been encountered.
CONTROL X:	This command clears the current line buffer. It is used to delete a line when an error is made before typing a carriage return.
CONTROL H:	Is used as a single character backspace function. You may backspace as many character positions as necessary to correct the entry.
PATCH:	Typing this command causes the computer to go to MIKBUG operating system where it will output *
TRACE ON:	When the trace mode is in use, each line number is printed out as that particular BASIC statement is executed.

TRACE OFF:	This command turns the trace mode off and returns the system to its normal mode of operation.
LINE:	The LINE command specifies the number of print positions in a line (line length). For example, LINE=80
DIGITS:	This command is used to establish the number of digits to be printed to the right of a decimal point. For example, DIGITS=10
STRING:	Typing the command STRING=N will set the maximum string length to the value specified by N. A maximum string length of 128 characters is permitted.
POKE:	POKE(A,B) takes the decimal value of B and places it in the decimal memory location A.
PEEK:	PEEK(X) returns the decimal value contained in decimal memory location X. For example, A=PEEK(255) will result in the variable A being equal to the decimal value contained in memory location 255 (decimal).
POS:	This command returns, in decimal, the current position of the print head on cursor.
SAVE:	Typing SAVE, followed by a carriage return will cause the system to ask for a file name. Up to an eight-character file name may be used, followed by a carriage return. If a password is desired to protect a file, the file name may be entered and followed by a comma and password characters. This will result in the password being required for future access to the file or loading the program. For example, SAVE filename(,password)
SAVE1:	As above but uses drive 1.
LOAD:	This command is used to load a desired program from disk into memory. For example, LOAD filename(,password)
LOAD1:	Same as above but uses drive 1.

TSAVE:	This command is used for storing programs on tape cassette. The program will be output at the control port and will appear on the user terminal simultaneously.
TLOAD:	Is used to load programs from tape cassette into memory.
TAPPEND:	This command works exactly like the TLOAD command except that present memory contents are not cleared out. The program which is appended is read in and placed at the end of any program which is existing within the memory at that time.
FILES:	This command causes the system to display on the terminal the various BASIC program files which are stored on the diskette.
FILES1:	Same as above but uses drive 1.

SUMMARY OF BASIC INSTRUCTIONS WHICH ARE AVAILABLE IN THIS VERSION (i.e. Version 1.2)

MATH OPERATORS:		RELATIONAL OPERATORS:	
↑	EXPONENTIATE	=	EQUAL
-	(UNARY) NEGATE		NOT EQUAL
*	MULTIPLICATION		LESS THAN
/	DIVISION		GREATER THAN
+	ADDITION		LESS THAN OR EQUAL
-	SUBTRACTION		GREATER THAN OR EQUAL

LINE NUMBERS:	May be from 1 through to 9999
VARIABLES:	Maybe a single character alphabetic or single character alphabetic followed by one integer 0 through 9 or $.
BACKSPACE:	Is a CONTROL H.
LINE CANCEL:	Is a CONTROL X.
BREAK:	Typing CONTROL C should bring BASIC back to the MSI READY # mode regardless of what the BASIC users program is doing.

FUNCTIONS:

ABS(X)

INT(X)

RND(0) or RND(5)

LET A=USER(X)

TAB(X)

SIN(X)

COS(X)

TAN(X)

ATAN(X)

LEN(X$)

ASC(X$)

CHR$(X)

VAL(X$)

LEFT$(X$,N)

RIGHT$(X$,N)

MID$(X$,N,M) or MID$(X$,N)

STATEMENTS:

REM

DIM

DATA

READ

RESTORE

LET

FOR....TO....(STEP...)

NEXT....

STOP

GOTO

GOSUB

END

ON...GOTO...

ON...GOSUB...

IF...THEN...
INPUT
PRINT
RETURN
DEF FNA

IMPORTANT: For more details of MSI BASIC refer to:
MSI Disk Extended Basic Guide

MULTI-USER

1. LOG-IN PROCEDURE

1. Turn ON power (i.e. the POWER switch on the 6800 computer system, the PWR switch on the AC-30 cassette interface, the POWER switch on the CT-64 terminal/s). See Appendix A for location of switches.

2. Load the 4 USER-BASIC tape in the recorder.

3. Press the RESET switch on the 6800 computer system. The system will respond with asterisk (*) on a new line.

4. Start reading the 4 USER-BASIC tape (i.e. push the PLAY switch on the recorder) and immediately type the letter L on the CONTROL KEYBOARD (i.e. the keyboard which is connected to the MP-C serial control interface).

5. The 4 USER-BASIC interpreter will be loaded into the memory and at the end there will be an asterisk (*) on a new line.

6. Type the letter G on the control keyboard. The system will initiate the 1-4 USER-BASIC and there will be a "!" prompt on a new line.

7. Now each user can enter his programmes and instructions.

IMPORTANT:

(a) Please note that under 4 USER-BASIC you can save and load programs on/from cassette tape.

(b) Please remember to switch power OFF at end of work.

EVALUATION OF BASIC INTERPRETER FOR SINGLE USER

1. The set of commands available covers most of the BASIC commands available on main frame computers.

2. I have run several benchmark programs and all of them ran successfully.

3. Using the set of commands available, the user can save and load programs on/from diskette or cassette tape.

4. The user can create and save files on disk which could be used by other programs. This facility is very useful, especially in a data base environment.

REMARKS ON THE M6800 MICROCOMPUTER SYSTEM

1. I think there is no proper documentation.

2. It takes a long time for a person to get used to the system. I had to read all the documents available to know how to use the system.

3. I have tried several commands under DOS, BASIC to know which command is working.

4. Most of the microcomputer dealers claim in their advertisements that a particular system has so and so facilities and that as soon as you plug in the particular board, the system will work. It is not that simple. In my situation I have tried and tried until I have been satisfied with the system's performance.

5. It seems to me that any person thinking of using a microcomputer should acquire some knowledge about micro circuit design.

APPENDIX 2: TEACHERS MICROPROCESSOR COURSE NOTES

MICROPROCESSOR APPRECIATION COURSE - April, 1979

Lecture 1 - How We Got To Here

In 1950 the National U.S. Census was made possible by ENIAC, a computer costing then $500,000 (i.e. 1950 dollars). Today, the same computing power can be purchased for $10 (1979 dollars). How has this been possible?

Over the past year, it must be very difficult for most non-computing people not to have heard of microprocessors. The popular press and other forms of the mass media have caught onto these "computers on a chip". Even governments and trade unions cannot refrain from discussing them, not only in this country but elsewhere in other European countries, America, Japan, etc. Sometimes one faction will claim that our very survival in terms of our economy depends upon extensive knowledge and use of such devices. At another time, we hear that microprocessors will destroy our society or, at least, change it beyond our imagination.

In this first lecture, we shall take a general look at computers to see where microprocessors fit into the overall pattern of development. We shall then be in a position to discuss the differences, if any, between the traditional computer and the latest arrival, the microcomputer.

Early Developments

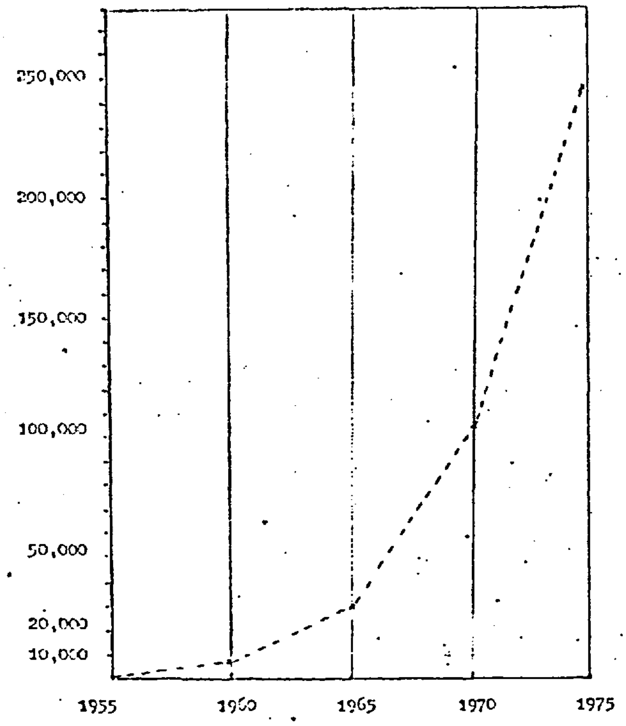
In October, 1946, an article by Dr.J.Comrie appeared in the journal 'Nature' headed "Babbage's Dream Comes True". It described the Harvard Mark I developed by Howard A.Aiken of Harvard University. The project, begun in 1937, became a reality in May 1944 and was initially used by the U.S.Navy for classified work.

The reference to Babbage results from his attempts to create his so-called Analytical Engine originally conceived as early as 1833. The absence in his day of electronics and, therefore, his total reliance upon mechanical wheels and gears, coupled with the lack of precision engineering, meant that his concept of the A.E. could not be realised. But had it been practical then the Analytical Engine would assuredly have been the world's first computer.

As it happened, the concept of a computer essentially as we know it today and first mooted by Charles Babbage in Cambridge, England, became a reality in Harvard University, Cambridge, Massachusetts, some 100 years later.

Once achieved, a phenomenal rate of development followed. On 15th February, 1946, the Electronic Numerical Integrator and Calculator, ENIAC, was formally dedicated at the Moore School of Electrical Engineering at the University of Pennsylvania. In a single hour, ENIAC could accomplish calculations which would have taken the Harvard Mark I one week to perform. It was designed for a specific purpose - ballistics - and its use was limited. Other machines quickly followed, the Manchester University (England) Mark I in June 1948, EDVAC and EDSAC, etc. All were the products of university projects.

The designers of ENIAC suggested at the time that four similar computers would be sufficient for the world's computing needs. To give some idea of the incredible rate of use since then, only thirty-three years later, there are today over 250,000 computers in the U.S., the U.K., Japan, West Germany and France. Furthermore, one small microcomputer, the F8, the product of the Fairchild company, is comparable to the power of ENIAC. Thus, in terms of computing power, the countries mentioned have considerably more computing power, measured in terms of hundreds of millions, than originally thought to be necessary by the ENIAC designers.



total number of computers installed in:
US, Japan, Germany, France and UK.

We could spend much more time discussing the early development of computers but we shall restrict further comments to two points. First, computers were originally conceived as fast and accurate calculating machines. Secondly, they originated because of the pressures of World War II which dicatated the need for such calculators.

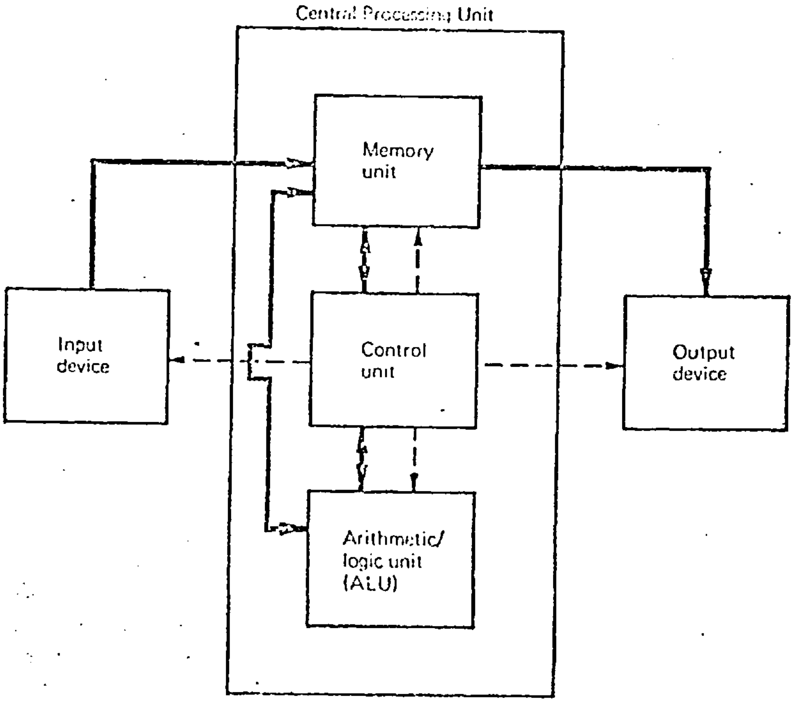
Basic Architectural Design

Essentially, a computer consists of five units, linked together through an address bus which permits information to flow from one of the units to another and possibly back again. So far, electronics is the best technology for constructing computers. Since it is easier (and therefore cheaper) to manufacture two -state electronic devices, information within a computer tends to be represented by electrical signals. Typically, one signal may carry a +5 volt, the other a 0 voltage. In turn, these states can be conveniently represented in binary, the base two number system which has only the two digits one and zero. The higher voltage is usually referred to as a binary 1, the lower voltage as the binary digit zero.

However, we use many different characters in everyday communication, letters of the alphabet, the ten digits of the base ten number system and many other more specialised symbols such as the comma, open and closed brackets, arithmetical symbols, and so on. These have to be converted into patterns of electrical signals (binary digits or 'bits') if they are to be understood or recognised by a computer. A device which is capable of performing the conversion of human readable characters to computer readable characters is called an input device. Once the computer has performed some action upon information, we usually want to see the results. If these are pay-slips, few of us would want to read a pattern of voltage levels, even if these were transcribed in binary. Consequently, the purpose of the output device is to perform the opposite function of the input device. That is to translate from computer readable characters to human readable characters.

The main units of a computer are often collectively called the central processing unit or CPU for short. They comprise a memory unit, an arithmetic/logic unit and a control unit. The memory unit stores or holds information for processing (i.e. manipulation by the CPU) as well as the results of any processing. In many ways it is similar in function to our memories as human beings. But no actual processing can take place in this storage unit. It is the purpose of the arithmetic/logic unit (ALU) to perform all arithmetical and logical operations. The function of the control unit (CU) is to interpret program instructions and when necessary transfer information from memory to the ALU for processing and transferring information back to memory once the processing has been carried out.

As an example of the interaction of the five basic units, let us take a trivial problem such as adding togther two numbers. It would be simpler and quicker



Basic Structure of the Computer

for us to perform this manually or even by the use of a pocket calculator. But to illustrate how this would be carried out by a computer, two amounts of information would be required. First, a set of instructions telling a computer to add together two numbers (NB any two numbers). Secondly, the two numbers to be added together, i.e. what is called the data. The input device will translate our instructions into binary and these will be placed in the memory unit. We shall assume that the two numbers to be added have also been placed in the central memory unit. The CU will read the set of instructions which tell the computer to add two numbers (not how to add). This arithmetical operation cannot take place in memory and so the CU will move the two data numbers from memory to the ALU. Assuming that we wish to see the result, the CU will place the result from the ALU back into memory and cause the result to be displayed at the output device.

This basic design is essentially the same for the very largest computer to the very smallest, even to the microcomputer. The difference between the two, apart from cost, lies not in the basic design but in the speed of the ALU, the number and variety of input and output devices, the size of the central memory, the size and range of backing stores and the size and complexity of the operating system.

Backing stores are auxiliary storage devices for holding data and programs. They contain information in computer readable format and are used to extend the central memory which is comparatively small because of its expensive electronics. Any information held on backing stores must be passed into the main or central memory before the CPU can recognise its exsistence. This procedure takes place at high speed. Magnetic tapes, magnetic discs and, more recently, smaller 'floppy' discs are typical secondary (backing or auxiliary) storage devices.

Because the input, output and auxiliary storage devices do not form the main computer units, they are sometimes called peripheral devices.

In a large computer with vast backing stores and central memory and a very fast ALU, the potential is too great for most applications. There are only a few cases such as real-time transaction problems or weather prediction which really require all that power at any one time. Consequently, for the sort of problems that the majority of computer users pose, the actual power of a given computer is divided up between many users at the one time. This makes the large computer more economical to run, rather like five people sharing the one taxi. Special computer programs (not written by the general user) called operating system programs perform this division of one machine over several user programs. Multiprogramming and time-sharing are two such operating systems. Essentially, such systems were developed to allow the maximum number of users to make use of very expensive equipment in the most ecomonical manner. Microcomputers ideally should obviate the necessity for such systems.

Characteristics

In order to understand the enormous growth of computer usage, we need to spend a few moments considering their characteristics.

Speed

Computers were originally developed as high speed calculators. As such they have been largely responsible for man landing upon the moon and exploring Mars.
If we want tomorrow's weather prediction today and not in six months time, then we need computers. The manual indexing of the works of Thomas Aquinas (13 million words) would have taken fifty scholars forty years but with the aid of a computer a few scholars were able to do this in a year. The speed of the computer brings

tomorrows knowledge today.

This is possible because the electrical signals travel at speeds close to that of light. The computer (i.e. the CPU) has no mechanical or electromechanical parts to slow it down. Thus, we do not talk in terms of seconds but in terms of

milliseconds - thousands of a second (as in 1st generation machines) - 10^{-3}
microseconds - millionths of second (2nd gen.) 10^{-6}
nanoseconds - thousand-millionths (current large mainframe computers) 10^{-9}
picoseconds - million-millionths (future machines) 10^{-12}

In reality this means that a machine the size of the CDC 6600 can perform three million calculations in one second (i.e. adding together two 18 digit numbers).

It is the internal speeds of the CPU that function at the above speeds, e.g. when performing arithmetic/logic and comparison operations; the moving of data about within central memory or from the ALU to the central memory and vice versa. Only the input, output and access to auxiliary storage devices operations can slow down the computer because of the reliance upon electromechanical peripherals such as teletypes, magnetic tapes and discs.

Accuracy

Computers do not seldom make mistakes. Programs written by human beings however are prone to errors, i.e. both the user application programs as well as the operating system programs. If the computer itself does develop a fault, it usually reports this fact and the programmer is alerted. It is, of course, the operating system program which will generate the error message. Computers with large (and therefore expensive)operating systems are very reliable in this respect. It is the smaller computer and especially the microcomputer with cheap and small operating systems which may not report hardware failures.

Tirelessness

Computers are not prone to human failings such as loss of concentration, tiredness or boredom. If it has to perform 3 million calculations it will perform each with exactly the same diligence.

Storage of Information

Although invented as fast calculators, the ability to store many forms of information (numbers, letters of the alphabet and hence words, symbols, graphs, designs, etc) has transformed the computer from a calculator to a processor of information. This fact together with its ability to store and retrieve at will a limitless amount of information on auxiliary devices provides us with a definition, namely, that of an information processor. It was this latter extension which caused the commercial world to take an interest in computers and so led to the manufacture of computers on a large scale rather than their being the offspring of university projects.

The main memory is very limited in size but with access to auxiliary storage, the computer can store vast amounts of data of all sorts in a data bank. Here, of course, we come against the current social problem. What type of information should be stored and thus be accessible to computers? It is not the computer itself that we fear but the humans who can retrieve the information from the data banks and manipulate it to their own desires.

It is possible to create a file on every individual from birth to death. His family history can be stored together with all his school records and work records. In addition, medical records, higher education records, tax records, car records, criminal records, subscription records to magazines, and, if the cashless society does evolve, records of how every penny is spent. Thus, it would be possible to know an individual's reading habits as well as the very food he eats. Once information is encoded into a computer readable format, then it can be combined with other encoded records and be reproduced on demand.

What Computers Can Do

If we return to the diagram of the basic structure, we can easily list the possible functions of a computer. It must be capable of performing input and output operations; arithmetic operations (all reduced to a form of addition); it can compare two numbers and decide which is larger (or smaller or whether they are equal); it can perform logical operations; and, finally, move or arrange data within central memory, or, to and from the ALU. That is all!

A programmer has the task of reducing a problem for computer solution to a series of individual instructions involving only the above very few and basic operations. In one sense, the computer is a very limited machine and yet, because of the basic nature of these operations, an overwhelming number of problems can be solved. Thus, its strength lies in its very simple operational ability.

Computer Generations

The following chart lists the dates of the various generations through which computers have evolved. No two experts will ever agree on one set of dates. We present one set which more or less approximates to most. The areas with

	FIRST-GENERATION 1951-1958	SECOND-GENERATION 1959-1963	THIRD-GENERATION 1964-1969	POST THIRD-GENERATION 1970-1980
PRINCIPAL ELECTRONIC COMPONENTS	vacuum tubes	transistors and diodes	integrated circuits	microscopic integrated circuits
INTERNAL OPERATING SPEEDS MEASURED IN	milliseconds (10^{-3} sec.)	microseconds (10^{-6} sec.)	nanoseconds (10^{-9} sec.)	approaching picoseconds (10^{-12} sec.)
CENTRAL MEMORY	mercury delay lines			
	cathode ray tubes			
	magnetic drum			
	magnetic core →	→	→	→ - - - - →
			thin film →	→
			LSI (large scale integration) →	→
SECONDARY STORAGE	punched cards, paper tape →	→	- - - - →	- - - - →
	magnetic drum →	→	→ - - - →	- - - - →
	magnetic disk →	removable packs introduced →	→	→
	magnetic tape →	→	→	→
			ECS (extended core store) →	→
OPERATING SYSTEMS	batch processing →	→	→	→
		multi-programming →	→	→
		time-sharing →	→	→
		real-time →	→	→
				networks →
INPUT AND OUTPUT MEDIA AND METHODS	punched cards, paper tape →	→	→ - - - →	- - - - →
	printers →	(on line) →	→	→
	magnetic tape →	→	→	→
		teletypewriter terminals →	→	→
		VDUs →	→	→
		OCR & MICR readers →	→	→
			key-to-tape/disk/cassettes →	→
PROGRAMMING LANGUAGES	machine code			
	symbolic languages →	→	→	→ - - - - →
	high level languages →	→	→	→
	Fortran, Algol, Cobol →	→	PL/1 → Basic → Pascal →	→
NOTABLE MODELS AND COMPUTER SERIES	UNIVAC I & II IBM 701 IBM 650 BURROUGHS E101	IBM 1401 IBM 7090 ATLAS UNIVAC 1004 HONEYWELL 400 BURROUGHS 200 CDC 160	IBM System/360 series ICL 1900 series UNIVAC 1100 series CDC 6000 series DEC PDP range HONEYWELL 200 series BURROUGHS 7700	IBM System/370 series ICL 2900 series CDC Cyber 170 range HONEYWELL 6000 series CRAY 1
OTHER DEVELOPMENTS			minicomputers →	→ microprocessors and microcomputers
			improved data communication techniques →	→
				word processing →
			package developments →	→
				voice response units →
BRIEF NOTES	Technology had advanced enough to get the computer industry underway, but, computers were expensive, relatively slow and unreliable, and generated so much heat that air-conditioning was a problem. Scientific applications at first, followed by beginings of data processing in business.	Use of solid-state technology (principally transistors) led to computers that were smaller (but still large), much more reliable, consumed less power, faster in operation, but still relatively expensive. Rapid growth in data processing applications. Introduction of time-sharing, real time systems.	Computers were smaller, still faster, more reliable, and used much less power. More powerful machines were developed and also minicomputers. The overall increased efficiency resulted in greatly reduced computing costs. Significant improvements occurred in the development of software and operating systems.	Yet more powerful and more versatile computers and computing systems; faster, smaller and less expensive. Continued reduction in costs dramatically accelerated by miniaturization (silicon chips). More minicomputers and the coming of the micros (the advent of the 4th generation). Advances in storage techniques.
	————→	indicates continuing use	- - - - →	indicates declining use

which we are most concerned are the principal electronic components, internal speeds and the programming languages and operating systems of the various generations. This latter two (programming languages and operating systems) are more generally called software, i.e. programs and are contrasted with the hardware which is the electronics, the devices which can be handled physically.

Hardware

The principal components of the first generation were vacuum tubes and because of their size (compare the old wireless sets) resulted in large though not necessarily powerful computers. The second generation were characterised by transistors. In each case, the components were discrete and had to be assembled into functioning units by hand. Thus, the labour costs of this assembly were high and much wire was needed to link the components. It is said that the Harvard machine used as much as 500 miles of wire. Third generation machines began to use integrated circuits which simply combined several logic elements together onto one basic layer of semi-conducting material. Late third generation computers extended this idea so that many more logic elements were built onto the same amount of space.

A semi-conducting material is neither a good insulator nor a bad conductor. Silicon is a good semi-conductor and is very cheap since it is the main ingredient of sand. When integrated circuits were first manufactured, a base of silicon contained only a few logic elements. This is sometimes referred to as small-scale integration (SSI). But as the manufacturing technology improved, more and more elements could be packed onto the same size chip of silicon. Today, medium scale integration (MSI) can build up to 100 elements on a silicon chip, and large scale integration (LSI) - the basis of micro technology - can currently pack up to 10,000 elements. Throughout the generations, the hardware has consistently become smaller and the cost decreasing.

Speed of Components

The first generation electronic devices operated at speeds of milliseconds; the second generation at speeds of microseconds; the third generation at speeds of nanoseconds; and, the late third approaching picoseconds.

Software

When a computer is designed, it is made to obey one language only, called its machine code. This language reflects many physical properties related to the actual structure of the computer. The machine code is often referred to as a low level or machine oriented language because of this. Inside the memory, the

program instructions will be in binary patterns (representing patterns of two-state voltage levels). Some of the early programmers who were often part of the original design team, wrote directly in binary or sometimes in groups of three binary digits (octal) or four bits (hexadecimal). If the following octal bits represented to the CU 'to place a number from central memory into the ALU' - say "111", then the programmer would use this pattern every time he wished the computer to perform this action. However, when it is realised that a computer may have a repetoire of between 50 and over 200 such instructions, it can be appreciated just how difficult it would be to remember all the various patterns. Thus, a mnemonic was used instead. 'LDA', for example, would stand for load the accumulator. However, since computers do not understand such symbols, some translating program has to convert our characters 'LDA' into the appropriate binary pattern. Such translators were called assemblers.
High level programming languages later developed which unlike the machine code and their mnemonic counterparts were not oriented towards the machine structure but more towards the types of problem which had to be solved. Mathematical and scientific problems could be more easily written in high level languages such as FORTRAN, ALGOL or BASIC; whilst business type problems were more easily solved by using languages such as COBOL and RPG. However, again there has to be a translation phase to convert the high level instructions into binary machine code. This is the function of compilers. The chart shows when each class was developed.

One hallmark of the third generation computer was the steady increase in the complexity of the operating systems. As the computers became larger, it became more necessary to divide or share their full power between more than one user at a time.

The Microcomputer

Microprocessors come from developments in LSI technology related to late third generation computers. Perhaps, the microcomputers will become known as the fourth generation? They are smaller and cheaper than computers of earlier generations and in this respect they are in keeping with the normal pattern of development. Therefore, we can say that the microcomputer is just the latest development in computer hardware and is nothing special at this level.

It has fourth generation hardware, but its internal speed is more in keeping with first and second generation machines, i.e. it performs in terms of microseconds and , in practice, often in terms of milliseconds. Its software is again closer

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to a second generation machine however. The languages available are certainly of the hexadecimal octal level, with assembly level as an alternative. Some high level languages are available mainly BASIC and FORTRAN. The operating system is very primitive and reflects again second generation development. This is perhaps the worst feature of microcomputers and the implications of this will be discussed at length in lectures 3 & 4.

In the next lecture, we shall turn towards microprocessors and discuss what they are and what is available.

Lecture 2 - What is here

Most of the technological achievements of the past ten years have depended upon microelectronics. Small and reliable sensing and control devices were essential to landing man upon the moon and to exploring Mars. Sadly, microelectronics play a similar role in intercontinental weapons which dominate world politics. Microelectronic devices are also the essence of new products ranging from communication satellites to hand held calculators and digital watches; from microprocessor controlled washing machines and microwave ovens to aids for severely handicapped people. They have also had an effect upon the computer and perhaps this will be their greatest significance.

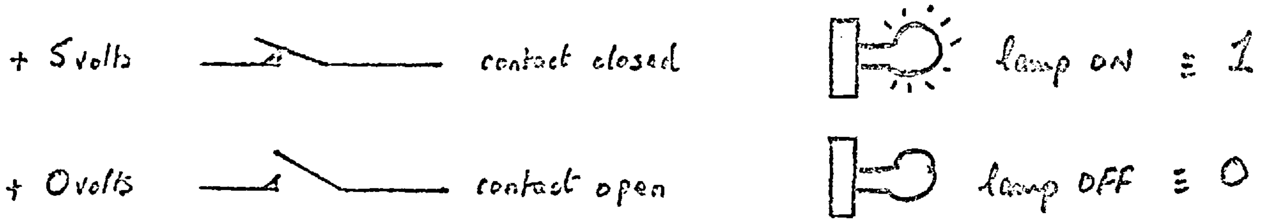
In spite of this latter role, it is an historical fact that the early efforts in miniature electronic components were not motivated by computer designers. Indeed, the tremendous potential of the digital computer was not quickly appreciated. Even the developers of the first computer felt that four such machines would be sufficient for the world's computation needs.

We have already seen that the first generation of computers used vacuum tubes, indeed, ENIAC used 18,000 of them. Larger machines using such technology would have been impractical since it would have taken nearly 24 hours each day to find and replace defective tubes. The computer was saved from a premature end by the invention of the transistor in 1947. But the point is that early computer designers were slow to make use of them.

The development of the integrated circuit in the late 1950's again made an impact on the size and cost of the digital computer. Today a similar transformation in the design of computers and other electronic devices is taking place by LSI. Many thousands of transistors and their interconnections, resulting in the logic elements which comprise digital computers can be packed or fitted onto a chip of silicon no more than a ½" square. A typical LSI circuit now comprises on one chip all the functions previously needing 10,000 separate, discrete transistor circuits, hence doing away with assembly tasks.

Great emphasis is placed upon the small size of LSI chips, but the real significance of the smallness is not their size but in the manufacturing technology which created them. Before discussing, briefly, the fabrication process, we shall remind ourselves about the logic elements in digital computers.

Being electronic machines, they respond to electrical voltage levels. Since it is easier to create a device with a two-state voltage level, then typically 0 volts indicates binary zero and +5 volts indicates binary 1.



Taking this one step further, a particular construction of open and closed gates or switches can be turned into a logic gate. Let us take a basic AND gate which may have two or more inputs but produces one output. Its operation is based on the following truth table:

A	B	output
0	0	0
0	1	0
1	0	0
1	1	1

Only when BOTH inputs have a +5 voltage (A and B) will the output be + 5 volts, otherwise any other combination will produce no effective output. Other logic gates such as NOT, OR, etc exist. These can be combined to form all the operations required by a computer. For example, an arrangement of 11 AND gates, 5 OR gates and 3 NOT gates will add together two binary digits.

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0 with 1 carry.

But two binary numbers will not do much arithmetic for computers. However, if the word length of a computer contains 16 bits, then by cascading and linking together 16 of the above two-bit adder circuits the logic elements will add together two 16 bit numbers. Other patterns exist for subtraction, multiplication and division; the decoding of computer instructions (in machine code); logical and comparison operations, etc. Very complex patterns involving 10,000 or more circuits can be built onto a single chip ¼" square to represent the logic pattern for a complete ALU and CU of a digital computer.

How is this possible?

Fabrication Process

Chemical materials differ in their ability to carry an electrical charge. Metal is a good conductor of electricity, insulating material is not. A semi-conductor material is neither a good insulator nor a bad conductor. Fortunately, silicon (the main ingredient of sand) is one of the most suitable semi-conducting materials available. It is therefore cheap in its raw state.

The following processes outline the manufacturing process of microelectronic circuits.

a) Raw silicon is first reduced from its oxide - sand,and,purified to 99.999 9999%. 10 kilograms is brought up to its melting point (1420 dgs Celsius). Certain impurities are added at this stage called dopants which will give the doped silicon ingot its required degree of conductivity.
A large single crystal is grown from this 'melt' by inserting a single perfect seed of silicon. From this crystal an ingot 3 or 4 inches in diameter and several feet long can be produced.

b) The crystal is sliced up by a thin diamond saw, smoothed on both sides and finally highly polished on one side. The final wafer of silicon is about 3 or 4 inches in diameter and half a millimeter thick.

c) Each wafer is tested for a smooth polished finish by a precision measuring device. There must be no defects, no damages caused by the polishing process, no scratches or even chemical impurities on the finished surface.

d) A batch of several hundred wafers are coated in a thin film of silicon dioxide by being heated in a stream of oxygen-containing gas. The dioxide plays an important role in the manufacturing process since it acts as an excellent insulator and also acts as a mask for the selective introduction of dopants at later stages in the process.

e) A layer of photoresist material is next placed on the dioxide. It is sensitive to light so that when a photomask is placed over it and exposed to ultraviolet light the pattern of the mask is left behind.

f) The photomask contains the pattern of the desired electronic circuits. The pattern is first designed often using a computer to assist (Computer Aided Design). The resulting layout is used to prepare a set of photomasks. The layout is enlarged usually tenfold and is called a 'recticle'. It is checked, corrected and regenerated until it is perfect.A photographically reduced image is reproduced to yield a final set of photomasks from which a large number of working plates are copied.

g) Photolithography is the process by which the microscopic pattern is transferred from a photomask to a material layer in an actual circuit as mentioned in step (e) above. A chemical process attacks the silicon dioxide leaving the photoresist and the silicon substrate unaffected. A final step removes the photoresist leaving the pattern etched into the silicon dioxide.

The most difficult circuits to design are microprocessors where the design and layout may take several years whereas the design for memories, which are largely repetitive, can be designed and laid out more quickly in a few months.

The silicon chip measuring either a standard 3 inches or 4 inches may contain many hundreds of circuits some of which will be damaged.

h) Each die on the wafer is probed to determine whether it works correctly. Defective dies are marked with an ink spot and later discarded. A computer controlled testing machine quickly tests each die and performs the inking process in the case of defective die (which may be as high as 200 out of 250). It keeps accurate statistics on the number of good circuits per wafer and these can be used to improve a yield of good circuits.

i) The wafer is then cut (sectioned) and the good circuits kept. These must now undergo one last operation, packaging. Circuits are bonded into packages and connected to electrodes which serve as connections to the outside world.

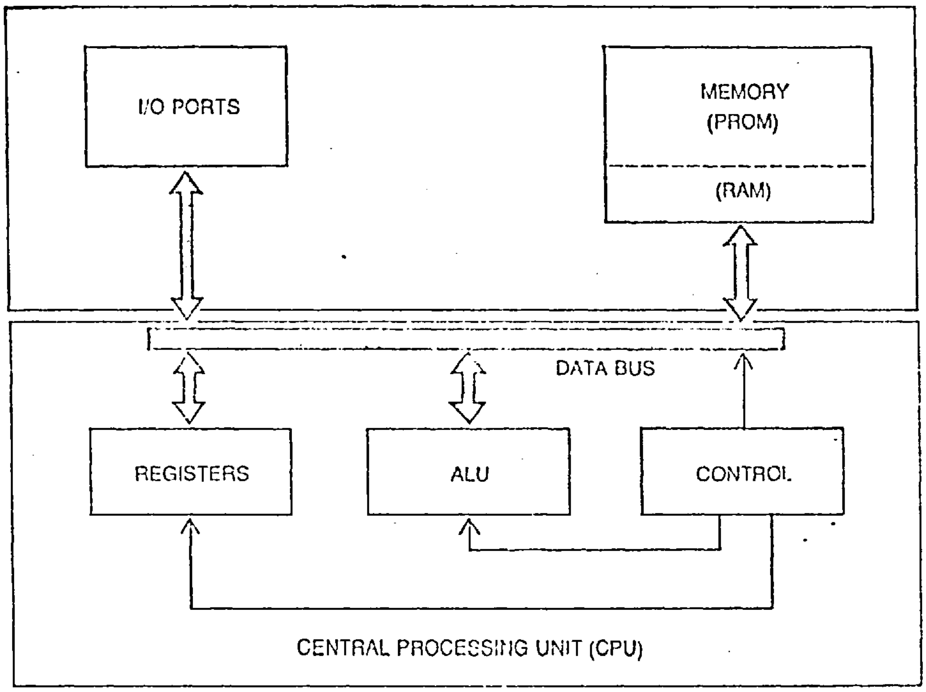
j) The package is then sealed and the device finally tested.

After individual dies are obtained from the wafer, the cost per manufacturing step rises enormously because the cost is no longer shared amongst many circuits.

The low cost of the final product hides the difficulties in its manufacture. The process indicated above is a gross simplification of the actual method especially for the layering techniques of the pattern and the introduction of selected dopants to create p-type and n-type channels. Nevertheless, the net result is the production of a complex set of circuitry at a very low cost.

Structure of a Microcomputer

Let us turn away from the manufacturing process and look at a simplified structure of a microcomputer. The heart of such a computer is the microprocessor, i.e. the ALU and CU together with the associated circuitry all of which is scaled down so that it fits onto a single (or more) silicon chip. This is the equivalent of the central processing unit (but without memory) of a traditional mini or mainframe computer. By itself it is not a computer. By adding anywhere from 10 to 80 chips to provide timing, program memory, random access memory, inter-



faces for input,output signals and other ancillary functions one can assemble a complete computer system on a board which does not exceed the area of this paper. Such an assembly is a <u>microcomputer</u>, in which the microprocessor serves as the master component.

About 20 U.S. companies are now manufacturing some 30 different designs of microprocessor chips, ranging in price from $10 to $300. More than 120 companies are incorporating these chips in microcomputer systems selling for $100 and more.

The block diagram of a typical microprocessor would show the following units:

a decode and control unit	- to interpret instructions from the stored program
an ALU	- to perform arithmetic and logic operations
registers	- to serve as an easily accessible memory for data frequently manipulated
accumulator	- a special register which stores partial results during the arithmetic operations of the ALU
address buffers	- to supply the CU with address of the next instructn
input/output buffers	- to read instructions or data into the microprocessor, or, to send them out.

Present microprocessors vary in their detailed architecture depending on their manufacture. One of the major distinctions is whether all the elements of the microprocessor are embodied onto a single chip or are divided among several identical modular chips which can be linked in parallel. The number of chips will depend upon the word size , 4 bits, 8bits or 16 bits. Such a multichip arrangement is known as a 'bit-sliced' organisation.

In the above figure, it is the I/O ports and Memory unit which convert the microprocessor into a computer system. The I/O ports provide access to peripheral devices such as a keyboard, a visual display unit, tape cassette or 'floppy' disc information storage units, a line printer, etc.

Memory Units

Modern information processing and control systems call for the rapid storage and retrieval of digital (bits) information. The amount of information to be stored varies according to the application. A pocket calculator will require fewer than 100 bits but a large system may require many millions. The memory units are also based on LSI techniques. A single chip of silicon may contain a matrix of transistor cells each capable of holding a binary bit. The limit at the present time for any one chip is 64k bits.

Some of the memories can only be read from. These contain information (some predesired program) which is static and is ideal for those microcomputers which tend to run the same program throughout their lives. These are called read-only-memories (ROMs). The program pattern is etched into the chip at the time of manufacture and it can never be altered. Other programmable-read-only-memories or PROMs exist. Again the memory can only be read, but if desired the program contained in the PROM can be changed by a special process. One such technique is to eraze all the information contained by exposing the chip to ultra-violet light. Once erazed, the chip can be re-programmed.

A third type of memory chip is the read to and write from memory RWM or random access memory (RAM) as is it more commonly known. These memories can be seen as the central memories of traditional computers, that is a storage unit for programs and data of a constantly changing nature.

* * *

References - further details about the material covered in Lecture 1 can be found in "Computers & Commonsense" by Hunt & Shelley, published by Prentice/Hall, 2nd edition, 1979.

Lecture 2 - "Microelectronics" - A Scientific American Book, published by W.H.Freeman & Co., 1977.

Both books can be purchased from the I.C.Bookshop.

Various accepted block diagrams of the traditional computer. The bottom two emphasise the address bus (information paths).

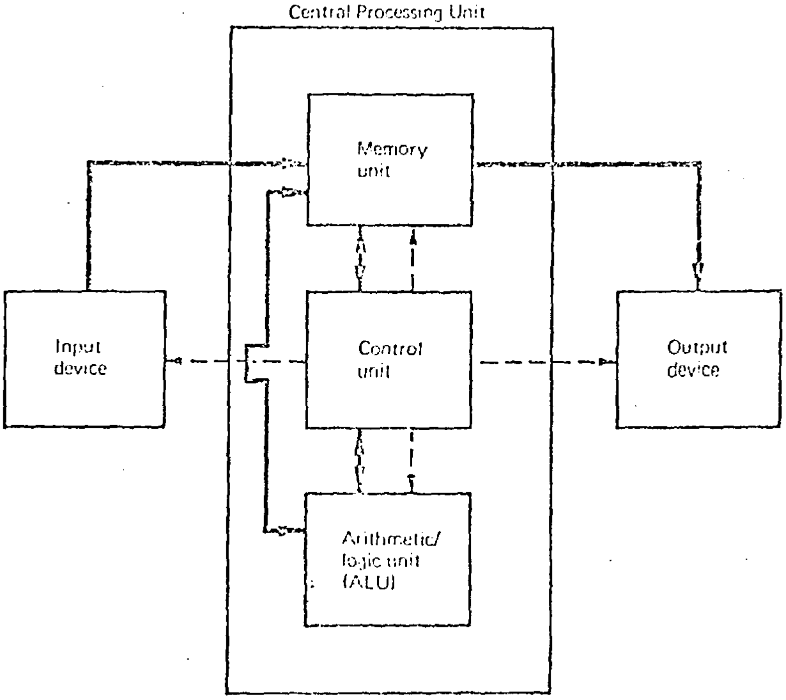
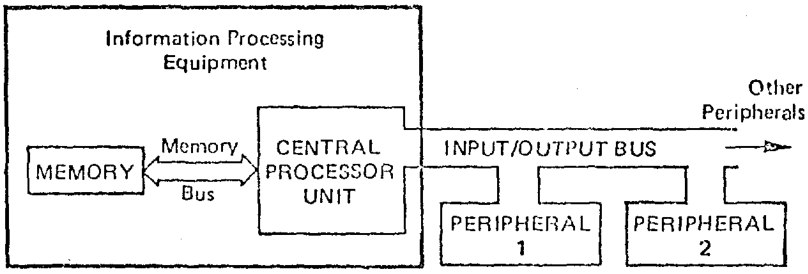
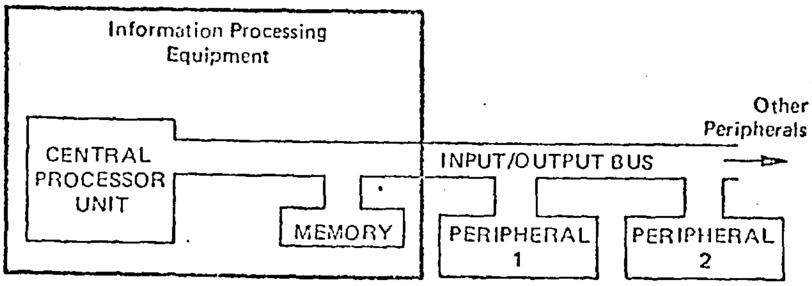


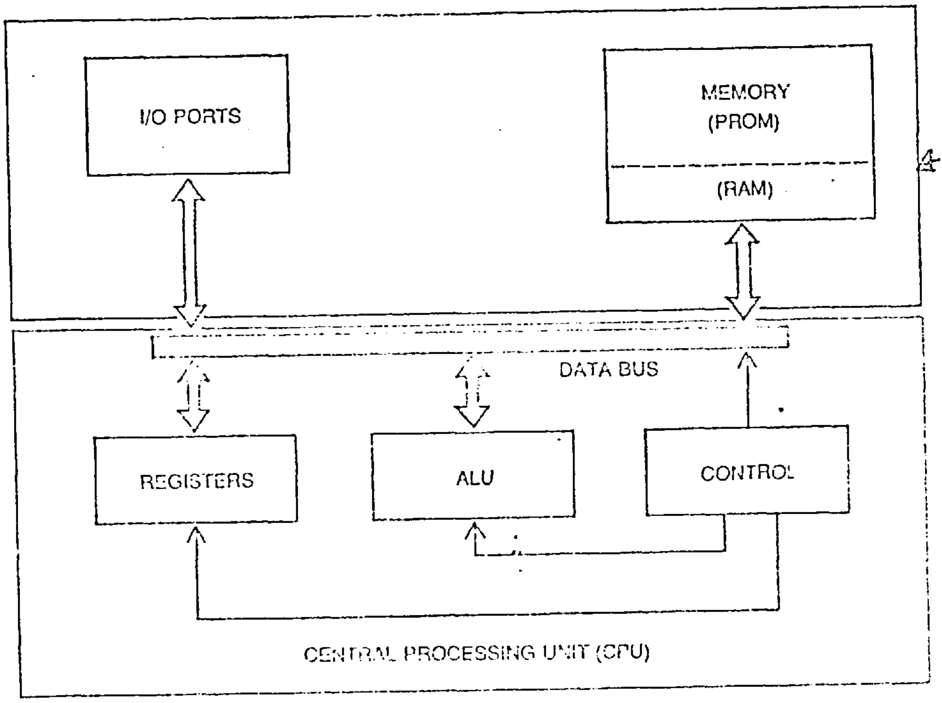
Fig. 2.1 Basic Structure of the Computer



Computer system block diagram

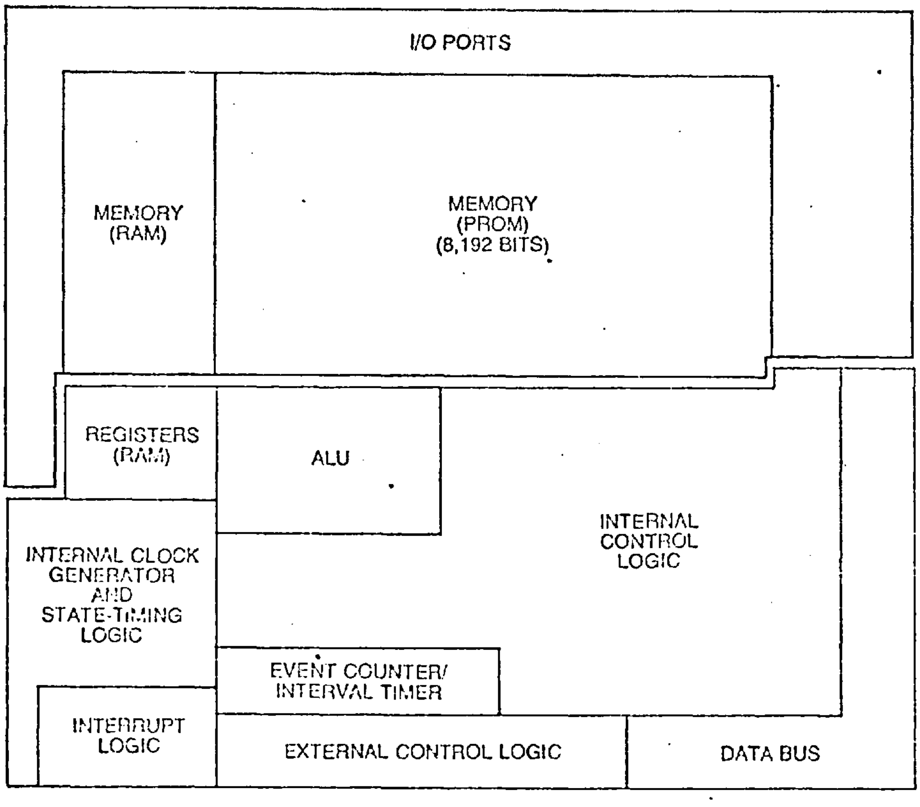


Alternative system block diagram

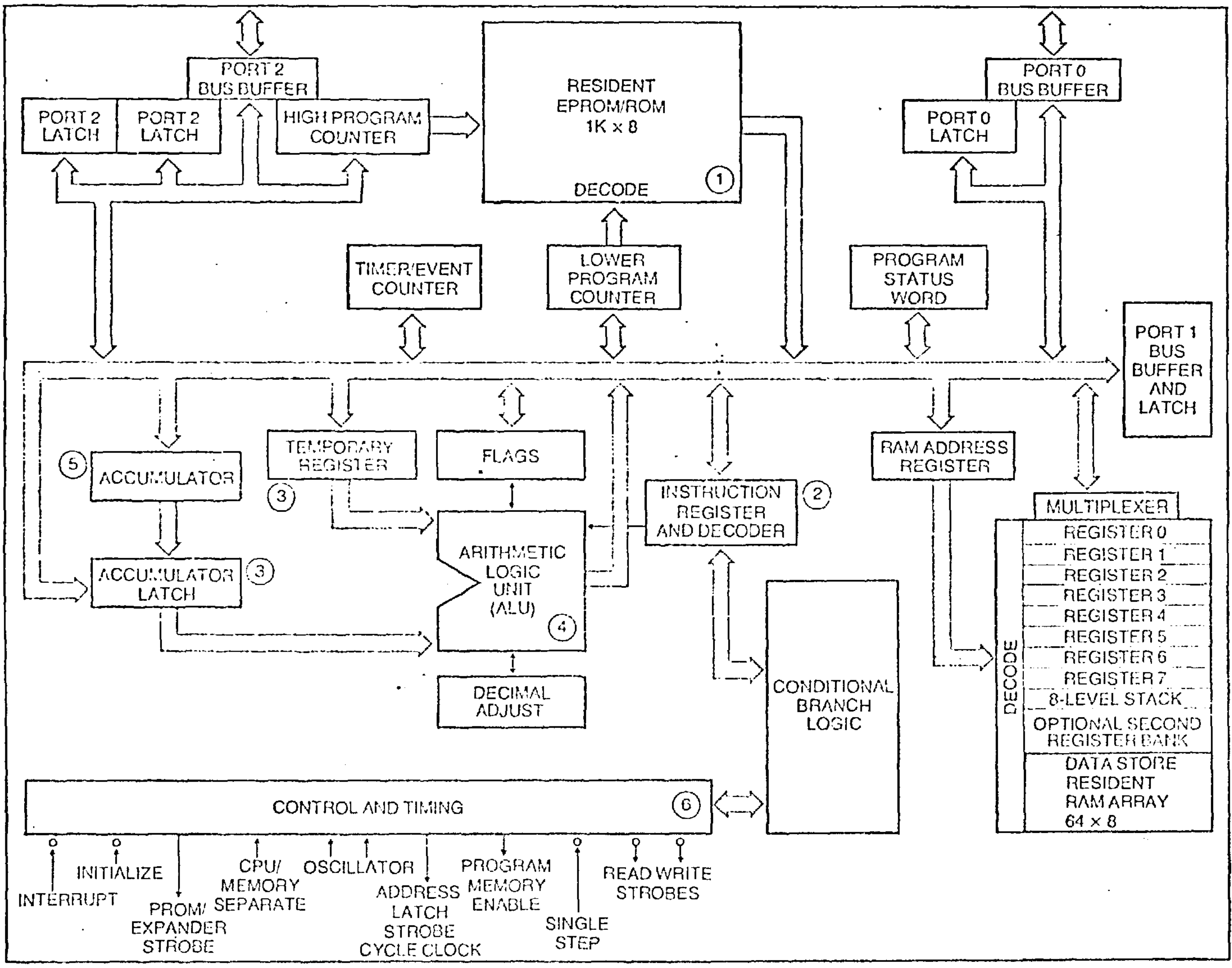


← coloured area.

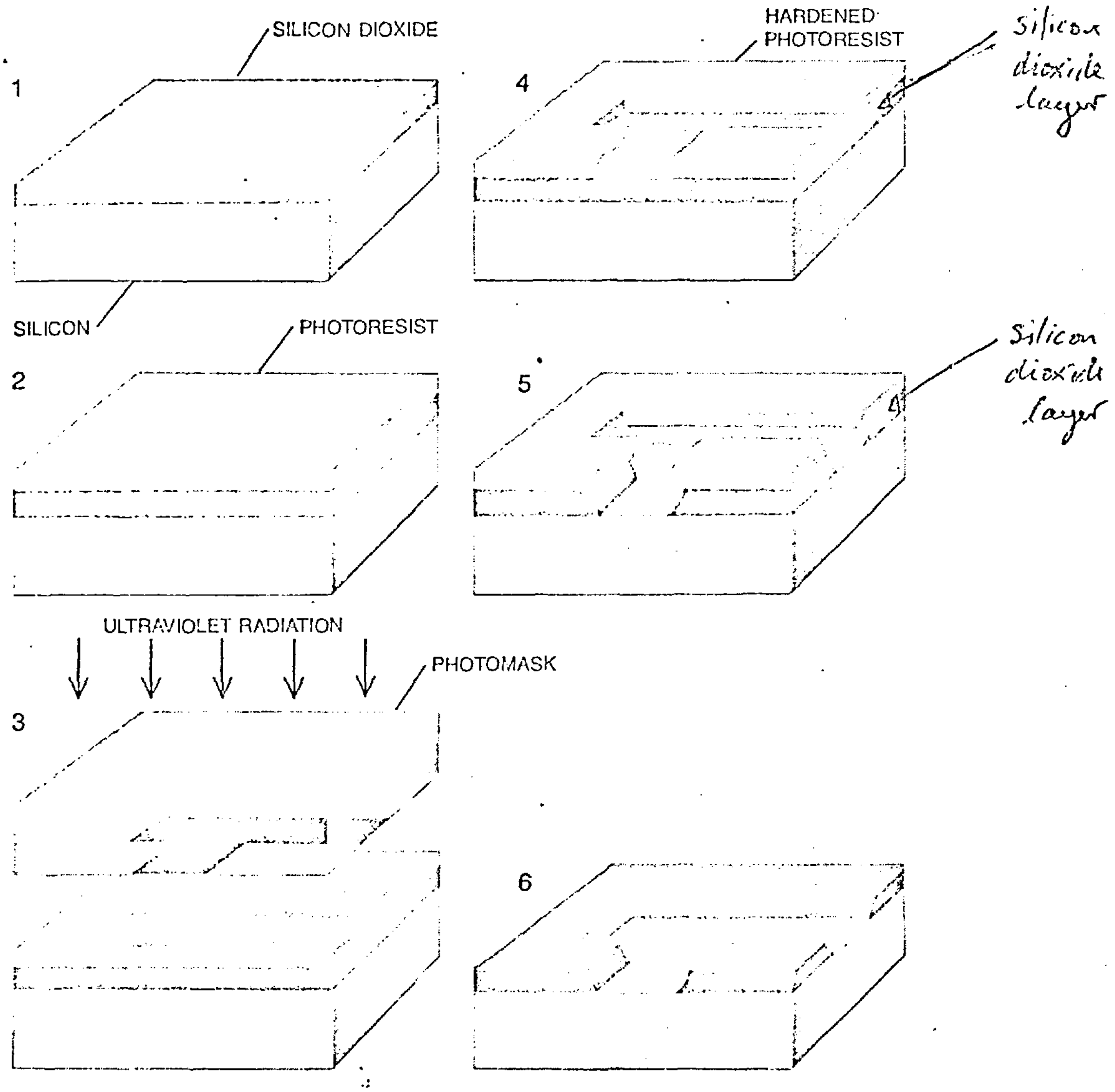
BASIC COMPONENTS OF COMPUTER SYSTEM can now be compressed onto a single chip, as in the Intel 8748. In this block diagram "control" includes control logic and instructions for decoding and executing the program stored in "memory." "Registers" provide control with temporary storage in the form of random-access memories (RAM's) and their associated functions. "ALU" (for arithmetic and logic unit) carries out arithmetic and logic operations under supervision of control. "I/O ports" provide access to peripheral devices such as a keyboard, a cathode-ray-tube display terminal, "floppy disk" information storage and a line printer. The functions that are in black convert a microprocessor (*color*) into a complete microcomputer.



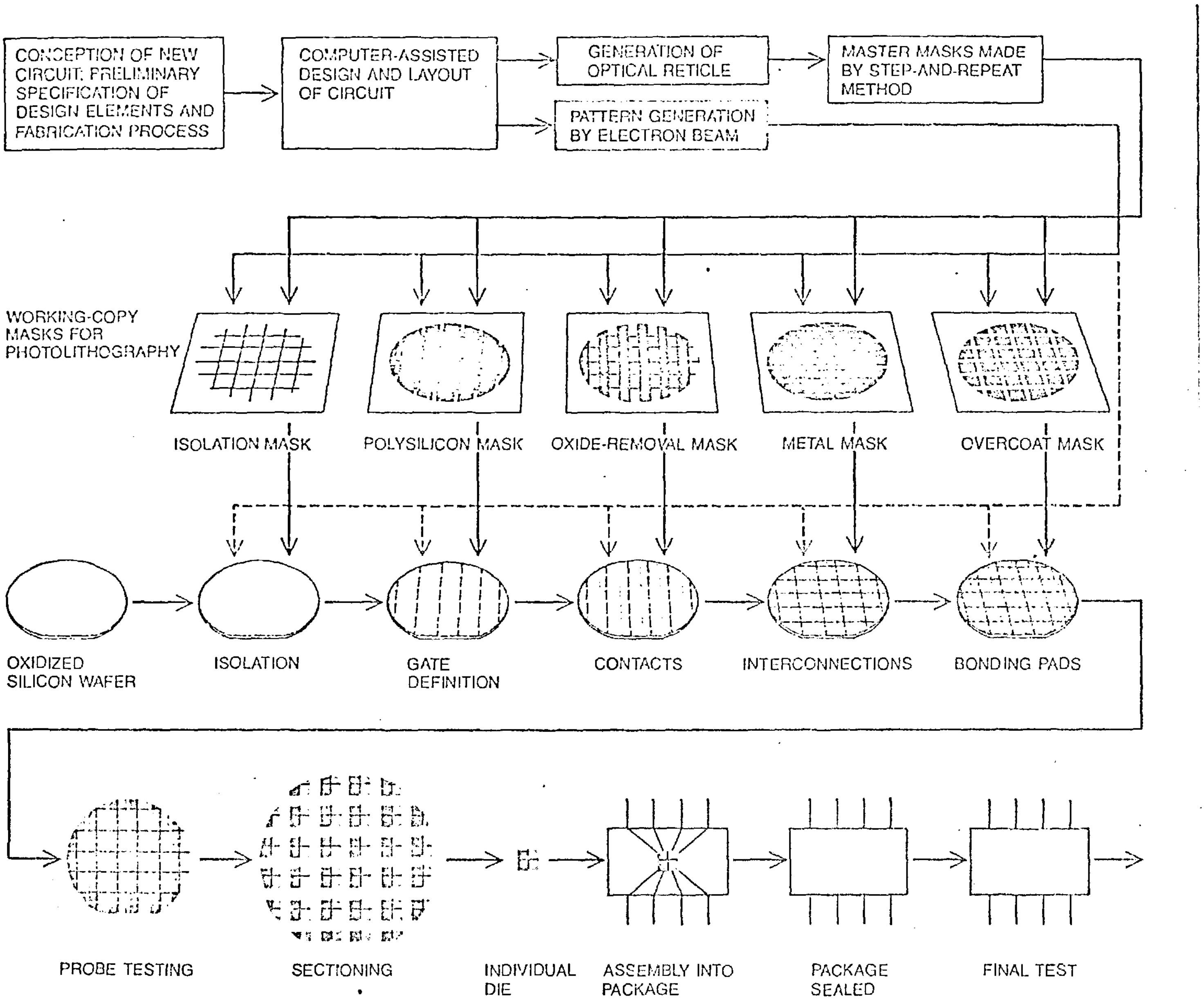
MAP OF 8748 MICROCOMPUTER identifies the location of the various computer functions. The color scheme used in the preceding illustration is repeated here. Each function can be assigned to one of the five basic functional blocks: control, memory, registers, ALU and I/O ports. The portions of the chip outlined in black represent the functions that transform the 8748 from a simple microprocessor into a microcomputer. Device holds some 20,000 transistors fabricated by *n*-channel silicon-gate metal-oxide-semiconductor (*n*-MOS) technology. Eight-bit central processor responds to 96 instructions in average time of 2.5 microseconds.



FUNCTIONAL BLOCK DIAGRAM of the 8748 microcomputer can be used to follow the sequence of steps involved in a simple operation, for example the addition of the contents of two registers, *A* and *R*, where *A* is the accumulator and *R* is any of the registers in the array at the lower right. The computer's first step (*1*) is to fetch the instruction from memory: "ADD A, R." The next step is to place the instruction in the instruction register and decoder (*2*), where the decoder finds that the instruction is to add *R* to *A* and to leave the result in *A*. In the next step the contents of register *R* are sent to the temporary register (*3*) and the contents of the accumulator to the accumulator latch (*3*). The ALU (*4*) then adds the contents of the two registers and the result is returned to the accumulator (5). Instruction ends and a signal is generated (*6*) to fetch next instruction. The 8748 microcomputer is capable of performing some 400,000 such additions per second.



PHOTOLITHOGRAPHY is the process by which a microscopic pattern is transferred from a photomask to a material layer in an actual circuit. In this illustration a pattern is shown being etched into a silicon dioxide layer (*color*) on the surface of a silicon wafer. The oxidized wafer (*1*) is first coated with a layer of a light-sensitive material called photoresist (*2*) and then exposed to ultraviolet light through the photomask (*3*). The exposure renders the photoresist insoluble in a developer solution; hence a pattern of the photoresist is left wherever the mask is opaque (*4*). The wafer is next immersed in a solution of hydrofluoric acid, which selectively attacks the silicon dioxide, leaving the photoresist pattern and the silicon substrate unaffected (*5*). In the final step the photoresist pattern is removed by means of another chemical treatment (*6*).



MANUFACTURE of a large-scale integrated circuit is outlined in this schematic diagram. The design of the circuit is often carried out with the aid of a computer, which helps to determine the most space-conserving layout of the circuit elements. The resulting layout is used to prepare a set of photomasks, each containing the pattern for a single layer. Usually this is done by first generating a tenfold enlargement of each layer, called a reticle, which is checked, corrected and regenerated until it is perfect. A photographically reduced image of the reticle is next reproduced hundreds of times in a "step and repeat" process to yield a set of final-size master masks, from which a large number of working plates are copied. (The electron-beam approach to pattern generation, represented here in color, is beginning to replace the optical method for producing the masks, thereby making it possible to eliminate two photographic steps and write the pattern directly on the working mask from the information stored in the computer memory; in time it is expected that electron-beam lithography will also be introduced directly into the fabrication of the circuits themselves.) The silicon "wafers" that serve as substrates for the circuits are obtained by sawing a long single crystal of silicon into thin slices, which are polished, cleaned and oxidized in preparation for the first patterning step. (A "flat" is ground along the length of the crystal so that each wafer will have a reference edge parallel to a natural crystal plane.) Following the five-mask fabrication process depicted in this greatly simplified example, the wafer is probe-tested to determine the good circuits, and the defective circuits are marked with an ink spot. Individual "dice" bearing good circuits are then selected from the sectioned wafer and assembled into packages. A final test is performed to ensure that the packaged circuit works properly.

ABSTRACT

We are concerned here with the likely impact of the 'micro-revolution' on the provision of computing facilities for teaching and research in Universities. We attempt to analyse quantitative and qualitative changes arising from the rapidly changing ratio between hardware processing costs and 'people' costs and we point out potential problem areas and possible solutions.

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1. INTRODUCTION

At present it seems that we are experiencing a remarkable amount of interest at national and government level in what appears at first sight to be a purely technical development. This concerns the realisation of the computation and storage components of a conventional computer system in such a form that they can for the first time be mass-produced in volumes and prices related to everyday use by the man in the street. Since such components have had a remarkable impact even when very highly priced and available in thousands, it seems reasonable to expect an even more significant effect when prices are low and production is in millions. The problem is that such developments have taken place so fast that there has been no time to consider or to plan for the new possibilities. Research and teaching in universities seem likely to provide areas for rapid development, and so we attempt here a preliminary analysis of ways in which the new microprocessors may affect these areas. First, we indicate without technical details what has become mass-producible, then we indicate how this may change the conventional pattern of University computing, particularly in relation to how responsibilities for the control of computing resources might change. The very considerable changes likely in the role of existing computer centres are specified and finally, we stress the need for all University members to consider the new situation urgently and plan for a sensible and orderly development.

2. THE IMPROVEMENT IN TECHNOLOGY

Let us consider the nature of this technical improvement which is claimed to have such a catastrophic qualitative impact on every human activity. To describe this we need to look at a conventional computing system in brief outline. It consists of five components. There is an input device which obtains data on which to work, an output device which puts out results, a central memory which stores all programs and data in the course of a computation, an arithmetic unit which carries out the necessary arithmetic and logical processes and finally, a control unit which co-ordinates and synchronizes the activities of all the other units under the control of the program. We may also add a sixth component which is the auxiliary storage, that is, the collection of magnetic disks and tapes which are necessary to store very large quantities of data needed in a typical larger computer system. The arithmetic control and centralised memory sections of the conventional computer are together usually referred to as the central processor unit or CPU. In the past this CPU has been assembled from discrete components, many thousands of logical circuits being assembled by hand to realise a particular design. It is now possible to put all of these circuits on a few chips of silicon and the price of making a CPU has decreased by a factor of 100 in the last few years. Notice that this decrease is <u>not</u> affecting the input or output units nor any mechanical arrangements such as the disk and tape mechanisms. Under the impact of mass production methods the price of the CPU is continuing to fall. But that price has already passed a critical point which causes the <u>qualitative</u> difference claimed and for the user of general computer systems any further reduction is not so significant. Note also that the way in which computing is done, that is, through the medium of instructions contained in a program has not altered at all. The actual electronic arrangement is also very little effected by the development of the <u>microprocessor</u> which has replaced the conventional CPU. Finally, the minute <u>size</u> of the microprocessor compared with the original CPU is hardly significant in this situation except so far as there has been a corresponding increase in the convenience with which a new microcomputing system can be brought into production. So how does this change in cost affect the situation so dramatically?

To investigate this further, let us consider the components of cost which go to make up the total cost of realising a particular application for a computer. In view of the latest development, we can look at four components of this cost. The first is that of the central processor unit and closely associated memory. The second is the electro-mechanical peripheral units for input and output, tape and disk drives. The third component covers the operating and maintenance costs of the total hardware contained in the first two sections. And, finally, we have the cost of making the hardware useful for a particular application through the provision and management of production, of software or programs. Since computers first appeared on the scene, the cost of the hardware relative to the total cost has been falling, but not dramatically. In recent years, the cost of each of these components described may be said to be roughly equal, except that the cost of the personal service component, that is, operation, maintenance and programming has been rising fairly rapidly, until it may be two or three times the cost of the central processor unit and peripherals combined during the life of a typical large computer system, say five to ten years. But now the situation has changed dramatically in computers which are employing microprocessors in the central processor unit. The cost of the central processor has fallen by a factor of 100 compared with the other three costs which are remaining comparatively stable or rising. Notice that this is not equivalent to saying that the cost of the hardware of a complete computer has suddenly dropped dramatically, since the central processor has very roughly occupied only one half of that cost. The overall impact is that from a certain price, say £30,000, the cost of a computer has dropped to £15,000. A significant amount of central processing can now be obtained for a few thousand pounds or less. This cost may continue to fall, but we see that the principal impact has already been made. Let us now consider the impact of this change on the method of computing.

3. THE IMPACT ON METHOD

We see from the previous section that the operation of the new type of hardware is essentially as before. It is rather slower and much cheaper. Soon, the performance may become the same as previously obtainable. But the decrease in cost opens up entirely new ways of arranging the computing process.

Until very recently we have centralised the central processor more and more. The very expensive storage and processing components have been divided in task to look after the relatively less expensive operations. The central processor realised in electronics is able to run much faster than the electro-mechanical peripherals. Therefore, the central processor has been made to carry out two very different functions with one lot of equipment. The first, conventional computation, is concerned with (mainly) arithmetic transformations on stored data. The second function is the control of data transmission to and from peripheral devices. The peripheral control function has in turn been time-shared between many distinct peripherals. For many years, the peripheral control functions have been moving away from the central processor and into the peripheral units themselves. But with the coming of the very cheap micro-processor this change can be rapidly accelerated and completed. Again, classically, the computation function has involved both the control of arithmetic function and the control of a program (looping and termination). From a storage point of view the so-called immediate access store has been used as a collecting place for a rag-bag of disconnected objects. The program statements have been jumbled together with temporarily stored data in various layouts and these two different types of material can obviously be separated with advantage.

In summary, the impact of micro electronics on computing method is profound but this impact is not immediate. The immediate situation is that the hardware realisation of the computation and associated storage aspects of a conventional computer are now available at roughly one hundredth of the cost of a few years ago. This moves the cost of such equipment form the budget range typical of a centralised computer service into the range applicable to a departmental laboratory. This implies that at least certain aspects of computing power can be made available locally in a department. We can have dispersed computing. This local power could be owned by a department, and this is the principal change in the situation which we need to discuss. An entirely new range of problems arises for those who control and own these dispersed computing facilities, and the design decisions of the former centralised organisation may not be relevant. From the point of view of a College, a new decision arises as to who should control this dispersed computer power in an overall manner, and to what extent the different computing facilities should be or need be dispersed. It seems likely that several types of computing service will continue to be available most economically in a centralised service such as the construction and maintenance of large databanks. Other types of computing such as that related to the processing of data from a single laboratory experiment can clearly be much more effectively carried out at the site of the experiment. These new decisions will be spelled out more precisely in the next chapter. In the following section we attempt to clarify a confusion which clearly exists in government circles.

It appears that the government is making available a considerable amount of money to train a new breed of "microprocessor engineer". The suggestion is that a new type of specialist is required to cope with the "microprocessor revolution". Professionals of this type are expected to be available in their thousands to re-design all existing industrial equipment in order to incorporate microprocessors.

We would understand from the newspaper reports that these new professionals will be adept at microelectronics and circuit design and will also 'know' about computing. In the courses planned for them so far, there seems to be a stress on electronics appreciation and machine code programming. Such topics are no doubt useful, but those who have worked on the design and construction of previous generations of computers will know that these 'low-level' considerations are secondary to genuine system design. This is much more concerned with the handling of a complex hierarchy of processes to satisfy a very incompletely specified series of constraints imposed by the application, by the nature of the potential users, by existing and projected cost structures and only to a relatively small extent by hardware details. Those who have worked in this area in the past have come from a wide variety of backgrounds but have shared a common characteristic: the ability to abstract from any particular hardware situation and to synthesise a system based on those abstractions. This involves qualities typical both of mathematicians and of engineers, not commonly possessed by single individuals. Certainly, an initial electronics background has not been particularly significant. While every initiative aimed at providing better training facilities for engineers is to be strongly supported, it is firmly believed that the quality design of fully co-ordinated hardware and software systems is likely to remain the province of a comparatively small elite.

Certainly, these people are at present found mainly in large computer manufacturers organisations and to a limited extent in University and Government computing centres. There are simply not enough of them to enable every university department to have at least one, even if their financial value were appreciated. In the light of this, let us consider the impact of micro computing developments on the departmental user.

4. THE IMPACT ON THE USER

The new decisions facing a project leader in a department can be summarised as follows:

1) What to do?

Much more information can be processed for the same amount of money. This makes possible an entirely new range of computing applications. For example, the administration of education can be considerably assisted, exchanging comparatively cheap computing equipment for the much more expensive time of the teaching supervisor. On the research side much more of the data gathering of quite small experiments can usefully be automated.

2) How to do?

The computing can be carried out by means of special purpose processors dedicated to a particular task, or a series of tasks can be carried out on a more general-purpose micro computing system. This special/general decision raises subtle problems. Again, a single department must consider the question of whether to disperse its own computing facilities between different laboratories or to centralise them, possibly in a more suitable situation for operation and maintenance.

3) 'Who' to do?

Decisions must be made concerning:- the organisation of the hardware - whether to buy or build it oneself; the software - again whether to buy in from a contractor or to construct it oneself; and finally the maintenance of both hardware and software - whether to buy it through a maintenance contract or take responsibility oneself. Decisions have to be made concerning whether to employ specialist hardware/software persons in house, whether to employ generalists who can do this work in connection with more general research support, or whether to employ contract specialists for all the various requirements. If contracts are considered, then outside firms can be employed or possibly, in future, the computer centre might offer contract specialists. Finally, the consideration of which way to go may well require the assistance of external consultants experienced in systems analysis and design to assist the project head. Most of the decisions described have in the past been made by members of the computer centre on behalf of their users and naturally a great deal of expertise has been employed which was never visible to most members of the user departments. The new degree of control exercised in computing matters by departments must be paid for in this extra decision-making.

Problems to be faced by departmental computing planners include the following:- Lack of control over computing projects through a lack of understanding of the decisions requiring to be made; Difficulties in the provision of a continous operating support for departmental users; Difficulties in the buying in of hardware and supplies required for maintenance. At a more fundamental level, we are likely to see even more the learning from scratch of fundamental computing principles by young technologists in every department. While it is to be hoped that the computer centres will maintain and expand their teaching services to assist these young designers, it is likely that the normal conflict between immediate departmental duties and more generalised educational requirements will result in disappointing attendances, as at present.

In summary, the difficulties of the users in the production of software familiar to computer centres will be extended to the design of hardware. In the next chapter we will consider the position of computer centres in the situation of mainly dispersed computing facilities.

5. THE POSITION OF THE COMPUTER CENTRE

For the past twenty five years, computer centres have been dedicated mainly to the provision of a computing service. The principal objectives have been to look after and maintain a large hardware installation and to maintain an ever increasing range of software support. It is likely that a range of hardware facilities will continue to exist at the computer 'centre'. And it is certain that the computer centre will continue to act as a gateway to more generalised computing networks. However, it seems likely that more and more of the conventional computational work will be dispersed to computers in the various departments. In view of what has been already said, it should be clear that there is greater need for experience in computing techniques than ever before by the members of every department, and that the members of the computer centre are likely to be best placed to satisfy this need. The computer centres are therefore likely to become much more consultation-oriented and in addition, it is likely that they will establish contract services for the provision of hardware and software to the departments. There will be clearly difficulties in setting up suitable accounting procedures to enable this type of work to proceed. Associated with the consultancy will be a dramatic increase in the amount and the range of training services to enable each department to pursue its own computing interests. A computing centre also provides the obvious focus for more general studies in computing techniques which will result in the definition of suitable hardware and software complexes for general use. It is clear that computer centres will be deeply concerned in the development of suitable standards in hardware and software and their active promotion in departments. It is to be hoped that the activities of computer centres in the future will bring their expertise on big systems to bear on the new problems of small systems, to the advantage of all users.

6. A DIRECTION FOR DEVELOPMENT

In this era of rapid change, it is essential that college authorities recognise the problems of the transition between centralised computing services and a more dispersed arrangement. At a college level, decisions must be made concerning those services which could remain centralised and those which are best dispersed,and the computing centre will require their terms of reference to be re-established with an increasing stress on training, consultancy and contract services to all departments. The training services must be extended to include hardware, as well as software and it is likely that large centralised laboratory services will be required to provide resource centres for those departments which cannot provide for themselves in this way. Above all, there must be course and materials provided to explain the 'total systems approach' which will be absolutely essential to those members of departments who are planning to develop hardware/software systems for teaching or research.
It is suggested that the computer centres themselves must take the initiative in defining what is new and different and in initiating a dialogue between all the parties concerned.

APPENDIX 3: MUSE GUIDELINES

Guidelines for Microcomputer Systems in Schools and Colleges

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by Roy Atherton, Bulmershe College of Higher Education, Reading

At its fifth annual week-end conference (July 1977) MUSE spent the whole two days talking about microprocessors. The talks took place in Berkshire amid the old lawns and old buildings of Wellington College. The impression of oak panelling and canned beer from the Master's fridge merged with visions of what might happen to a microcomputer in an inner city comprehensive school as members grappled unceasingly with attempts to define guidelines for teachers wishing to purchase microcomputer systems.

Some amendments to MUSE's constitution were quickly incorporated to make it clear that MUSE is interested in micro as well as mini computers. Their main philosophy is that the machines should be small and in schools, rather than large and in county centres.

The main result of the week-end's efforts are contained in the policy statement given below. The words in italic represent the agreed statement by MUSE and the additional comments are the author's. It should also be added that the starting point for MUSE's deliberations was a set of principles evolved by the Berkshire Working Party on Microprocessors and, though details and wording have changed, the essential principles have remained. The statement is therefore a product of the combined experiences of about thirty or forty teachers, college lecturers and others with, between them, experience of about ten microsystems ranging from basic 4K machines to highly developed systems.

Perhaps it should also be mentioned that the principles have emerged as a result of experiences which could only be gained largely on the basis of cheap do-it-yourself systems. It may seem that MUSE is saying, "Do what we say but not what we do". The principle of the closed box is nevertheless a very important one. It could not be followed in the past but most educational establishments could follow it in the future as the price of ready made systems comes down. At the time of writing one can buy a 16K system with power supply, keyboard and interfaces for TV output and cassette backing store for less than £1,000.

Policy Statement on Microcomputers in Schools

MUSE (Minicomputer Users in Secondary Education) consider that any school or college planning to buy a microcomputer system should take into account the guiding principles set out below so that the systems will be capable of expansion to satisfy the needs(1) of teachers and students.

1. *The Closed Box Principle*

   The various plug-in hardware modules of the system should be made commercially and regarded as closed boxes which teachers would not modify themselves.

   Although kits are available which are advertised as easily constructed, unless the teacher has expertise and experience in electronics and computing, he should be wary of undertaking the construction of a microcomputer from a kit.

   If a system were not commercially produced then, for expansion and maintenance, it would be necessary to have an expert permanently on the staff.

It is a curious but observable fact that amongst all the microsystems so far acquired by MUSE members and acquaintances it is not easy to find two identical systems though most are based on the M6800 CPU. Because of the non-standard nature of most systems maintenance is not easily guaranteed. While the comment which likened the developments so far to a crop of weeds was a little unkind, it would be wise to cease the undisciplined pioneering for a while and attempt to establish standards to apply to new purchases. If such standards were accepted by users in a county or several counties the benefits would be enormous. But even minor modifications which seem sensible, even ingenious, at the time can cause endless difficulties to inheritors of a system after the modifier has moved on. Thus the Closed Box principle means that the hardware should be commercially produced to a standard and should be altered or expanded only along certain agreed lines. It does not mean that the system should never be examined internally and it certainly does not mean that no attempt should be made to understand how it works.

2. *The Minimal System*

   A minimal system should be available at low cost including at least a keyboard, 16K bytes of memory, interfaces for a T.V. screen and a domestic cassette tape recorder and software which includes Basic, a low-level language, assembler and editor.

Those involved had some difficulty in deciding what a minimal system should be and the above statement recognises that a lot of useful work can be done with only a TV set and cassette for output. It is desirable for hard copy to be produced at some stage, and if examination courses are involved it is essential. However, there are circumstances in which the minimal system might reasonably be purchased. Among these are:

(1) As a cheap start on computing so that experience may be gained with the intention to add a printing device as soon as possible.

(2) To attach to an existing teletype.

(3) To use as a supplement to other computing facilities, e.g. a batch system which provides hard copy. Programs could be tested, perhaps in modular fashion, using TV and cassettes and eventually transferred to coding sheets or mark sense cards for batch processing.

3. *Expansion*

   Standard modules should be available to expand the system in reasonable price increments. The modules available should include hard copy facilities, additional memory, floppy disks, mark sense card readers and multi-user capabilities.

   When buying a system, both ease of expansion and maximum expansion capabilities should be checked with the supplier. New versions of the supplier's software should be available at little or no extra cost.

The ideal school system should allow file handling and data processing and, generally speaking, the most desirable developments in hardware terms would be a printer and file structured backing store (discs or equivalent). Dot matrix printers are excellent but there seems to be a gap in the market between the 40 column printers at about £300 and the 80 column versions at nearer to £1,000. A mini floppy disc drive can be incorporated for about £700 and each disc will hold at least 100K characters. Timesharing may be a desirable development but consideration should be given to two other schemes:

(1) Extra stand-alone computers;

(2) A mark-sense card reader to provide a fast *local* batch processing service for up to a dozen schools in an area.

With the exception of the mark-sense card reader it is encouraging to note that the possible developments of a system including the initial purchase can be achieved over a period of years at costs in the range £500 to £1,000 for each development. On this basis many schools will be able to manage the funding.

4. *Safety and Security*

The modules should be robust, portable and safe.(2) *Accidental damage or unauthorised moving should be preventable by a simple lockable device which enables the equipment to be securely attached to a piece of school furniture.*

It is to the credit of MUSE members that, surrounded by tall trees and acres of grassland and well fuelled by the college catering service, they focussed down on the practicalities of computing in the classrooms of rather less smoothly running secondary education establishments and recognised the above very important principle. One suggestion was a bolt through a hole or bracket on the computer, through a hole in a table and padlocked underneath. Electrical safety is of course essential.

5. *Maintenance*

Simple and inexpensive maintenance procedures should be arranged at the time of purchase. When it is not possible to identify and replace a defective component using local expertise, a circuit-board or module should be returnable to the supplier or an independent maintenance contractor. The equipment should go to the repairer rather than the repairer coming to the equipment.

New concepts in reliability are seen to be possible. A standard 16K or larger computer, with interfaces and controls for TV set, keyboard and cassette recorder on only two circuit boards, makes maintenance simple. If standards are observed and external plugs and sockets are minimised we should be able to achieve very high standards at very low costs.

6. *Standardisation*

If a number of schools in an area are purchasing microcomputers the benefits of careful standardisation are considerable. This is strongly recommended as the development of teaching materials, the development of the system and maintenance can call on the combined resources of the schools rather than those in an individual one.

The final principle is the cement which binds the others together. Without it we store up trouble because, even if failures are infrequent, they are disastrous when they happen if courses and examinations are machine dependent. The pressures against standardisation are strong but if we can achieve it substantially the benefits are enormous. It is again to the great credit of MUSE, a collection of individualists if ever there was one, that they recognised the essential nature of this principle.

That sunny week-end in East Berkshire, when excitement about micros was as high as the pollen count, may well prove a turning point not only for MUSE as an organisation but for the development of computer education in Great Britain.

Footnotes

(1) This very difficult area was discussed at the Bulmershe Conference (March, 1977). See the paper: "Towards Criteria for the Viability of School Based Computer Systems in England".

(2) The safety standards recommended by the ILEA Advisory Unit on safety of school equipment should be adopted.