UNIVERSITY OF
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Computing at the University of Edinburgh 1980-1985

Dr G.E. Thomas
P.E. Williams
Dr A. McKendrick
C.H. Nicholas

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SUMMARY

This paper is the mid-term review for the Computing Service at the University of Edinburgh. In it we identify the developments that have taken place since the provision in 1980 of the last major enhancement of the mainframe facilities designed to meet the needs of the University and the local community of Research Council Institutes. Apart from occasional references the paper does not discuss developments in the regional service provided by the University.

The Computing Committee of the University has recently surveyed the needs of its users within the following categories of computing or related activity:- communications, software provision, distributed facilities and central mainframes/file servers. It is the University's preference that the Board apply any financial support that it can provide at this time to the enhancement of the local mainframe service.

The intentions of the University to continue its investment in the other categories of service are described in sections 6.1, 6.3, 6.4, 6.5, 6.6 and 6.7.

The uses that have been made of the local mainframe/file server services are described in sections 2.1 and 2.2 and the requirement for the development of these services is described in section 6.2.

A proposal that would satisfy these requirements is presented to the Board for their consideration in section 7.

The report has been prepared by members of the Edinburgh Regional Computing Centre and is submitted after approval by the Convenor of the Edinburgh Computing Committee for the consideration of the Computer Board at their meeting on 22nd May 1984.

G E Thomas
May 1984

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1. History of the Computing Service

ERCC was set up in 1966 as one of three regional centres recommended by the Flowers report, to serve the University of Edinburgh and a variety of publicly funded research institutes in and around Edinburgh. The University's computing requirements had previously been serviced at Manchester, using a paper tape based link run by the Computing Unit. The Edinburgh Regional Computing Centre was charged with special responsibilty for the provision of large scale multi-access services. This led to the setting up of a joint project between the University and English Electric Marconi (later ICL), under the auspices of the Department of Trade and Industry, to produce a suitable multi-access system for the System 4-75. The project generated a lot of useful design principles but failed to produce a usable system by the time it ended in 1970. Staff of the Computer Science department and later the Regional Computing Centre were however encouraged to pursue the project's objectives and succeeded in producing a system (EMAS) which went into service in the autumn of 1971. That service supported 20 simultaneously active users and marked the start of interactive services in Edinburgh.

The service evolved, by refinement of the software and by the installation of more main memory and backing store, until saturation occurred at about 40 users. A second 4-75 was approved by the Computer Board and installed in 1974. The submission to the Board also included a proposal to move to an intelligent front end processor, replacing the hardwired ICL communications controller. This enabled direct connection of terminals to be replaced by mainframe-independent network connection via terminal concentrators, an initiative which has developed into the present very extensive network.

The second 4-75 enabled the service to expand to support about 74 simultaneous users. The EMAS service also supported a substantial batch load but neither the original single 4-75 nor the twin 4-75 were able to meet the whole of the University's computing demand. The shortfall was serviced by a series of rented IBM machines which succeeded the KDF9 installed in 1967 to provide a stop-gap until the 4-75s could be delivered. These machines gradually took on a wider role, providing services to the Universities of Glasgow and Strathclyde.

In 1973 this led to the proposal to install one of the first of ICL's "New Range" machines, a 2980, to provide interactive and batch services to the three universities. This machine should have been delivered in 1975 but was diverted to the European Space Agency and yet another stop-gap, a 2970, was installed instead. This was the first 2970 to be supplied to a customer site and it confirmed the attractiveness of the architecture. The state of the operating system at that time was another matter and the machine was unable to provide any significant public service in the interval between its delivery and the delayed arrival of the 2980 in 1976. It did, however, enable work to progress on the production of a FORTRAN compiler to IBM standards, a necessary provision if users were to be able to move easily from both the IBM machine and the 4-75s, which also used a similar compiler. The FORTRAN compiler, and one for ALGOL 60, were marketed by ICL and the development led ultimately to the present collaboration, whereby ERCC supplies ICL with FORTRAN 77 compilers for the 2900 range and several other machines.

Meanwhile, in 1975, the rental of the local IBM machine (by that time a 370/158) was terminated. This was originally proposed in the expectation that the 2980 would be able to take over that load. The delay in delivery of the 2980 resulted in the service being transferred to the new IBM 370/168 at Newcastle University as yet another stop-gap measure. When the 2980

eventually arrived it was a considerable disappointment. Hardware reliability was extremely poor and the operating system was very lacking in facilities. The crucial deficiency lay in the support of communications, and although increasing amounts of batch work were transferred to the machine it was unable to provide the interactive services required.

The failure to provide interactive services threw a heavier burden on the twin 4-75 and faced the University with the problem of how local interactive demand could be satisfied. The original EMAS project had been begun in the expectation that a successor to the 4-75 (the 4-85) would be produced and that continuity of service could be maintained as demand increased. When that line of development was abandoned the 2900 range was the only option politically open to the University. It was, however, architecturally an attractive one and the failure of the 2980 service under VME/B to come anywhere near the original projections was very disappointing. It seemed reasonable to expect that ICL would succeed in substantially improving the reliability of 2900 hardware; what was much less certain was whether VME/B would ever, at least on the 2980, support the scale of interactive service required.

It was against this background in 1976 that a few people in ERCC and the Department of Computer Science began to consider attempting to move EMAS on to 2900 hardware, and in the process to redesign the basic supervisor to apply lessons learnt on the 4-75s. When the 2980 failed to meet the final deadline in 1977 for completion of its benchmark trials the 2970 was transferred from its regional service role to an exclusively Edinburgh one to meet the shortfall in local services (Glasgow and Strathclyde were separately compensated). This gave added impetus to the EMAS on 2900 project and a pilot service began in April 1978, followed by a full service in the autumn.

In 1979 a case was put to the Board for replacement of the 4-75s by a dual 2972, thus building on the service started on the 2970 and maintaining, albeit with considerable enhancements, a user interface introduced in 1971. This case was accepted and the dual 2972, absorbing most of the 2970 installation, was installed in 1980 and went into immediate service replacing the 4-75s. The machine has been enhanced in various ways since, in part with the assistance of the Board's Minor Facilities Grant, and is now a dual 2976 with two DAPs. The first DAP, with its associated 2 Mbytes of memory, was installed in 1982 and was partly funded by the SERC and partly by the University. The second came late in 1983 and was a gift from ICL, though the cost of maintenance is a charge on the University. The DAPs have had a dramatic effect on the progress of some types of research in the University and it is a matter of concern that there is no obvious way in which this development can be sustained beyond the next two or three years. The DAP service is, however, ancillary to the main 2976 service and its replacement does not form part of this submission.

The successful service on the 2970 was in marked contrast to the struggle that was still going on in 1979 with VME/B on the 2980. Much had improved since the machine failed its final benchmark in 1977 but the efficiency of the multi-access facilities, and the ease with which they could be made available via the network, left a lot to be desired.

In the latter part of 1979, with the agreement of Glasgow and Strathclyde, the use of VME/B was abandoned and EMAS introduced. The effect was very marked, and by 1980 the 2980 was fully loaded, though the interactive load was limited to a maximum of 80 simultaneously active users to ensure that a reasonable part of the machine's power was still available for batch work. The introduction of EMAS also solved the communications problems and the only difficulty remaining was the poor reliability of the central

processor. This was relieved in 1982 by the replacement, without extra cost, of most of the installation by a 2988, which has performed very satisfactorily.

A major objective during the past 15 years has been to try to maintain an expanding and developing service without involving the user community in large amounts of work when a new machine is introduced. This has been easy with the EMAS service; with the IBM machines in 1969-75 great care was taken to avoid users' becoming dependent upon facilities available only on IBM systems. A similar policy was followed with VME/B on the 2980, though in that instance the concern (at least initially) was to try to avoid users' getting too deeply involved in system facilities for the advisory service to cope.

The same considerations were applied in the Centre's approach to the support of microcomputing in the University. One of the first concerns of the Centre's Microcomputer Support Unit, set up in 1980, was to define a software strategy that would meet the needs of most users and survive changes of hardware. As part of this strategy software was provided to enable microcomputers to connect to the network for the transfer of files. This approach, coupled with assistance to users in ordering and setting up equipment and by negotiation of favourable purchase and maintenance arrangements, has been successful in avoiding an unnecessary proliferation of different types of microcomputer and operating system around the University. The present policy is currently being reviewed to ensure it will meet the University's needs over the next five years.

The central mainframe service has satisfied the bulk of demand for computing from the Centre, though there has of course been substantial growth in local computing provisions within departments. In recent years at least the University's own capital expenditure on computing has matched that received from outside sources. An important aspect of departmental computing has been (as in other universities) the use of UNIX, and although the Centre does not provide a UNIX service it has for the past two years provided system support in a number of ways, partly because this is useful for the departments concerned and reduces the duplication of effort that would otherwise occur, but also because of a recognition of the importance UNIX will have in the development of personal computing. This support has been well received and has recently been expanded.

The use of EMAS has brought many benefits but has posed a problem for users who wish to import packages. A number of the most popular packages have been transferred to EMAS by the Program Library Unit (now the Centre for Applications Software and Technology), but experience has shown that this is rarely as easy as the package suppliers suggest, and often involves a great deal of work. In any case it is not possible to do it on a large scale, nor to transfer packages which rely heavily on a particular operating system. There is no single solution to this problem; the Centre's approach has been to recognise that package use, though important and growing in volume, is still only a fraction of the total demand for computing and should not be satisfied at the expense of general purpose services. To this end a VAX 11/750 was installed in 1983 to provide a service for packages which could run under VMS. This was funded by the University, so far to the extent of almost £120,000 including software costs. The service will need major expansion in the next few years and the cost of this is expected to be borne from University funds.

In the 18 years since the setting up of the Centre the computing scene has expanded to an extent that could hardly have been imagined in 1966. The Centre's own services have grown and diversified but the core of them is still the central interactive service, accessible through a network that extends into all parts of the University.

There has of course, in Edinburgh as in other Universities, been intensive questioning of the role of a central service as the cost of acquiring local hardware, for departmental or personal use, continues to fall. There has in fact been a good deal of local provision, some of it seeded by funds normally used for the expansion of central services. The prospect of an injection of funds as a result of the Board's mid term review occasioned renewed debate on the use to which such funds should be put. The virtue of a machine on one's desk was well recognised, but a clear consensus emerged that the time had not yet arrived when such a machine could economically provide the quality of service currently provided by the central EMAS service. There is therefore agreement that any funds available should be used to expand that service, not merely in terms of numbers supported but also in such a way as to increase the raw power available to heavy cpu users, whose work forms an important part of the load.

The recommendation is readily understandable. Unfortunately it places the University once again in a position where, through no fault of its own (and, indeed, despite efforts to avoid it), it is forced to make another change in hardware direction: the present machine cannot be enhanced, only supplemented by another separate machine, and no suitable upgrade path exists. The new 2900 "L" series represents a significant departure from the architecture of the earlier "P" and "S" series. The progression from the 4-75 was abandoned by the manufacturer and the 2900 series was selected as a progressive new direction. That progression has now changed direction. It is in that situation that the present proposal is put forward.

2. DEVELOPMENT OF COMPUTER USAGE

2.1 General Trends

The most obvious trend in computer usage seen in Edinburgh is similar to that in all British Universities at this time, that is a continual growth in demand (and provision) right across the computing spectrum; from simple commercial word processors and stand-alone personal micro workstations, through departmental "multi-user minis" to large central mainframes, most of these facilities being connected to or accessed by an ever expanding network of terminals.

Table 2.1.1 gives a measure of the growth in use of the central EMAS service now based on an upgraded dual 2976 configuration. All classes of usage continue to increase but it can be seen that there is little scope now for any further increase in interactive service which is near saturation point. Users are ever increasingly having to work in the evening and weekend to progress their research projects or even complete their undergraduate projects; over 100 users have been recorded after 9pm on more than one occasion, and in excess of 50 simultaneous users have been logged on at the weekend. One of the major growth areas not shown in the table has been in users' requirements for file space which always seems to exceed our rather slowly increasing provision. The long term storage of important user files in the magnetic tape-based joint EMAS archive store is also posing a problem because of its size: it has now grown to over a quarter of a million files amounting to nearly 25 gigabytes of data and held on about 2500 duplicated magnetic tapes. A more secure, more manageable medium must be adopted in the near future.

Perhaps the most important trend functionally in the past three years, however, has been the growth in importance of national and international connectivity and the evolution of the roles which the central mainframe and local communications network have played in interconnecting a much wider range of computing users in the University itself. The two most important aspects of this trend have been the emergence of an effective electronic mail service and the transformation in ease with which users' data can be moved between computing hosts. EMAS has offered an electronic mail service to its community of several thousand users since 1981 using locally implemented protocols, In a similar way file transfer was achieved by mutually agreed mechanisms which were very effective in local contexts. However, by the end of 1981 Mail and File Transfer standard protocols had emerged and become well defined under the auspices of the Joint Network Team (JNT) and Edinburgh committed itself to the adoption of such standards as part of the UK's Open System Interconnection (OSI) plans. The development and implementation of the File Transfer (NIFTP Blue Book) and Mail (JNTMAIL Grey Book) protocols was seen as the logical means of extending such services to give access to the national (and international) academic community.

The NIFTP and JNTMAIL protocol developments were completed and offered as a service on EMAS in the first few months of 1983, the changeover being transparent to the user. EMAS users are able to communicate with users on a wide variety of hosts attached to JANET, PSS and ARPANET, giving access to over 70 systems within the UK and in the USA. The growing connectivity of the UK academic community has given a greater flexibility to users whose local system, like EMAS, provides the tools to make use of it. Table 2.1.2 shows the volume and growth of mail and file transfer traffic with EMAS over the review period, the current volume of traffic being one of the highest nationally.

Table 2.1.1 **The growth in use of the central EMAS service**

	Academic year 1980/81	1981/82	1982/83	1983/84
Total registered usercodes (2976 & 2988) (Ed Univ & Research Councils)	4860	4600	5070	5300
Total registered users of central 2976 service	2292	2781	3180	3450
Total registered undergraduate users of the 2976 service	912	1212	1565	1726
Average number of interactive sessions per term-time month	21700	45000	51400	52600
Average number of background jobs per month	1040	2388	4730	7265
Notional income based on standard charging formula	£994904	£1663271*	£1622469	£1800000+

*This figure is higher than might have been expected and is due to the 2972 service providing an overlap service for the region while the 2988 was being phased in in place of the 2980 system

+This is an extrapolated figure based on the first six months notional income for this year.

Table 2.1.2 **Growth of Electronic Mail and File Transfer activity**

	Nov 81	Nov 82	Feb/Mar 83	Nov 83	Feb/Mar 84
Daily number of new mail messages received	75	281	313	477	506
Daily accesses to Mailer services	90	479	498	670	564
Weekly total of files transferred using FTP	-	-	236	594	2416
Weekly total of FTP traffic (in Kilobytes)	-	-	5950	52427	223076
Weekly total of Network Mail messages by FTP	-	-	181	443	1238

The EMAS Mailer Executive itself is structured according to the recommendations of the CCITT X.400 Standards. In practice this means that a clear division exists between the mail message transfer agent and the reliable file transfer service. This has already allowed the change from RJE file transfer to NIFTP file transfer referred to above to be made in a straightforward manner. Any future change to newer OSI protocols is again expected to be made without disruption to service. The user interface to mail facilities is also JNT approved; the EMAS design was adopted by JNT for use on its own machines and recommended as an appropriate model for implementation on other systems.

Use of the Mail service in Edinburgh has grown considerably since its introduction. It is now beginning to be used locally to communicate between administrative staff groups - Faculty Offices, University Secretary's Staff Offices etc - as well as between individual users. In addition, the management of the central computing service itself has been improved. In handling users' suggestions and in areas such as User Support, Accounting and the Advisory Service, Mail is increasingly replacing the telephone or letter as the main method of communicating with users.

The effectiveness of these higher level protocols depends on the success of the communications network and lower level protocols on which they are carried. The trend here has also been gradually to replace locally developed protocols with international standard protocols. The most recent major change was the transfer of our wide area/medium speed network to the X25 standard. We are also investigating the slightly more critical changeover from our own well developed interactive protocols to the standards collectively known as "Triple-X". The current state of the Edinburgh wide area network is shown diagrammatically in Figure 4.1 and Table 2.1.3 gives a measure of the growth in network traffic and facilities.

Table 2.1.3 **Growth in Network Traffic and Facilities**

	Academic Year 1980/81	1981/82	1982/83	1983/84
Host computers connected to Network	3	5	9	26
Synchronous Network Connections	48	55	60	66
Asynchronous Network connections (terminals)	400	500	832	1253
Network Line Printers	37	46	54	60
Network Graph Plotters	5	7	13	18
Peak Traffic rate (packets/sec)	100	Not Available	150	280

It can be seen that the major expansion has been in the number of connected terminals, which now exceeds 1250. Although not so impressive in magnitude perhaps, the number of network line printers and graph plotters nevertheless gives a good impression of the scale of the network. A more recently emerging trend is the growth in demand for document quality output devices. We are currently deploying letter quality multiple-font dot matrix printers but are also investigating low cost laser printers.

A trend which is hidden in the terminal figures is the move away from hard copy consoles (around 75% in 1980/81) to visual display units (nearly 80% in 1984). Associated with this change has been the development of user facilities more suited to VDUs. The main centrally supported facility, VIEW, takes an ordinary text file and displays it in frames of 20 lines on the terminal. By including various directives in the file, the text can be divided into sections and sub-sections similar to a technical report format. Sections have numbers, names and keywords associated with them and a section can be located and displayed by specifying any one of these. View is currently used

- for browsing through documents (including computer programs)
- as a simple document preparation aid
- as the basis of the EMAS "HELP" documentation
- to support the Edinburgh University Library Accessions system
- as the basis of the Scottish Crop Research Institute's Retrieval system for Herbicides in Horticultural Crops

The next development in this area of central services is the implementation of SSMP (Simple Screen Management Protocol) on cheap intelligent terminals connected to commercially available Camtec PADs.

Although not strictly part of the central computer services it is worth noting here the complementary growth in other parts of the University which has been brought about by the reduction in unit costs of computing engines made possible in recent years by the major advances in electronics technology. Commercial word processors are purchased directly by departments and exact numbers are not known, but we do know that some 200 personal workstations based on the UCSD operating regime, which is recommended and supported by the ERCC Micro Support Unit, are currently distributed around the network. This trend is an integral part of the office systems strategy which has been developing over the past three years in collaboration with the Secretary's Office. Multi-user mini-computer (MUM) systems have also been growing in number and are an economic way of enhancing the computer provision in some of the larger departments. Most of these systems are DEC VAX and PDP systems running under VMS or UNIX. Only one MUM is under the control of the ERCC; a VAX 11/750 system was installed in 1983 to complement the central EMAS service by running a package service on the VMS operating system. Its purpose was to make more standard packages available to the Edinburgh user without the overhead of converting them to EMAS standards. One of the consequences of this decision is that the problems of funding the increasing costs of new packages and their continuing recurrent maintenance are now having to be faced in the overall computing budgets of the University.

The files that cannot be economically archived or retained on our distributed or central systems are transferred via the network to the central file server which ERCC constructed in 1980 from the newer storage devices left over when the twin 4-75 installation was dismantled. This system is complete with its own tape archiving system and its development is a novel feature of the Edinburgh computing environment which our users are anxious to retain.

Finally, although not directly funded by the Computer Board but of major importance to the future of computing provision, is the experience gained in Edinburgh since 1982 in the area of large scale parallel processing. Two ICL Distributed Array Processors (DAPs) are now connected to the central 2976 mainframe making the unique computer configuration shown diagrammatically in Appendix C. The first DAP was mainly funded by SERC through grants to theoretical physicists in Edinburgh, and the second was donated to the University in 1983 to mark its Quatercentary. This provision has allowed our physicists to stay in the forefront of their research fields and it has also yielded useful results in Molecular Biology. One of the problems facing the British computer industry is how it can maintain its early lead in this field in the face of strong competition from the USA and Japan. Many people feel that this development points the way to the most important future trend to the increased use of parallel processing in "fifth-generation" applications as well as in large-scale scientific research.

2.2 Use of the Computing Service Computers for teaching

Notwithstanding the growth in departmental computing facilities recorded elsewhere in this review, many of which are used for teaching as well as research, the central service computers and in particular the dual 2976 system, play a vital role in the teaching of computer methods and applications to the University's undergraduate population. Both the numbers of students and the range of disciplines accessing the computer have increased dramatically, although not surprisingly, during the past four years as can be seen from Table 2.2.1.

Although in percentage terms the Computer Science department has dropped in its share of registered usercodes, it is still the dominant department in terms of use of the central EMAS service. It uses by far the highest proportion of the computer resources required by undergraduate teaching .and often occupies in excess of 40 simultaneous interactive slots at peak periods. The Computer Science department moved most of its honours course teaching to its own departmental VAX service at the start of this review period. However it also introduced one of the more interesting new courses of recent years in a one-year Information Systems course designed to increase the awareness of the emerging world of Information Technology among undergraduates who are taking up careers in other walks of life. This course now attracts in excess of 100 students each year.

Several departments, such as Geography, Chemical Engineering and Mechanical Engineering teach computing related courses in most or all of the stages of their degree courses. Although some departments still teach programming to their own students, the trend in departments such as Geography and the School of Engineering is to an increasing use of packages, many of which place heavy demands on central processor time and disk transfer capacity. Some departments are moving away from reliance on the central mainframe; Forestry has recently moved one of its courses to a BBC micro based laboratory.

In the main, undergraduates access the computer via terminals and do not normally make severe demands on the background job streams. Undergraduates are very active users and nearly 75% of the registered undergraduate users make use of computing facilities in any one week in term time even although some courses are taught primarily in only one of the three terms. When computing resource is especially scarce during term time, undergraduates are often forced to work in the evenings and some even choose to work during the night in buildings where terminal access is offered throughout the 24 hours of the day. During term time students are also the

main users of the "unmanned" weekend service.

The EMAS subsystem provides facilities for a course organiser to tailor the user interface seen by the student to suit the particular course. Some departments provide a different command structure for their students, others restrict the interface to the one command necessary to run the special package which they have provided for their course. If it is desired, course supervisors can have privileged access to the files belonging to their students and can also monitor how student console sessions have progressed.

Although most of the teaching is addressed to the needs of undergraduates the central EMAS service is also used for other courses. ERCC runs courses on the use of the service, on programming languages, etc, and there is an increase in courses run by departments providing specialised tuition in their particular disciplines.

Table 2.2.1 The growth in undergraduate use of the central EMAS service (as shown by the number of registered undergraduate usercodes)

University Department	Academic Year 1979/80	1980/81	1981/82	1982/83	1983/84
Computer Science	316	429	500	550	540
Mechanical Engineering	18	30	80	140	150
Geography	-	30	50	125	125
Business Studies	18	15	90	100	125
Psychology	5	15	30	65	110
Mathematics	-	40	50	94	99
Statistics	-	-	15	24	99
Chemical Engineering	19	46	60	80	88
Forestry & Natural Resources	12	75	80	70	85
Civil Engineering	55	80	105	145	80
Physics	25	50	60	70	70
Artificial Intelligence	27	26	30	38	51
Economics	-	7	10	20	40
Chemistry	13	20	20	20	20
Social Anthropology	-	-	-	10	15
Zoology	2	2	2	2	12
Electrical Engineering	11	9	5	2	4
Others	41	38	25	10	13
Total	562	912	1212	1565	1726

2.3 Usage of remote computers and data bases

In 1980 there remained a substantial dependency on the MVT service of NUMAC which had been transferred there from the ERCC when the 370/158 service was closed in 1975. The MVT service was closed in 1982 and since that date use has been confined to that of a transfer process to the MVT services at Cambridge.

The work previously processed at NUMAC was either moved on to one of the EMAS systems at the ERCC or onto one of the national facilities of the SERC or the Computer Board with a small residual use of IBM specific packages at Cambridge.

The recommended Computer Board national site is UMRCC and throughout the review period attempts have been made to provide network support of a quality equivalent to that obtained at NUMAC in the 1975 - 1982 period. It is unfortunate that while the RCO has been dismantling its use of the IBM/HASP protocols since 1980 (on the advice of the JNT) the preferred method of providing access to the recently introduced Amdahl/MVS service at UMRCC is still that protocol with the JNT standards still not supportable until sometime in 1985.

The network links that do exist to UMRCC have not compared favourably with those available to the SERC sites at Rutherford and Daresbury via SERCnet. Wherever possible we have therefore encouraged our physicists and quantum chemists to work within SERC sponsorship. The high energy physics group in Edinburgh have been served throughout the review period in this manner with specially provided GEC workstations directly connected to the Rutherford Laboratory and via that site to the facilities at CERN. This arrangement is now under review and it is expected that communication with the SERC and CERN facilities will in future utilise JNT pads on JANET while departmental or Computer Board funded facilities will be used for local processing and distribution control.

Our theoretical physicists have preferred the superior performance characteristics of the ICL DAP for their work and for this purpose they use the QMC DAP and its related support organisation. The network access to QMC has been satisfactory through the use of a selection of methods and since the provision of the local DAP systems our demands on that site have been manageable. Now that the local DAPs are saturated we have an arrangement with ICL to use spare capacity on the NPL DAP; this we are doing with PSS as our method of network connection.

The quantum chemists have a library of programs which they move from centre to centre in phase with improvements in performance of the host systems and the ease of network access. This work commenced in the mid 1970s on the IBM machines at NUMAC, Rutherford and Daresbury. When the NUMAC service closed the possibility of using the 7600s at UMRCC was explored and the necessary packages were obtained. Use at UMRCC has proved difficult because of the mismatch of network facilities even though the RCO committed substantial effort to the provision of a protocol converter at Strathclyde to interchange between the 7020 protocols of the UMRCC 1900's and the protocols in use in the RCO.

Edinburgh has been a lead site in the use of JNT protocols to UMRCC and we now use such a link to the 1904S to supplement the 7020 route. A satisfactory level of network connection was achieved by these means late in 1983 when the restriction consequent to the development of the Amdahl/Cyber facilities became apparent on the 7600 system on which we were dependent. An allocation of 2% of a 7600 became unusable without substantial software

effort and the work was transferred at that time to the Cray at ULCC. There has been use of the Cray by the quantum chemists throughout its period of availability as a SERC facility and the programs developed for that purpose are now used also for the non SERC funded activities.

The difficulties of communication with UMRCC have been apparent for several years and as a contingency measure some use was made of ULCC facilities; in 1982/83 a formal allocation of 1% of a 7600 was obtained. The networking facilities of ULCC have been little improvement on those of UMRCC but recent experience suggests that the necessary protocols should be available before the end of 1984. This prospect and the provision of the Cray service led to the increase of our allocation at ULCC to 2% of a 7600 for the whole of 1983/84. We were not successful at the same time in our attempts to reduce our allocation at UMRCC from 2% to 1% to equate with the move of work to ULCC.

The prospects are now better of our being able to use effectively the vector processing capabilities of the Cyber 205 at UMRCC and the Cray at ULCC during 1984/85 and in subsequent years. In the absence of any guaranteed replacement of the ICL DAPs at ERCC it is probable that we shall have to increase substantially our allocation of time on both of the Computer Board National Centres and on any current or projected SERC facilities.

In addition to our super-computer usage there has been significant use of other national facilities such as the Lasercomp at Oxford.

The local provision of matching interfaces to a large number of interactive and file transfer protocols in use on remote systems has encouraged substantial interactive and block transfers between Edinburgh and other peer type communities. The use of electronic mail and information retrieval protocols is now commonplace and the local gateway computer that arbitrates between our network and those accessible through SERCnet and PSS now has the addresses of over 200 remote hosts encoded in its software.

The relative scale of use of the national centres is presented in the table of payments for services given in section 8.5.

2.4 Departmental Computers

There has been a large growth in investment in departmental computers over the past five years up to the point where the projected rate of investment on distributed computing is the same as that in central facilities. The balance between the two in the future will be dependent on the quality of the communications network and the relative cost effectiveness of very big processors and file stores and the more modest provisions at a departmental level. An indication as to the amount of computing equipment now in use in departments of the University is given by the following figures:

VAX or equivalents	20
PDP 11 or equivalent	45
Sirius or equivalent	100+
BBC or equivalent	100+
Apples or equivalent	50+

Computers in departments were originally used for laboratory monitoring and control and this remains a significant category of departmental use. Word processing and departmental administrative computing is a new and expanding category of use. Certain types of teaching where there are classes of students with modest requirements provide a significant reason for larger departmental installations, as are requirements for particular operating system environments - such as VMS and UNIX - to enable applications packages to be utilised without the significant costs associated with package conversion. Departmental installations of this kind will often be quite expensive in terms of the necessary staffing to manage and maintain the system. The Centre is committed to providing limited public services for both VMS and UNIX as an aid to systems support of departmental installations and access to individual research teams who could not justify a system of their own.

The Centre provides support to many of the user communities with common computing environments by encouraging interchange of ideas, by setting up common purchasing and maintenance arrangements, by support for communications software and the provision of central archiving and information on the University Data Network. In some cases the Centre is contracted to provide more specific system or operations support to a department. The effect of this development so far has been little more than to divert some of the burgeoning growth in computer demand away from the central systems. The fact that these central resources have become saturated over the past few years for major portions of the autumn and spring terms may have accelerated the process, but undoubtedly computing that requires an absolutely dependable response characteristic, such as word processing or the movement of large quantities of data as in interactive graphics, is best done on dedicated systems. However the wheel is however to some extent turning full circle in that the availability of inexpensive terminals with a local processing capability and storage is causing some rethinking as to which activities are best suited to interaction with a central mainframe over a network.

Two considerations that may become more significant reasons for departmental computing are the requirement to increase the security of some data, and the development of processors with architectures tailored to the solution of specific problems.

In the next five years departmental computing will increase whatever central provision is made, but in order to do so efficiently it is going to need complementary central investment. This is catered for in the University's five year plan, described in Section 6.

2.5 The Operational Requirement in retrospect

At its meeting in September 1979, the Computer Board approved the University's submission requesting that its twin ICL 4-75 installation be replaced by significantly upgrading its ICL 2970 computer to a dual processor 2972 configuration. The Board's timely approval allowed the complicated replacement programme to be carried out over the long vacation in the summer of 1980 and the new installation entered user service almost exactly one year after Board approval. A report on the installation and its early performance was submitted to the Board in January 1981.

The key point in the 1979 Operational Requirement (OR) was that the University wished to maintain continuity of the user characteristics provided under the EMAS operating regime, which first entered service in Edinburgh in 1971, irrespective of what physical or architectural changes were necessitated by evolution at the hardware level. The 2900 version of EMAS (now referred to as EMAS 2) has continued to serve the Edinburgh user community well (and

in addition those users of Strathclyde and Glasgow Universities who have accessed the RCO 2980/2988 installation, and those of the University of Kent using the 2960 installation). This success made it natural that the University of Edinburgh would wish to continue with a further evolution of EMAS (referred to as EMAS 3) into the 1990s; this decision was taken after careful consideration of the improving versions of the UNIX operating system and the more recent emergence of DEC's VAX/VMS system.

Arising from the heavy restrictions in access to the overloaded twin 4-75 installation in 1976-79, another major issue in the OR was to ensure that enough capacity was obtained to allow a real growth in simultaneous interactive access to the EMAS 2 facility. It was expected that demand would grow to some 200 simultaneously active users within three years and this prediction turned out to be valid, although their distribution between the dual 2972 system and the Edinburgh share of the regional 2980/2988 system was slightly different from that envisaged. It was expected in 1979 that 160-170 slots would be provided on the local service topped up by 30 or 40 slots from the regional machine. In practice the peak loads in 1983 showed a distribution of 140-150 slots on the 2972s and 50-60 slots on the 2988. EMAS is tuned to ensure that interactive response to small demands such as file editing remains good up to 150 simultaneous users but at this level of service users have to wait too long for the heavier CPU based functions such as program compilations. It was therefore to be regretted, though inevitable, that a resource allocation scheme had to be put into operation in 1982 to share out the scarce prime shift resource more equitably and to restrict typical user levels to the 100-120 user range in order that work requiring some CPU time could be completed in an acceptable elapsed time. In practice however user sophistication combined with the increasing use of packages means that CPU demands are always on the increase, and system monitoring shows that there is never any idle time on the 2972 when the user load is above the 65-70 user range.

On the hardware side, in the latter years of the 4-75 service the machines were very unreliable and the OR naturally called for a significant improvement in reliability from the replacement 2900 computers. The wisdom of specifying a dual processor configuration for a P-series configuration has been amply justified since, although each of the processors accrue some 50 hardware incidents in a year, the actual availability of a user service (from the mainframe point of view) on at least a single processor configuration has averaged 99.7% of scheduled time. This fact alone has allowed us to make full use of this ageing architecture. Much of the equipment itself is also somewhat old as can be seen from the table in Appendix C. The past four years have underlined nevertheless the sense in getting the right hardware base on which subsequently to expand the installation. The deficiencies in resilience in the initial 2972 configuration were gradually repaired by a policy of purchasing selected equipment as it became available second-hand, at considerable savings compared with new prices. Consequently for most of the review period we have been able to partition the installation, allowing a user service on one "half" of the system to proceed in parallel with hardware maintenance or system development on the other "half". It is worth registering here that this ability is a major advantage of "true" duals over dyadic processor systems.

One area of the OR which has not quite materialised was that of sufficient file storage. It had been hoped that the initial 1600 megabyte of on-line disc storage would have been able to have been significantly increased particularly through the addition of much larger capacity devices. In practice such discs did not become available on P-series machines. Instead we have increased the 2972 file store by 200 megabytes approximately every year to the present level of 2400 megabytes (200 megabytes of this being purchased

by SERC and reserved for the DAP service), but the increase in the user population and the expansion of individual requirements have meant ever increasing management problems in constantly rebalancing both user allocations and overall disc allocations. It is perhaps worth noting here that this problem is equally apparent on the RCO 2988 configuration where more modern discs are available.

In summary, it is worth reflecting that although the OR has largely been satisfied, it failed to anticipate two of the main service extensions which have actually taken place: that is, the advent of parallel processing facilities in Edinburgh, and the speed with which OSI protocols are being implemented. The experiences in this last four years have re-emphasised our belief that ORs which specify hundreds of detailed requirements are somewhat misguided. What is much more important to achieve is a flexible hardware and software base with significant expansion capability which can be simply accomplished at ever decreasing costs as time progresses, through improved hardware technology and an expanding second-hand market place. We would therefore support those Universities who have indicated that their requirements are best served by a more qualitative approach to ORs rather than the quantitative approach followed historically.

3. COMPUTING IN RESEARCH

The contents of this section were contributed by the research staff involved. A separate statement is made in Appendix D of the co-ordinated programme of work in the general area of Information Technology.

3.1 Physics

The Physics Department is one of the major users of computing facilities in the University, making extensive research use of the 2976 and 2988 mainframes as well as using its own VAX 11/750, several PDP 11's, a GEC 4400, and a considerable number of microcomputers.

The largest single component of the Department's usage is catered for by the two ICL DAP's which are driven by the dual 2976 mainframe computer. Of the Department's 89 mainframe users, 26 are registered as DAP users, most researching in the fields of condensed-matter physics, statistical mechanics, and fundamental field theory. The advent of the DAP's has profoundly influenced the work of these groups, and their work with these machines has earned international respect.

A developing interest in image-processing will create a new requirement for array-processing facilities which can be linked on-line to experimental equipment such as array cameras on optical spatial-filtering benches. Since there are several groups of experimenters working on image-processing and pattern-recognition in various parts of the University, the need for on-line array processing facilities is likely to grow, and may require the central provision of shareable facilities.

In addition to the specialist requirements alluded to in the two preceding paragraphs, there continues to be a strong demand in the Physics Department for large general-purpose number-crunching facilities, from experimental and theoretical workers in condensed-matter physics, fluid mechanics, high energy physics, nuclear physics, optical physics and theoretical physics. These workers all require access to a substantial CPU, and their requirements increase from year to year as microprocessor-based data-acquisition techniques become more sophisticated and more powerful.

R M Sillitto

3.2 Chemistry

The Department is one of the largest users of ERCC facilities and also the largest user of ECC funded computing facilities at the ULCC and UMRCC National Centres, in its research effort. In almost all of the areas of work described below in (i-iii), the research becomes nonviable in international competition in the absence of major computing facilities.

All Chemistry Honours Degree students have at least one teaching course on the computational aspects of chemistry, and this is likely to expand.

We thus attach major importance to enhancement of the ERCC computing facilities to keep in line with both national and international standards.

Two main areas of research in which computation is either almost the total effort or at least a major part are (i) quantum chemistry and (ii) crystallography. In detail these are concerned with (i) ab initio configuration interaction calculations of the ground, electronically excited, and ionised states of molecules both organic and inorganic in type. This is 'state-of-the-art' computing. For (ii) Direct Method x-ray crystallography is applied to a very wide range of molecules. There is both a Departmental service for all Groups and individual Groups concerned with both bio-organic systems and organometallic compounds. The other Groups (iii) are relatively small users in comparison with (i and ii) but are themselves large by many Departmental standards. This Group includes those researching in nuclear magnetic reasonance, electron diffraction, infra-red and ultra-violet spectroscopy, molecular beams and heterogeneous catalysis. Their usage is both for data reduction and for interpretation of the results.

Dr M H Palmer

3.3 Chemical Engineering

Present and projected research work in Chemical Engineering falls into three categories with respect to computer usage.

1. Laboratory experimental work using on-line personal computers.
2. General research work requires off line access for a computer system for data analysis and evaluation, general modelling work, etc.
3. Research and development of Chemical Engineering CAD tools.

In general we expect an expansion of all these areas and of the demand for computer facilities in each. Some notes follow

1. Laboratory Computing - We see considerable expansion here in the field of automated experimental design and control. This department appears to be well in the forefront of U.K. Chemical Engineering departments in this area. The need for communication with ERCC network has been met by BBC X-talk. In future LANs will play an important role.
2. General research computing - The requirement is currently met by EMAS. We forsee increased demand for this type of service, but by and large are not concerned with how it is met so long as compatability of existing software is maintained. The only major package for which we see significant new demand is for finite element analysis.
3. CAD Software - The development of CAD software in industrially backed projects is a significant part of the department's present research activity, and we expect further growth. We require access to a substantial machine for algorithm and method development (currently EMAS) and access to commercially accepted hardware and operation systems from package import and export (e.g. VAX/VMS).

Dr J W Ponton

3.4 Forestry and Natural Resources

EMAS is used for the development of complex simulations of ecological processes: for statistical analysis of data (mainly using SPSS or Genstat) and for the development of high-level software for ecological data-handling and modelling.

* This last activity has resulted in the development of a very flexible menu-based package called Presto, which provides within a single menu-based environment a very wide range of features: graphical and statistical analysis of data; grid and 3-D mapping; specific ecological simulations; and generalised facilities for constructing ecological models. The package is heavily used by undergraduates (in a teaching context) and by postgraduates.

* A study looking at sheep grazing behaviour has involved a considerable amount of computing. The position of sheep on photographs taken at 10 minute intervals were digitised, giving 10000 sheep points. In order to transform these co-ordinates to the plan view, each point had to be overlayed on a topographic representation of the hill-side, allowing for perspective and movement of the camera. As well as requiring a large data storage capacity and the ability to carry out a large number of complex calculations, this project would have been impossible without the ability to generate a large volume of graphical output to check on the correctness of the various transformations.

Dr R I Muetzelfeldt

3.5 Genetics

The main computer users in the past have been research workers concerned with quantitative genetics and its application to animal breeding, for which Edinburgh is the main centre in Britain, and this work continues. The types of work are of several kinds:

i) Statistical analysis, usually by means of packages, of small sets of data collected in the laboratory to estimate genetic parameters.

ii) Maintenance of files and statistical analysis of very large data sets on animal breeding collected in the field. In particular we receive annual records from the Milk Marketing Board of production of all Friesian cows recorded in Britain, almost one million animals a year, on eight magnetic tapes. These data require both good tape handling facilities, extensive on-line file stores (up to 20Mbyte) and substantial computing power.

iii) Development and use of statistical methods appropriate for animal breeding data. Increasing use is being made of maximum likelihood methods which make heavy demands on CPU time.

iv) Theoretical studies in population and quantitative genetics. These often use Monte Carlo simulation, with demands on CPU time.

The main area of development in computing in the department is in the handling and analysis of DNA sequence data. This work comprises

i) Statistical analysis and searches of databases collected worldwide and sent regularly on tape from EMBO. This database is expanding very rapidly.

ii) Storage of sequence data collected in the laboratory for publication and comparison with the database in (i).

Much of our work requires substantial amounts of CPU time (jobs of an hour or more on the 2988) which, coupled with the need for tape handling and large files, means we shall have a continued demand for a large central mainframe. We are also installing micros, which have an important function as terminals, for data input and editing, and as word processors.

Professor W G Hill

3.6 Biochemistry - Simulation work

The research over the last 10 years has been concerned with the simulation of large biochemical systems, in the form of organized fractions of cell metabolism. Typically, about a hundred variables and two hundred rate constants are involved. For this work, two packages developed by AERE Harwell, namely CHEK and FACSIMILE have been used. Frequent use has also been made of optimization procedures, mainly SIMPLEX.

This work is continuing and it is hoped to broaden its scope by experimenting with Monte Carlo simulation techniques. In addition, we have recently been doing some work on the behaviour of immobilized enzymes in columns, using two-dimensional diffusion equations. Both this work and the Monte Carlo studies are likely to make use of the DAP.

Dr J H Ottoway

3.7 Business Studies

A major part of the Department's research activity is the JIIG-CAL Project, which uses information technology in the support of careers education and guidance, to help youngsters prepare for the increasingly difficult transition from school to work. Funded by the Scottish Education Department, the research has generated a computer-based system comprising a comprehensive data base, the JIIG-CAL Jobfile, which contains information on all the most common occupations. This data is accessed by a package of Fortran programs which enable youngsters to obtain from the Jobfile a personal printout giving ideas and information about those jobs best suited to their interests.

The system is licensed to Local Education Authorities to run on their own computers, as a service to their schools. It has so far been taken up by about 50% of authorities in the UK, and growth in usage is steadily increasing. The software is highly portable, and currently runs on hardware from 9 different manufacturers and under 14 different operating systems.

Continued funding has recently been provided jointly by the Scottish Education Department and the Department of Education and Science for further research and development of the system.

JIIG-CAL is a joint development with the Educational Computer Centre of the London Borough of Havering.

Dr S J Closs

3.8 Centre for Educational Sociology

The Centre for Educational Sociology conducts research in a number of related disciplines centred round the Scottish Education Data Archive. It has made both substantive and methodological contributions in the fields of survey methodology, education, sociology, and cognate social sciences, and it has attracted substantial funding from both the ESRC and government bodies since 1972.

Much of the research conducted by the Centre is based on biennial (soon to be annual) surveys of about 13000 young people, requiring approximately 15 Mbyte per survey. This data is held in a SIR/DBMS database and is the source of most of the substantive and methodological work. Data from other sources is also linked with the main survey, and additional surveys are conducted from time to time. Methods of storing data more effectively, and accessing it quickly are also investigated.

The computing needs of the Centre are determined both by the operation and management of the surveys and the resulting database by the need to use advanced statistical modelling techniques in the analysis of the data. Thus the Centre's fundamental computing requirements are for facilities for storing and manipulating large databases and for large amounts of CPU time for running statistical programs.

Dr J M Lamb

3.9 Department of Economic History

The Department of Economic History administers the National Sample from the 1851 Census of Great Britain, developed since 1972 with support from SSRC. This project has extracted a 400,000 individual sample from the enumerators' books of the 1851 census, transcribed them into machine readable form and processed them in a variety of ways so as to allow both analysis of the nineteenth century social structure and long run comparisons with more recent census and survey material. The 1851 census data base in its various forms now contains about 1 Gigabyte of data, most of which is held on the FILESTORE, some on the EMAS archive; up to 40 Mbytes can be active on EMAS at any one time. The project undertakes both data library and data analysis functions. The data library functions involve the conversion of machine readable transcript data into standardised and coded files suitable for export to other sites and for entry into data analysis packages and data base systems. The data library software is currently written in IMP80 and is EMAS-specific. An application for support of further development work including further data transformation and enhancement is currently with ESRC.

The data analysis work involves at present SPSS and SIR, using files currently up to 12Mbytes but expected to rise to 24Mbytes within the next twelve months. Comparative analyses are also undertaken using General Household Survey and Census Small Area Statistics. Some graphical and map output (using GIMMS) is also undertaken.

Much of the other work of the department is also concerned with the transcription, transformation, linking and analysis of substantial bodies of data, typically using a combination of purpose-written IMP or PASCAL programs and packages like SPSS and SIR. At least six projects, most with current or recent ESRC support, are currently under way, with active data sets ranging from 1 to 15 Mbytes. Some of this work is now moving into more complex relational database applications. Most of these projects have a five to ten year life span at least, frequently involving adding material to existing data sets. Stability of the computing environment is of major importance to projects of this kind. Increasing use of some of these data sets for teaching is also planned.

Other computing applications in the department are less specific to it. Considerable use is made of econometric packages (especially TSP) on relatively small bodies of data for both teaching and research. Quite complex graphical and cartographic work is also now being undertaken and this is a rapidly growing area of activity. Some mainframe word-processing is also done, although most of this work is now performed on the departments SIRIUS microcomputer.

Professor M Anderson

3.10 Geography

The Department has been involved with the development of software for computer mapping and graphics for at least 15 years. Two products initiated within the Department are used externally. The most widely distributed of these are the GIMMS systems for mapping and graphics, which in close co-operation with the Department, is distributed to more than a dozen countries by a company based in Scotland with a subsidiary in the USA. This system is arguably the most advanced thematic mapping system in the world.

The second system, CAMAP, is used extensively in the UK for the analysis and mapping of large data sets such as the Agricultural Census.

Major projects recently have been with Stanford Research International on financial restructuring for large organisations, and the Scottish Development Department on using census data to evaluate amongst other subjects, unemployment and housing deprivation. A major project with the Ministry of Agriculture and Fisheries has involved the collection of land use data for the whole of England and Wales for use in computer mapping projects.

The department also provides a range of consultancy services in the area of the use of new technology, and its effects, for bringing information, as opposed to data, to the decision maker. The clients include international organisations like the World Health Organisation, North American governmental services such as the US Forestry service as well as UK governmental and public authorities.

Dr A J Crosbie

3.11 Computer Science - Stylometrics

To establish criteria for the authorship of classical Greek text one needs to examine a large part of all known text of that sort. To decide whether there are any aspects of their styles that can reasonably be used to test the hypothesis that Bacon wrote Shakespeare's plays we need to examine most Jacobethan drama and a good deal of contemporary non-drama. To justify an opinion on the vexed question of the oral composition of the Iliad we must examine large bodies of orally composed epic poetry and non-orally composed epic poetry. We must have available a great deal of data and from it generate a great deal more. Making a concordance expands a text by a factor of about 25. Thus one of the most pressing needs is for rapid access to a very large database. Until now most of the work in this field has been done on mainframes with large disc backing stores. It is now becoming practicable to consider the use of powerful personal computers connected by high-speed local area network to network file servers. In either case, a well organised service which provides back-up, archiving and database management is necessary. Connection to a reliable wide area network more than doubles the working time available to the researcher. The provision of high quality print servers on the network, coupled with a data-rate suited to screen editing and text processing (>9600b/s) eases the preparation of readable output and papers, while the provision of optical character readers capable of reading from books without damaging them would free one from reliance upon other peoples haphazard collections of texts. It doesn't take much to make a stylometric happy, just a really good computing service.

Stylometry has been defined as the scientific study of the usage of words in an attempt to resolve literary problems of authorship and chronology. The traditional methods of stylistic analysis were largely based upon the subjective evaluation of internal textual evidence, often leading to endless disputation. With the availability of computers as tools, new ideas have burgeoned and new approaches to these age-old problems have led to an increased need for statistical analysis of observational data. Edinburgh has done much of the pioneering work in this field.

Professor S Michaelson

3.12 Archaeology

The Archaeology Department's main use of computers - mainframe and micros linked up to the mainframe - is for storage, retrieval and analysis of excavation data. None of the existing database management systems has been found flexible enough for our data sets and an Australian package 'MINARK' has just been obtained for this purpose. Apart from this, CLUSTAN and a clustering package developed in our department for use with mixed quantitative and qualitative data, FLEXI, are extensively used by staff and postgraduates for data reduction and classifications of, for instance, results from neutron activation analyses of pottery. CATALOGUE has been used for simple sorting purposes; MAIL is used by several members of staff; SPSS, and other statistical packages - some written for use on micros by our undergraduates - are used frequently as are word processing packages - preferred: SPELLBINDER - for publication of excavation reports and departmental publications e.g. Occasional Papers.

Dr B Ottoway

3.13 Middle English

The Middle English Dialect Project, begun in 1952, will culminate this year in the publication of 'A Linguistic Atlas for Late Mediaeval English', ca. 1350-1450. For a period when the written language existed in a great variety of local forms, but when no one form could in any sense be regarded as a national standard, the geographically ordered presentation of the linguistic atlas affords by far the most useful conspectus. The Atlas will consist of four main sections, and the computer plays an essential part in all of them.

1. Linguistic profiles - Over 4000 analyses of the writings of late mediaeval scribes have now been made, and some 2000 are on disc (ca. 5 Mbytes). A formatting program for printing the profiles via the Oxford University Lasercomp has been recently completed.

2. List-maps - A list-map displays the variant spellings in use for a given test-word at each point in a fixed array of over 1000 survey points. The text for a given map is abstracted from the linguistic profiles by means of an indexing program. The text is then processed for printing via a computer photosetter, the ERCC Digitron. Once the base format for the series of maps has been determined, production is fully automated.

3. Dot Maps - Each diagnostic map will display the points of occurence for the variant(s) in question, and dot-size will be graded according to the relative frequency of the variant(s) at each point. These maps are derived from the same source as the list-maps, by means of another indexing program, and printed via the Digitron after further processing.

4. Manuscript descriptions - The sources for the survey are the writings of late mediaeval scribes, and over 5000 have been examined to date. Brief descriptions of all of these are to be published.

Lastly, it may be noted that a large library of programs for various types of data manipulation and analysis has been built up over the last few years, and is an essential apparatus for the efficient exploitation of the Project's materials. Without the support of ERCC, or of some comparable organisation, neither the work nor the publication could well have been completed.

M Benskin

4. NETWORKING

The Centre's first exposure to communications with computers came with the installation of an RJE link to NUMAC in 1968. This was succeeded by RJE connections to the Centre's own 360/50 in 1969, which also provided services to Universities in the West of Scotland. The first proposal for a communications node (switch) was made, but not granted, in 1970. The start of an interactive service in 1971 led to the growth of asynchronous terminal connections, initially direct to the mainframe but from 1974 onwards gradually merging with RJE traffic to form an integrated network.

The eventual outcome was a wide area network embracing the Universities of Glasgow and Strathclyde as well as Edinburgh, using packet switching but necessarily based on locally developed protocols. In 1980 the decision was taken to develop a Cambridge Ring interconnecting some of the most heavily used items on the network, mainly to gain experience of a high speed local area network but also to relieve the load on the existing network switches. The Cambridge Ring was chosen because circuit diagrams for its interfaces were available. The Centre's preference would have been for Ethernet, because even at that time it seemed likely that the backing behind Ethernet, if nothing else, would ensure that it would become an international standard. The Cambridge Ring went into service in 1981, interconnecting the 2972s, several of the more heavily loaded terminal concentrators, the PSS gateway and, more recently, the network filestore.

Last year the Board approved the provision of two GEC 4190 CPSEs as part of the proposal to change the network from local to X25 standards. This changeover is virtually complete and the Edinburgh network now supports 26 hosts, 78 printers and plotters, and over 1200 interactive terminals, including several hundred microcomputers. The change to X25 was necessary, and has eliminated the major bottleneck in the previous switches. The protocols are, however, in some respects less efficient than the ones they replaced and this, together with the failure of the GEC CPSEs to distribute the load evenly between multiple front end processors, is causing bottlenecks on the 2976 service. The latter problem cannot easily be solved with the existing front end processors, which are based on PDP 11s and have inbuilt addressing limitations, but needs to be taken into account in the plans for connecting a replacement for the 2976s to the network. The present network is shown diagrammatically in Figure 4.1.

There is no obvious single solution to the future networking needs of the University. It is intended to connect the successor to the 2976s to an Ethernet serving other hosts and terminal concentrators in that part of the Centre on the science campus of the University, and it is likely that this Ethernet will in due course be connected to others, such as the existing one in the Department of Computer Science, covering the rest of the science campus.

The method of servicing the rest of the user community elsewhere in the University is much less clear. In the immediate future the wide area network is the only possibility. In the longer term a mixture of local area networks and wide area connections seems likely. The only concrete step being taken at the moment, however, is the provision of a microwave link between the science campus and the most concentrated part of the rest of the University, 2km away. This will provide in 1985 a total communications capacity of 8 Mbit/s between the two sites, each of which has a CPSE. Some of this will be used to increase the speed of the connection between the two CPSEs; the rest will be available for links between LANs and for the University's replacement telephone network, which is also being planned at present.

Figure 4.1 Edinburgh Regional Computing Centre — Communications Network (EDNET)

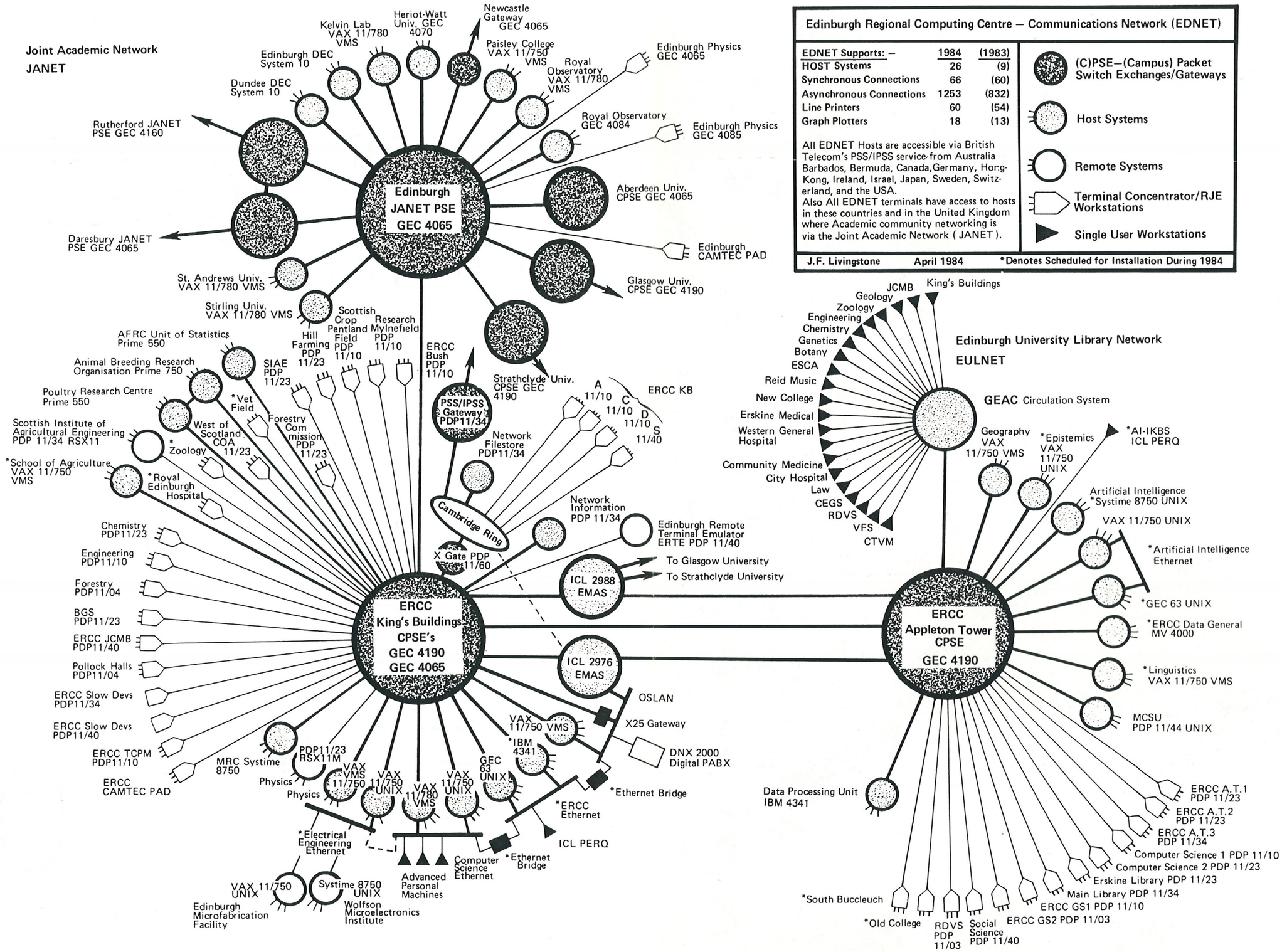
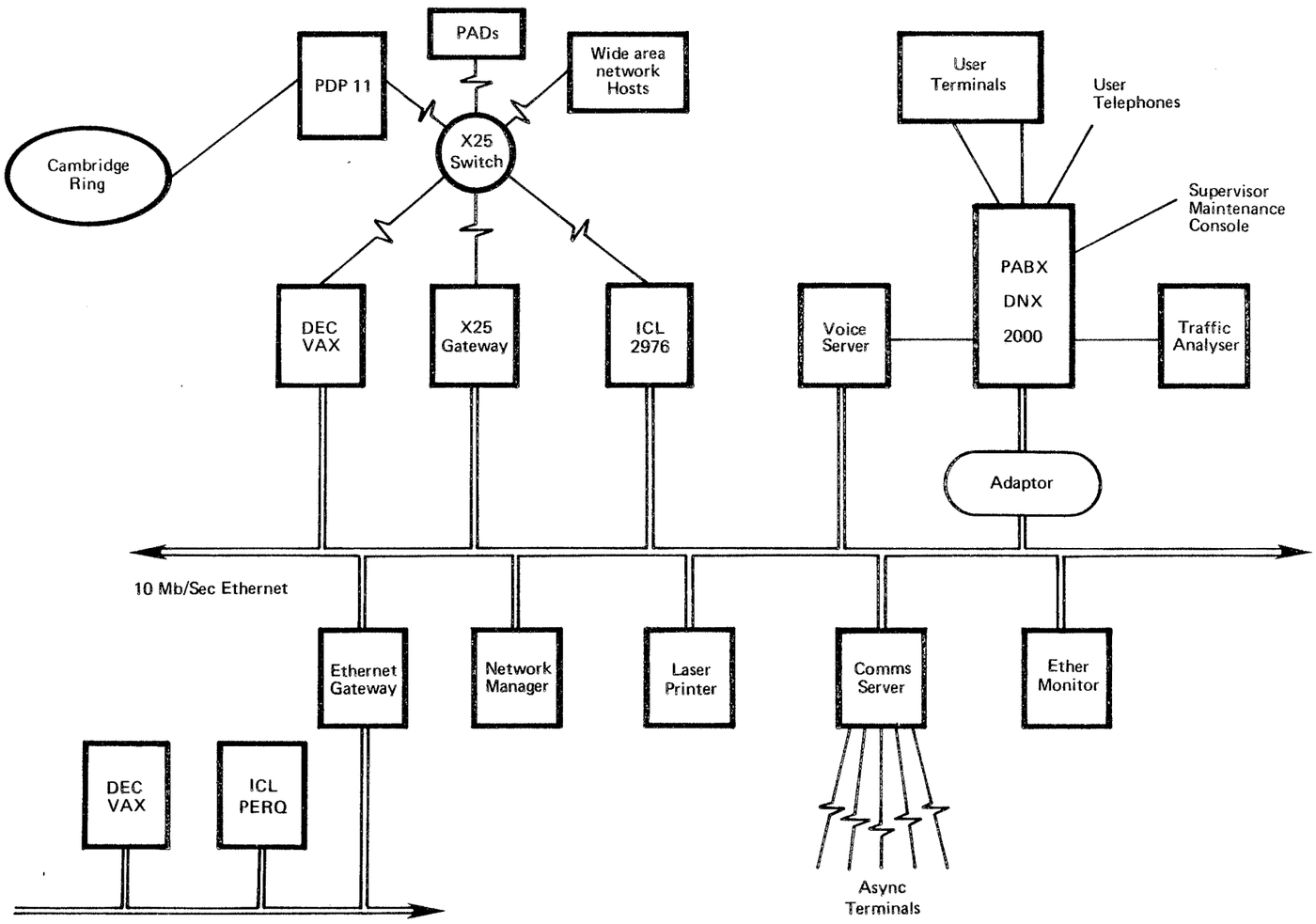


Figure 4.2 Schematic of the PABX/LAN Network of ERCC based on ICL Open Systems Local Area Network



The role of any future third generation PABXs in large scale data transmission in the University is not clear. There is, however, a joint University/ICL project underway, partly funded by the Department of Trade and Industry, which includes a DNX 2000 exchange linked to a pilot Ethernet. This will give the University direct experience of one of the most advanced of the third generation exchanges. It will also enable the Centre to try out, and in some cases develop, a variety of Ethernet devices, including terminal servers and X25 gateways, as well as connections to the 2976s and the 11/750. The pilot Ethernet project is illustrated in Figure 4.2.

5. RESOURCE ALLOCATION AND CONTROL

The allocation of resources and decisions related to the metering of resource usage are the responsibility of a subcommittee of the Edinburgh Computing Committee. This comprises representatives of the Faculties, the other RCO universities, the Research Councils, the Users Committee and the Centre. All usage is costed according to a formula reflecting the different resources involved in the execution of a computing job. The rates for the different services have been designed to be acceptable to the Auditor General because of the significant amount of work done for Research Council Institutes. For those users who do pay real money for their computing, the relative pricing of different elements of the service provides a means of influencing the usage made of particular subservices; for example the balance between on-line and archived files.

Control is exercised at three levels. The execution of individual jobs, both batch and interactive, is controlled by a system mechanism which results in those submissions which are very demanding in terms of computing resource being disproportionately penalised in execution if the system as a whole is heavily loaded. The automatic scheduling of batch work to complement the daily pattern of interactive work is determined by means of factors which are functions of the time of day.

There remains the requirement to control interactive use during periods of congestion, to ensure a reasonable level of response and to maintain the agreed proportions of resource to different users or groups of users. The maintenance of a reasonable level of response ensures that the system is not so grossly overloaded that system overheads rise and thereby reduce the amount of computing resource available to users per unit time, or that users waste a considerable amount of their time waiting for the system to respond. What individual users regard as a tolerable minimum performance by the system depends on the nature of processing they are involved in - and other less quantifiable personal attributes - but the endeavour is to satisfy as many users as possible with modest computing requirements during peak hours. It should not take long, for instance, to prepare a job for submission to the batch queue. What is done is to keep a separate account of the usage made of the machine during peak periods. What constitutes peak times is determined solely by the number of users using the system exceeding a publicly advertised threshold. This is a crude measure but given the number of users involved, at any one time approximately 100, there are averaging effects and it has the great merit of simplicity resulting in a low system overhead for its computation and monitoring and it is also comprehensible to users.

Each user or group of users has a finite amount of resource to use in these peak periods each week. If that resource is used up the individual or group of users will not be able to log onto the system during peak periods and indeed if a user runs out whilst on the system, after a warning, his session will be terminated. The distribution of this peak time resource is done on a hierarchical basis with the main allocation subcommittee determining the allocations to Edinburgh University Faculties and other equivalent groupings. The subdivision of this allocation is then the responsibility of the grouping concerned and may involve more than one level of distribution. Any user who controls some of this resource at the final level of subdivision is free to donate some of his weekly allocation to any other user, or group of users, similarly holding an allocation. The system manager can alter the value of the resource units distributed each week and the threshold which determines when the peak time control mechanisms are invoked. Normally these are held constant over long periods of time unless, for some reason, the capability of the system is significantly reduced. This system of control ensures the full

utilisation of the computer at all times, with minimal overhead, and the ability to adjust rapidly to the major changes in demand that occur during an academic year whilst ensuring when necessary that relative usage is controlled. The effect of this method of control has been to reduce the peak number of users on the system and spread the interactive load over a much larger proportion of the day. It has also resulted in departments and larger groups assessing the relative priority of the work being done and allows them to protect access to the system for certain critical purposes such as laboratory classes, tutorials or research staff working to deadlines. A significant amount of redistribution of resources took place over the first few years but now a relatively stable situation has been arrived at, only perturbed by major new requirements.

The Allocation Committee also controls the development of the communications network to ensure that the accessibility of the computing resources is fairly distributed, given the physical and economic constraints involved. It is also the responsibility of the committee to determine the policy for the purchase of external computer resource from other Centres using central funds, and determine its distribution. The amount of money available for this purpose has been the same for the last five years, but has been supplemented by departmental expenditure.

6. REQUIREMENTS FOR THE FUTURE

6.1 Planning of computing and related facilities

The responsibility for planning the development of computing and related communication services within the University of Edinburgh is vested in the Edinburgh Computing Committee (ECC). In the summer of 1983 that body reported upwards to its parent committee, the Educational Policy Committee with a "Forward Look to 1987-88". The Faculties of the University have recently responded to that central projection and in essence endorsed it.

The ECC is therefore confident that it has an accurate knowledge of the current requirements of its constituents. It has approved the following analysis of need and recommends to the Board the specific area of Central Mainframe enhancement for support at the time of the 5 year review.

The ECC's forward look concentrated on the five year period to 1987-88. That period is likely to see significant changes in the central computing service as a result of a number of factors both internal and external. Firstly, there is changing technology. New generations of computers have become available which can dramatically increase the amount of computing power in the University at much lower running costs. Also, as a result of the increase in computing power in relatively cheap computers, more departments will have computers of their own. Secondly, the variety of software has increased substantially, and is available for a large number of distributed machines rather than a single central machine. Thirdly, the emphasis being placed on information technology and the development of the teaching of computing in schools is likely to lead to an increase in the number of computer users and the spread of computing into departments which have not traditionally been users.

6.2 Central Mainframe services

Having considered a report of a Working Party which investigated this area, the ECC concluded that within the planning period large central mainframe(s) must continue to provide an important part of the computing service. A large central machine will economically meet the needs of many users, it provides the only way of meeting certain requirements which require large amounts of 'raw' computing power, and it is necessary to provide a reasonable degree of continuity with the existing service.

As a result of this analysis the ERCC has for the last year been investigating the various strategies for providing continuity of service beyond 1985 for users of the present EMAS and VMS services. The two forms of service are designed to provide support for the very large body of existing software and to permit the early importation of packages from the international community served by VMS.

The existing dual 2976 cannot be enhanced to support more users. It could be supplemented by another machine, but any form of supplementation has several drawbacks, such as increased recurrent costs and accommodation and communications problems. It would also not be possible to provide a unified EMAS filestore. In any case, part of the 2976 installation dates from 1975. (see Appendix C).

The university has therefore considered alternatives involving the replacement of the dual 2976. The obvious possibility of moving to the 2900 "L" series, in the shape of an Estriel, is unattractive, partly because of ICL's timescale for that machine, partly because of its relatively modest processor power, but primarily because the Estriel does not offer a secure forward progression over the next five to ten years. This is because it is designed specifically to run in conjunction with VME: ICL will not commit to a particular hardware architecture on which an EMAS service could be guaranteed to run without major alteration each time ICL made a change in specification. The issue has been explored at length with ICL who agree that the future exploitation of EMAS would be better done on 370-XA architecture. This involves the modification of EMAS to use that architecture but then gives as secure a forward prospect as can be obtained. It also satisfies a number of the university's other requirements.

The advantages and disadvantages of running EMAS were considered at length in the University's submission for the 2972s in 1979. It is hoped that the Board does not require an extensive defence of the University's desire to continue to use EMAS, but a few comments may be useful.

During discussions with the user community a strong preference emerged for the principal central computing service to continue to be based on EMAS. In part, this conclusion reflected users' desire not to be faced with a major upheaval in transferring their work to a new system. This is a very important consideration: a change of operating system costs a computing centre a great deal of effort, but the main burden falls on the user community. Even so, a change may be justified if the advantages outweigh the disadvantages (as was felt to be the case in 1979, when the regional service switched from VME/B to EMAS).

A possible problem is users' ignorance of alternative systems. This is not thought to be a significant problem in Edinburgh. In the past the Centre has run services based on IBM and ICL systems - MVT and VME/B - and some users are still using them elsewhere. More recently many users have been exposed to VMS and UNIX, and SERC-supported users on the DEC System-10 run by ERCC are familiar with TOPS-10. There are therefore good reasons for regarding the user community's preference for EMAS as a considered judgement, and not merely the result of inertia or ignorance.

The disadvantage of EMAS is in the support of software packages. A number of widely used packages have been transferred, but the transfer often involves a good deal of work and there is inevitably a delay in introducing a new version. Moreover, some packages take advantage of particular features of the systems for which they were designed, and run less efficiently on other systems.

Package use is vital to some users, and important to many others, but in total it still only forms a minor part of the load on the central service - less than 10% in terms of cost in the six months up to February 1984. This figure relates only to externally produced packages transferred by the University's Centre for Applications Software and Technology (previously the Program Library Unit). There may be other packages transferred by users themselves, and there are of course many locally produced pieces of software. Nor does the figure include use of the system preparatory to the running of a package, so 10% is certainly an underestimate, but the main conclusion still stands.

The University's policy, therefore, is to recognise that the import of packages is a requirement that cannot be met completely on any single machine or system, and either to purchase suitable machines, such as the

Centre's 11/750 with VMS, or to set up access to external services. This is not a perfect solution, but in the University's view it is the best that can be achieved, and the University is planning to commit substantial funds to it over the next five years. Figures for the use of external services are given in section 8.5, but these are in terms of the charges levied by each service and are difficult to compare with the use of central services. The use of UMRCC alone, however, represents at least 2% of a 7600.

The ERCC has therefore concentrated on preparations for the move of EMAS onto the 370-XA architecture and in defining with users throughout the various EMAS user communities those changes in the user interfaces needed to keep EMAS in the forefront of operating system practice.

The enhancements of the EMAS service that are required by the ECC are as follows:-

1) To adapt EMAS as implemented on the 2900 series (now known as EMAS 2 to distinguish it from EMAS 1 on the System 4/IBM 360 architecture) to run on the IBM 370-XA architecture (and to be known as EMAS 3). As part of this process EMAS to be upgraded to include the best features of other current operating systems, such as UNIX.

2) To convert our EMAS hosts to interface to the Ethernet local area network standard in concert with our existing VAX/VMS and GEC/UNIX hosts and with the proposed PABX replacement telephone/data exchange and the existing GEC packet switched exchanges.

3) To provide in an initial system at least double the present processing power of our combined allocations on the regional 2988 and local dual 2976 and to concentrate that power in a single central processor (instead of the present four), despite some loss of resilience, so that at off peak times much more intensive processing can be applied to particular jobs.

4) To provide in the initial system at least double the present on-line file capacity available to EMAS users i.e. 10 Gigabytes.

5) To provide the potential for cost effective enhancement on an annual basis of both the processing power and on-line file capacity.

6) To provide hardware components of demonstrated reliability to replace the P series ICL hardware of mid 1970's design vintage.

6.3 The smaller multi-user machines

The VAX computer, although not considered suitable to take over the main central service at Edinburgh, is widely used in departments. In addition to the ERCC system there are now 13 of these machines in departments. The ECC believes that it is inevitable and proper that more of these machines will be introduced in the planning period to meet particular needs in departments. The manufacturer's operating system (VMS) has a large range of applications software, some of it very specialised, and it would not be possible or sensible to attempt to provide all that software centrally on another type of machine. The SERC has chosen the alternative operating system (UNIX) as the base for developments in information technology. Edinburgh is a centre of expertise in information technology and so UNIX can be expected to be a very important research tool in this University.

The ECC believes that it is essential that it should continue to invest in UNIX and VMS services and resources to provide a limited service for users who could not justify their own machine, to provide centrally some widely used applications software which it would be very expensive to provide on a number of separate departmental machines, and to give ERCC and CAST staff sufficient experience of these systems to support users in departments. The funding of this is not part of this proposal. The ECC plans to commit £250K capital to these purposes over the five years of the present forward review period.

6.4 Personal Computers

There are already a large number of personal computers in the University which are used for research, administration and word processing. As the power of these machines increases, and as the cost falls and the software becomes easier to use, the ECC expects the number of personal computers in the University to grow substantially.

The ECC believes that it must invest in a representative selection of personal computers and the software used on them if ERCC and CAST are to provide the support that users will require and a further capital sum from University resources of £250K is designated for investment in new equipment over the review period.

6.5 Software

As has already been mentioned, the amount of software available has grown substantially. However, the cost of software has not fallen in line with most other costs in computing because its production is labour intensive. Edinburgh has been fortunate in obtaining much of its software at little or no cost through the work done by CAST on conversion and through other contract work but it is unlikely that such a high proportion of software can continue to be provided in this way.

The cost of the software for many systems is now comparable to the cost of the equipment itself. With the growth of distributed computing, software is now being bought for a whole range of machines where hitherto it would have been provided on only one or two central machines: software costs of £500 may not be much for a single machine but it becomes a significant cost to the University if 100 machines are involved. Much of this cost is paid not by the ECC from central funds but by Faculties from their own equipment grants.

The ECC has established a Working Party on software to develop a strategy for procurement. Among the aspects which the Working Party will be considering is the balance to be struck between central and Faculty funding for software, and bulk software licence agreements covering the whole University rather than a single machine.

6.6 Communications

Edinburgh has been a leading site in the development of interactive computing and has therefore had a well developed communications network linking most parts of the University. In the planning period, communications are likely to become still more important. Users will wish to use the network to transmit data among distributed computers and between distributed computers and central services at much higher rates than are required for simple terminals. In particular the Library and the Secretary's Office will each

have their own computers linked to the network and containing information of great importance to the University at large.

The existing network has insufficient capacity to deal with the load of the various new uses projected for the next 5 years. Furthermore, the existing network cannot transmit information fast enough, and the cost of connection to the network is too high compared with other computing costs. Steps are being taken to remove the main bottlenecks in the network and to introduce a means of interconnecting the various local area networks now being established throughout our community. Another possible element in solving the problems of speed and cost of connection is the introduction of digital telephone exchanges which can transmit both speech and data. These exchanges would allow information to be carried in the same telephone lines as speech.

The ECC regards the replacement of the existing telephone network by a new digital network as potentially a very significant factor in the development of computing in the University.

6.7 Investment Priority and assignment of funding

The ECC intends to assign priorities to the investment of all its resources against each of the categories of service defined in the preceding sections of this paper. In addition to the capital funds of £500K assigned to personal computers and smaller multi-user systems within the control of ECC, it is expected that more than double that investment will be undertaken by departments from their own funds and research grants.

The requirements of network enhancement, software provision and the replacement of terminal and peripherals are expected to need at least another £500K of capital support from the ECC and a matching sum from departments and other dependants on the network.

The advice we have received from the Computer Board secretariat is that with the recent Computer Board grant of £100K for network development it is unlikely that the Board would be sympathetic to any request for additional funding in this regard for the second half of the 10 year planning period. The ECC is therefore planning on the use of non Computer Board funds for developments relevant to communications. The cost of the University's PABX replacement is likely to be in excess of £2M and the funding of that enterprise has to be treated as a separate exercise, though this will inevitably constrain the amount of capital available within the University for other purposes.

The expenditure on personal computers and smaller multi-user machines is continuous and distributed in Edinburgh across external sponsors, Faculties and the central funds of the ECC. The justification of any particular component in this category of resource requires a very detailed understanding of the make-up of the University's present investment in this area. The ECC is therefore hesitant to approach the Computer Board at the 5 year review period in this connection unless there is some obvious matching of requirement to some specially promoted investment programme by the Board. The recently circulated report on the need for additional computer facilities to support the teaching functions could be such a situation. The University is therefore taking further advice through its senior academic planning machinery to ascertain whether the teaching staff wish us to mount the recommended new initiatives at a time of continuing reduction of funding from UGC sources. Meanwhile the ERCC and CAST are exploring the opportunities for supplementation of the various existing activities which address the objectives

defined in the Computer Board's report. There is no developed proposal available at this time which we are in a position to submit to the Board as a case for funding at the time of the 5 year review.

In these circumstances and in view of the local plans to invest in excess of £2M of its own capital in other areas of computing over the next five years the ECC invites the Computer Board to concentrate its attention at this time on our needs in the Central Mainframe area. The following section presents a statement of how that need might be satisfied.

7. PROPOSAL FOR A 2976 REPLACEMENT

To satisfy the specification of mainframe service enhancement defined in section 6.2 five options have been analysed and costed. The results of that analysis are given in the following sections.

The net cost to the University and/or the Computer Board of the recommended option would be £750K-£800K over the five year period 1985-1990 and would provide a secure base for further enhancement both within that period and beyond if so required. The configuration of one of the preferred systems is given in Figure 7.1.

The options that have been considered are; (i) the retention of the existing dual 2976 and the regional 2988 with the procurement of a second 2988 processor; (ii) the replacement of the dual 2976 with an ICL ATLAS I configuration; (iii) the replacement of the dual 2976 with an IBM 3083 B configuration; (iv) the further enhancement of the IBM 3083 B to the J model on closure of the 2988 service (v) the replacement of the dual 2976 with an Amdahl 5850 configuration.

7.1 Processing Capacity

A series of calibration tests have been run on the 2976 and 2988 processors at the ERCC and with the assistance of ICL, IBM and Amdahl these have been compared with measurements on the ATLAS I and L processors, the 3083 B and J and the 3081 D and K processors of IBM, and the 5850 and 5860 processors of Amdahl.

Table 7.1 represents the best available comparison between processors of the 2900 and the three 370-XA architectures; the test programs were compiled with comparably mature compilers and identical compiler options.

The tables show the results of three test programs which have been run "stand-alone" on each of the processors indicated. Although processor speed is but one factor in the assessment of a machine, these programs are known to give reliable indications of certain aspects of system and user-program performance under EMAS, having been run on a wide variety of 360-370 and 2900 processors since 1968.

An important part of the operational requirement is a good "single-instruction-stream" performance: since a given user program will execute on one processor, those users requiring to execute really long programs will clearly get better use overnight, when system load is lighter, from a single processor of 10 Mips than from two processors of 5 Mips each.

The comparisons are therefore separately presented in terms of single instruction stream performance and the throughput measure where the effects of multi-processor combinations are revealed.

One test program executes a weighted series of cycles of instructions to give an indication of average user-program performance, for programs without a strong floating-point content. The performance of the existing dual 2976 with DAP's is defined as unity and the options are measured relative to that base. In Table 7.1 the performance is quoted for a number of machines and this average user measure falls between the limits that apply to the other two test programs.

Figure 7.1 Atlas10 Configuration for EMAS-3

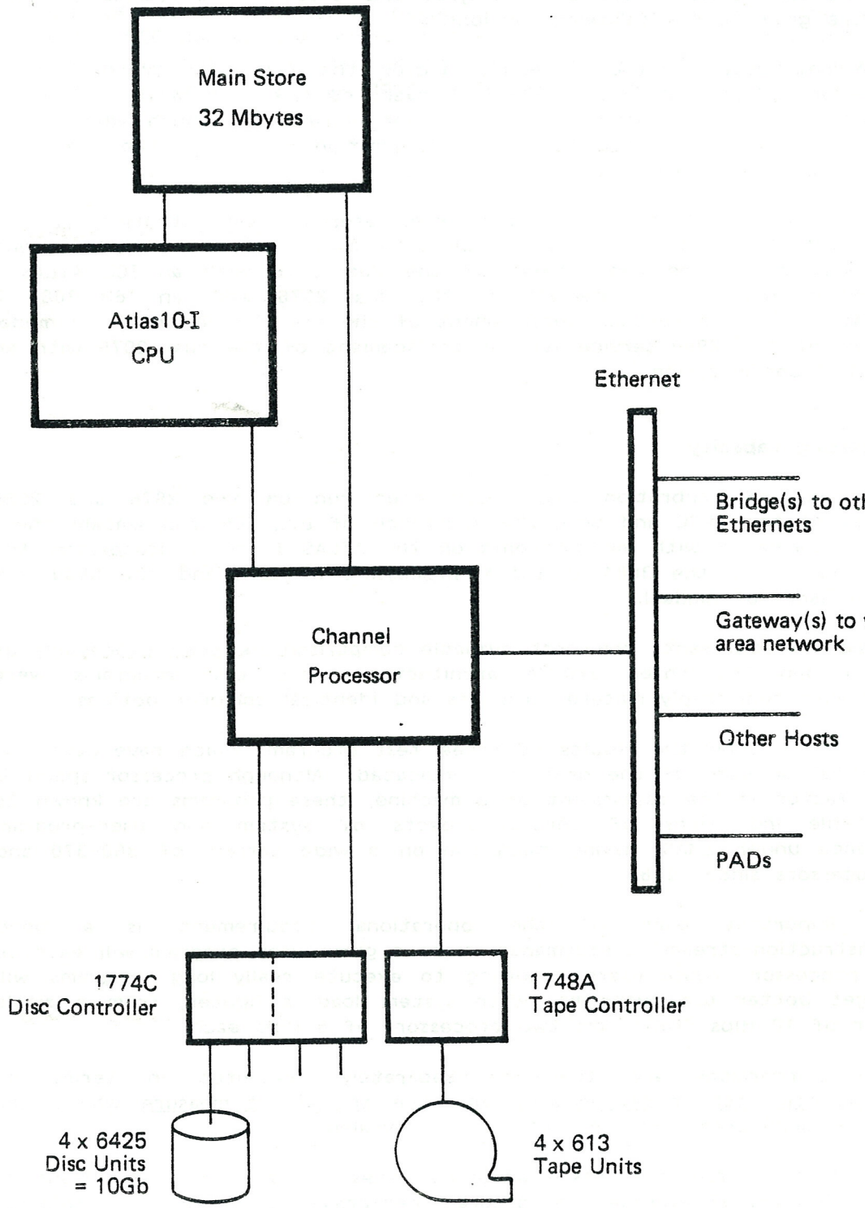
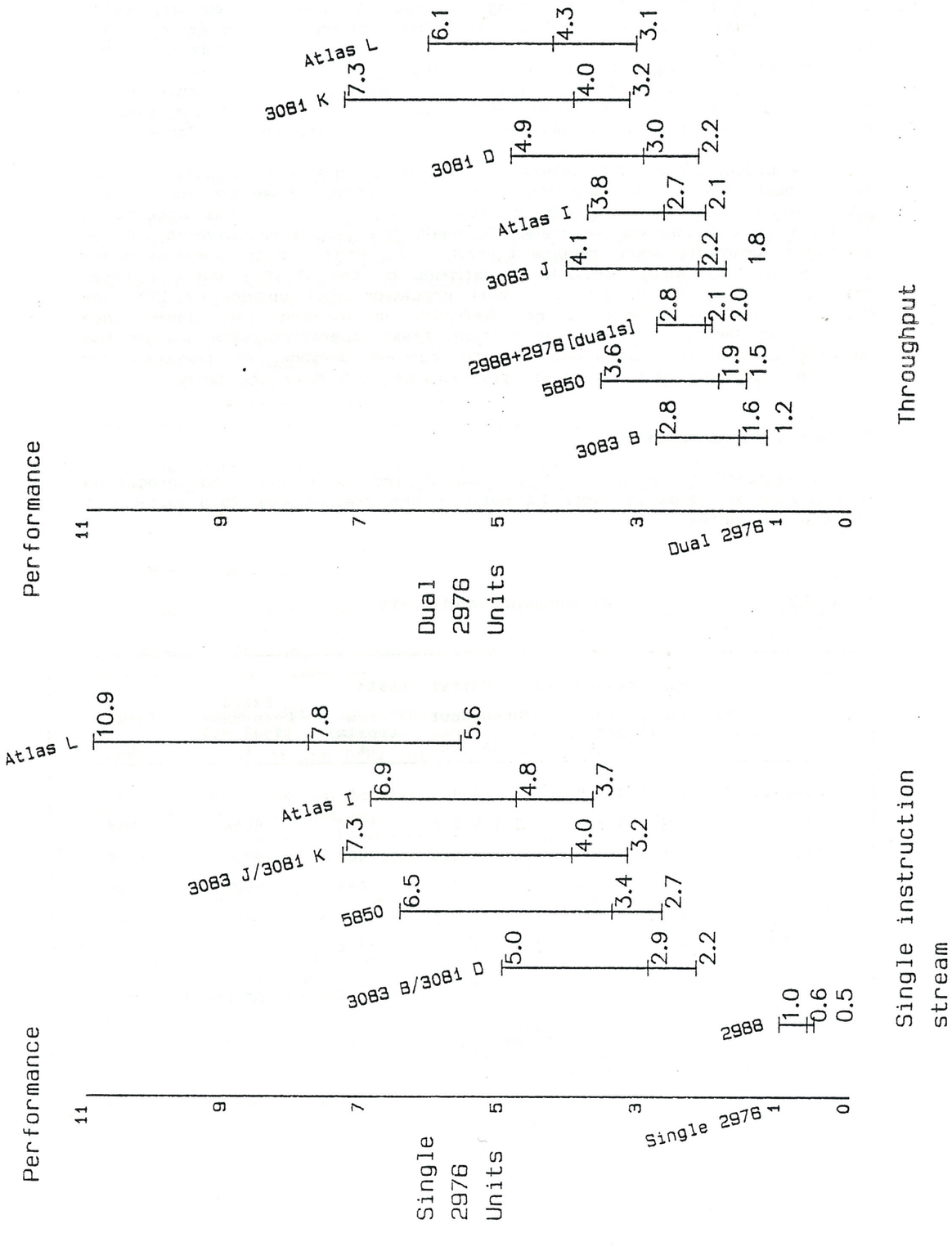


Table 7.1 Performance Comparison Between 370-XA and 2900 Processors



The second test program performs computations on a 100*100 matrix of double-length floating-point numbers, and gives a good indication of "heavy computing" user-program performance in normal service. The results of these tests represent the lowest limits in Table 7.1

The third test program measures the best time for execution of a procedure call in the IMP programming language. It uses a limited set of the fastest machine instructions. Since the EMAS supervisor involves execution essentially only of this set of instructions, the results of this test give pointers to the maximum number of simultaneous users which could be supported - given sufficient main store and channel capacity. Alternatively, it can be regarded as a measure of EMAS supervisor efficiency on the relevant system. The results of these tests represent the highest limits in Table 7.1.

The processing capacity presently available to Edinburgh users is made up of the dual 2976 and DAP and one third of the 2988. If we use the average job measure of performance and the data given in Table 7.1 this amounts to 1.2 units in the comparative scale. To meet the stated requirement of the Edinburgh community would require a total of 2.4 units for this measure which in terms of throughput can only be satisfied by the ATLAS I and L options, the Amdahl 5860 option and the multi processor 3081 options of IBM (the Models D and K). There is no difficulty in meeting this performance improvement factor for single instruction stream operations with any of the options, this is not surprising as the current arrangement involves four separate processors each of modest performance by today's standards.

7.2 Cost v Performance

A comparison of costs (both capital and recurrent) and processing performance are made in Table 7.2 between the present dual 2976 installation and the five options.

Table 7.2 **Performance and costs**

Configuration	Performance+ (2976 Units) Single Inst. Stream A	B	C	Throughput A	B	C	Costs New Capital £	Extra Recurrent (1985-90) £	Total £
1. Dual 2976	1.0	1.0	1.0	1.0	1.0	1.0	0	0	0
2. 3083 B	2.2	2.9	5.0	1.2	1.6	2.8	1,150K	-500K	650K
3. Amdahl 5850	2.8	3.5	6.5	1.5	1.9	3.6	1,250K	-500K	750K
4. ATLAS I	3.7	4.8	6.9	2.1	2.7	3.8	1,300K	-500K	800K
5. 3083J	3.2	4.0	7.3	1.8	2.2	4.1	1,450K	-500K	950K
6. Dual 2976 & Dual 2988	1.0	1.0	1.0	2.0	2.1	2.8	750K	350K	1,100K

Note: Capital prices include VAT

+Performance tests carried out:
A Matrix/floating point test
B General instruction mix test
C Procedure call test

Each of the cases 2 - 6 allow for the provision of 10 Gigabytes of disc space and 4 tape decks of modern design. The front end processor requirement for these systems has also been included in the estimates.

The net cost of the IBM 3083 J option would be subject to negotiations in the event of a two phase provision e.g. the 3083 B as an initial installation followed by the J as an upgrade following closure of the 2988 facility would probably be cheaper than indicated.

While the additional 2988 option represents the lowest capital cost it is also the greatest in net cost to the Board over the remaining five years of the 10 year review period.

7.3 Development Potential

The option of retaining the dual 2976 and enhancing it with a dual 2988 does not seem cost effective. It would also exhaust the potential of the present 2900 series as a vehicle for EMAS services, and although there is no certainty that there will be a requirement for EMAS in five to ten years time it is very likely that there will be.

The IBM 3083 B and J models the ATLAS I and the Amdahl 5850 have upgrade paths capable of providing further processing power with minimum disruption of service, although the ATLAS and Amdahl processors can better satisfy the requirements of users having heavy CPU requirements in batch mode because both models, are based on uni-processors.

The costs of these upgrades are expected to fall steadily over the next three years and to be affordable from within ECC local funds if the investment priority at the time favours central mainframe enhancement.

7.4 Recommended options

The option preferred by the University is that of replacement of the dual 2976 system by a system based on Fujitsu components supplied and supported by ICL, in the shape of an ATLAS I processor with 10 Gigabytes of disc storage and 4 tape decks.

The target date of closure of the present 2976 service would be October 1985 with a skeleton system sustained after that date for the benefit of users of the DAPs until the summer of 1986.

To meet these target dates it will be necessary for the University to obtain access to or delivery of the replacement processor from the summer of this year and negotiations have been started to effect such an arrangement both within the University and with ICL.

It is hoped that the Computer Board will be able to advise the University after its May meeting on the level and timing of support that it can provide against these proposals and as to what selection procedure should be employed. A capital grant of £1.3M, or a grant of £0.8M and approval to retain subsequent savings in recurrent grant over the period 1985/86 - 1989/90 would enable the University to proceed with its global investment programme without prejudicing one or more of the other areas of development which have been described earlier.

8. FINANCE

8.1 ERCC - Income and Expenditure 1978/1984

EXPENDITURE

Financial Year	Staff	Computer maint/rent	Other	Transfers to Capital	TOTAL
	£	£	£	£	£
1978/79	935227	323998	581319	65000	1905544
1979/80	1135675	303198	680396	150000	2269269
1980/81	1494670	319737	893016	70000	2777423
1981/82	1612889	347169	910187	84900	2955145
1982/83	1695871	402280	1142213	80000	3320364
1983/84+	17644500	402800	1076600	94000	3337900

INCOME

Financial Year	Computer Board*	University	Other	TOTAL	Surplus/ Deficit
	£	£	£	£	£
1978/79	700526	623029	572853	1896409	-9135
1979/80	860975	744405	641786	2247166	-22103
1980/81	516774	1578666	711867	2807307	29884
1981/82	619665	1652458	802033	3074156	119011
1982/83	641530	1599739	956671	3197940	-122424
1983/84+	656800	1636560	1095300	3388660	50760

*Computer Board grant includes the maintenance and rental costs of the Regional 2988.

+Estimated.

8.2 Computer Board Capital Grants (excluding any for Regional service)

			£
1979/80	C092/050/01	Terminals (50%)	10,648
	C092/053/01	2972 (installation, air cond, etc)	102,620
	C092/053/02	2972	1,558,574
	C092/054/01	Microprocessor equipment	14,953
	C092/055/01	Microprocessor development system	15,803
	C092/058/01	Cambridge ring (50%)	5,750
	C092/057/01	Network enquiry facility	12,347
1980/81	C092/054/02	Terak (for NAG Pascal project)	6,446
	C092/056/01	Terminals (50%)	13,800
	C092/060/01	PSS gateway	19,820
	C092/061/01	2972 Store access controller (50%)	13,225
	C092/063/01	2972 additional FEP (50%)	17,250
1981/82	C092/065/01	GEC 4065 X25 switch	24,321
		Minor Facilities Grant	13,000
1982/83		Minor Facilities Grant	39,000
1983/84	C092/068/01	GEC CPSEs (part cost)	100,000
		Minor Facilities Grant	39,000
		Total	2,006,557

The years are academic years. Costs are actual for each project, not the grants originally awarded.

8.3 University Grants to Edinburgh Computing Committee

		£
1979/80	UGC Equipment Grant	55,450
	UGC Microprocessor (earmarked) Grant	21,500
	Capital transfer from revenue	65,000
1980/81	UGC Equipment Grant	56,498
	Capital transfer from revenue	65,000
	Capital transfer for Regional service	85,000
1981/82	UGC Equipment Grant	85,500
	Capital transfer from revenue	70,000
	Transfer from Science Faculty	10,150
1982/83	UGC Equipment Grant	74,000
	Document Preparation Grant	43,000
	Capital transfer from revenue	84,900
1983/84	UGC Equipment Grant	125,000
	Capital transfer from revenue	80,000
	Total	920,998

8.4 University Grants to Faculties for Computing Equipment

	£
1979/80	327,794
1980/81	364,708
1981/82	339,373
1982/83	457,074
1983/84	583,115
Total	2,072,064

8.5 Payments to Remote Computing Centres

Year	NUMAC	Cambridge	UMRCC	ULCC	Total
	£	£	£	£	£
1979-80	2104	75	1800	-	3979
1980-81	1865	82	3971	-	5918
1981-82	2750	50	4600	-	7400
1982-83	-	160	4600	-	4760
1983-84	-	-	4600	4600	9200

8.6 Research Council Grants to the University

	1979/80	1980/81	1981/82	1982/83	1983/84
	£	£	£	£	£
AFRC	120,197	220,152	239,723		
MRC	645,608	1,398,162	1,427,508		
NERC	148,350	233,756	213,626		
SERC	626,937	1,674,233	1,920,224		
ESRC (SSRC)	139,745	312,269	236,217		
Total	1,680,837	3,818,572	4,037,298	5,969,963	6,000,000

A breakdown is not available for 1982/83, but the total includes an individual project grant of about £1.5M (from SERC). The total for 1983/84 is an estimate, since not all grants have been awarded yet.

APPENDIX A

STAFF AND STUDENT NUMBERS BY UGC SUBJECT GROUP

FTE STUDENT NUMBERS

UGC SUBJECT GROUPS	1978-79		1979-80		1980-81		1981-82			1982-83		
	Ug	Pg	Ug	Pg	Ug	Pg	Ug	Pg		Ug	Pg	
Education	20	49	17	58	11	73	7	73		5	89	
Pre-Clinical (Med & Dent)	409	46	445	41	437	42	457	39		463	37	
Clinical Medicine	583	202	566	182	582	183	602	185		616	182	
Clinical Dentistry	143	1	146	1	152	1	146	1		140	1	
Studies Allied to Medicine	74	25	70	24	75	30	80	25		80	29	
Engineering	310	55	334	48	371	52	399	62		421	74	
Agriculture & Forestry	254	116	273	111	271	125	275	122		254	118	
Veterinary Science	256	66	259	69	253	66	256	76		253	77	
Biological Sciences	422	113	415	118	390	120	363	131		340	137	
Mathematics & Computing	565	84	606	74	662	87	673	87		681	86	
Physical Sciences	821	174	776	155	746	160	759	170		759	176	
Business Studies	241	49	286	46	299	46	304	48		315	59	
Social Studies	1938	363	1807	319	1808	356	1823	399		1790	397	
Architecture & Planning	133	150	140	135	125	126	127	122		122	106	
Arts	2198	419	2134	356	2237	349	2268	313		2214	322	
TOTAL	8368	1914	8272	1735	8418	1816	8538	1854		8451	1890	

FTE STAFF NUMBERS

UGC SUBJECT GROUPS	1978-79			1979-80			1980-81			1981-82			1982-83		
	Lect	Res	Other	Lect	Res	Other	Lect	Res	Other	Lect	Res	Other	Lect	Res	Other
Education	15	4	3	16	6	3	15	7	3	14	10	2	9	10	0
Pre-Clinical (Med & Dent)	74	14	3	75	18	2	76	15	4	74	13	5	67	15	2
Clinical Medicine	184	69	2	202	61	2	200	78	2	199	87	2	196	106	3
Clinical Dentistry	26	0	7	34	0	8	34	0	8	33	1	9	31	1	4
Studies Allied to Medicine	12	9	0	12	9	0	12	8	0	8	7	0	11	6	0
Engineering	54	21	0	54	27	1	59	12	0	57	38	0	53	45	3
Agriculture & Forestry	35	9	0	37	10	0	36	7	0	34	5	0	32	2	0
Veterinary Science	76	26	1	81	29	1	84	25	1	80	22	0	73	24	0
Biological Sciences	79	59	2	81	72	2	78	76	2	75	73	1	73	73	1
Mathematics & Computing	67	20	5	66	27	5	68	30	7	67	31	9	64	34	8
Physical Sciences	113	32	5	116	39	5	116	48	6	107	56	5	101	48	5
Business Studies	20	3	1	22	3	1	22	4	1	22	2	1	20	1	0
Social Studies	174	46	1	178	54	1	175	47	1	172	40	1	158	34	1
Architecture & Planning	28	10	1	28	4	1	30	7	1	29	9	1	25	6	1
Arts	279	11	3	280	14	3	273	14	4	256	14	4	246	17	2
TOTAL	1236	332	34	1281	372	35	1277	395	42	1227	406	41	1157	421	30

NOTES:

1. All figures given are for full-time equivalent numbers.
2. "Lect" means lecturing staff including UGC funded research staff.
3. "Res" means staff on research contracts other than UGC funded research staff.
4. "Other" means staff on administrative or 'Other related' scales.

APPENDIX B

LIST OF USER DEPARTMENTS

Faculty of Science

Science Faculty Office
Agriculture
Machine Intelligence Research Unit
Animal Genetics
Astronomy
Zoology
Forestry and Natural Resources
Molecular Biology
Botany
School of Artificial Intelligence
Computer Science
Chemistry
Mathematics
Statistics
Geology
Meteorology
Physics
Geophysics
Electrical Engineering
Fire Safety Engineering
Chemical Engineering
Mechnical Engineering
Civil Engineering

Faculty of Social Sciences

Accounting
Architecture Research Unit
Business Studies
Centre for the Research in Educational Sciences
Economic History
Economics
Educational Studies
Geography
Politics
Nursing Studies
Psychology
Social Administration
Social Anthropology
Sociology
Centre for Educational Sociology
Urban Design and Regional Planning

Faculty of Medicine

Anaesthetics
Biochemistry
Faculty Office
Cardiology
Child Life and Health
Clinical Surgery
Conservative Dentistry
Oral Medicine and Oral Pathology
Geriatric Medicine
General Practice
Medical Computing and Statistics Unit
Medical Information
Opstetrics and Gynaecology
Orthopaedic Surgery
Pharmacology
Preventive Dentistry
Physiology
Clinical Oncology
Forestry Commission Research
Respiratory Diseases
Psychiatry
Community Medicine
Surgery
Otolaryngology
Pathology
Clinical Chemistry
Regional Hormone Laboratory
Medicine - Royal Infirmary
Medical Physics & Med Engineering
Ophthalmology
Rehabilitation Studies Unit
Oral Surgery
Human Genetics
Medicine - Western General
Medical Physics - Western General
Forth River Purification Board
Scottish Council for Research in Education

Faculty of Arts

Arts Faculty Office
History of Medicine and Science Unit
Linguistics
Middle English Dialect Atlas
English Literature
English Studies (Foreign Students)
French
German
History
Institute for Applied Language Studies
Linguistic Survey of Scotland
English Language
Philosophy
School of Scottish Studies
Archaeology
Humanity
Islamic Studies

Faculty of Law

Criminology
Faculty Office
Legal Practice Unit
Scots Law

Faculty of Veterinary Medicine

Animal Health
Veterinary Computing Group
Tropcal Animal Health
Veterinary Pathology
Veterinary Pharmacology
Veterinary Physiology
Tropical Veterinary Medicine
Veterinary Surgery
Small Animal Practice Teaching Unit

Faculty of Divinity

Systematic Theology

Non-Faculty Departments

Careers and Apptments Advisory Service
Data Processing Unit
Secretary's Office
Centre for Human Ecology
Industrial Consultancy and Liaison
Library
Dictionary of the Older Scottish Tongue
Centre for Application Software and Technology
School of Epistemics
Bangour Village Hospital
East College of Agriculture
Craigie College of Education
National Museum of Antiquities
West College of Agriculture
Dunfermline College of Physical Education
Daresbury Laboratory
Dundee College of Technology
Lothian Regional Council
Economic and Social Research Institute
Moray House College of Education
North College of Agriculture
Napier College - Chemistry
National Library
Alcohol Research Group
World Federation of Haemophilia
Scottish Office Computer Service
Institute of Occupational Medicine
Astley Ainslie Hospital
Young Peoples Unit
South Lothian District (LHB)
Scottish Cancer Trials Office
Royal College of Surgeons of Edinburgh
Roslynlee Hospital
Royal Scottish Museum
Scottish Health Service
St Andrews College of Education
Scottish Development Agency
Lothian Health Board
Edinburgh Geological Society

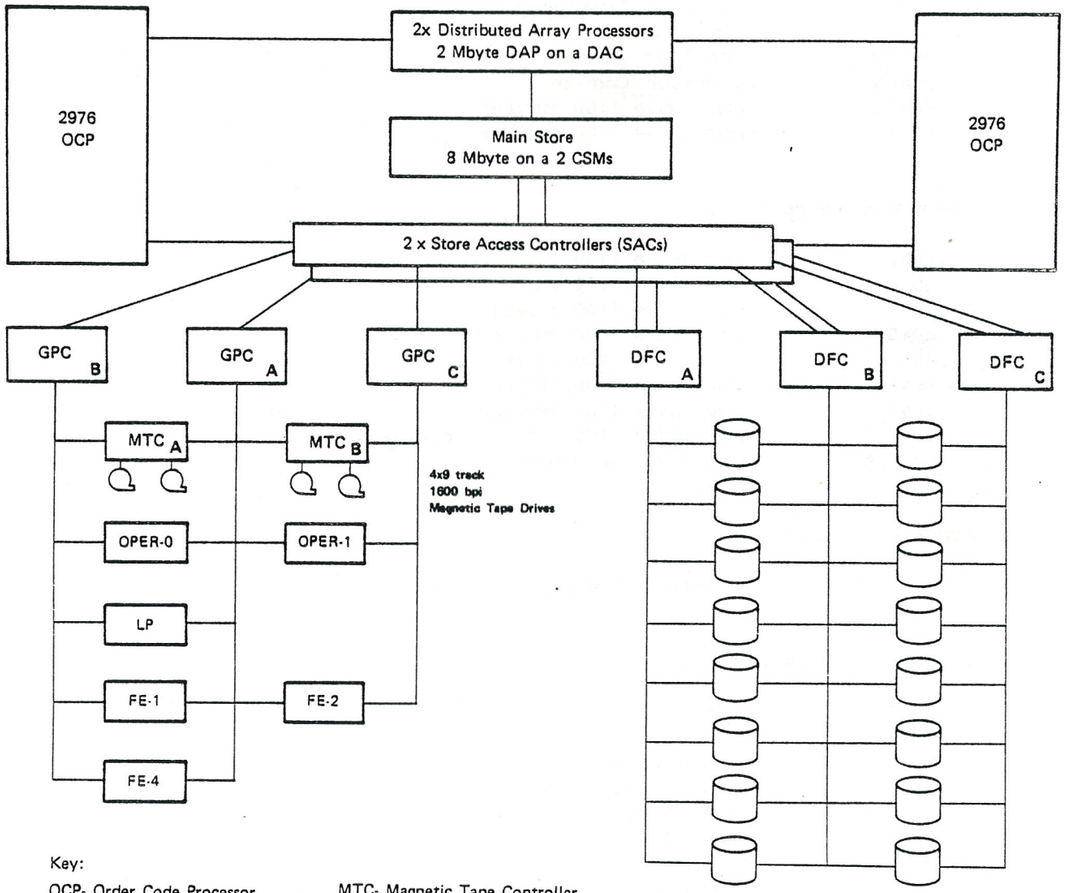
Commercial Users

ICL Mini-DAP Project
John Wilder (Engineering) Ltd
Bank of Scotland
British Telecom
R H Cuthbertson & Associates
D O Forfar
GIMMS Ltd
ICL Communications System Department
Inveresk Research International
MEL Ltd
MACROC Ltd
M A C Weir
Nickerson Group Management
Oceanroutes (UK) Ltd
Telecom Australia Research Labs
Wood Mackenzie & Co
Scottish Council (Dev & Industry)

Research Council and DAFS Institutes

Animal Breeding Research Organisation
Glasshouse Crops Research Institute
Unit of Animal Genetics
Poultry Research Centre
Rothamstead Experimental Station
ARC Unit of Statistics
Brain Metabolism Research Unit
Clinical and Population Cytogenetics Research Unit
Epidemiology of Psychiatric Illness Unit
Mammalian Genome Unit
Reproductive Biology Research Unit
Freshwater Biological Association
IGS Geological Survey of Scotland
Hill Farming Research
IGS Geomagnetism Unit
IGS Marine Geophysics
IGC Computer Unit
IGS Global Seismology Unit
Scottish Marine Biology
Institute of Terrestrial Ecology
Animal Diseases Research Association
Scottish Crop Research - Invergowrie
Rowett Research Institute
Hannah Research Institute
Scottish Institute of Agricultural Engineering
Scottish Crop Research - Pentlandfield

Appendix C – ERCC Dual ICL 2976 Configuration



Key:

OCP- Order Code Processor
DAP- Distributed Array Processor
DAC- DAP Access Controller
SAC- Store Access Controller
CSM- Common Store Module
DFC- Disc File Controller
GPC- General Peripheral Controller
MTC- Magnetic Tape Controller
OPER- Operator Console
LP- Line Printer
FE- Front End (Communications Processor)
Mbyte- 1,048,576 bytes

Approximate Age of 2976 Equipment as at 30th June 1985

Equipment 10 years old

DFC 'C'	-Disc File Controller
GPC 'A'	-General Peripheral Controller
GPC 'B'	-General Peripheral Controller
MCT00	-Magnetic Tape Controller
MCT01	-Magnetic Tape Controller
MT00	-Magnetic Tape Drive
MT01	-Magnetic Tape Drive
MT10	-Magnetic Tape Drive
MT11	-Magnetic Tape Drive
LP	-Line Printer
OPERM	-Operator Console
OPERS	-Operator Console
ED01	-Disc Drive (100 Mbyte)
ED02	-Disc Drive (100 Mbyte)

Equipment 9 years old

ED00	-Disc Drive (100 Mbyte)	
ED10	-Disc Drive (100 Mbyte)	
ED13	-Disc Drive (100 Mbyte)	
ED40	-Disc Drive (100 Mbyte)	
ED41	-Disc Drive (100 Mbyte)	
ED42	-Disc Drive (100 Mbyte)	
ED44	-Disc Drive (100 Mbyte)	Stand-by spares
ED45	-Disc Drive (100 Mbyte)	provided by ICL
DFC 'A'	-Disc File Controller	

Equipment 7 years old

GPC 'C'	-General Peripheral Controller

Equipment 5 years old

OCP2	-Processor
OCP3	-Processor
SAC0	-Store Access Controller
SAC1	-Store Access Controller
CSM 'A'	-Main Store (4 Mbyte)
CSM 'B'	-Main Store (4 Mbyte)
DFC 'B'	-Disc File Controller
ED03	-Disc Drive (200 Mbyte)
ED04	-Disc Drive (200 Mbyte)
ED06	-Disc Drive (200 Mbyte)
ED12	-Disc Drive (200 Mbyte)
ED14	-Disc Drive (200 Mbyte)
ED43	-Disc Drive (200 Mbyte)
SRU	-System Reconfiguration Unit

Equipment 4 years old

ED05	-Disc Drive (200 Mbyte)
ED15	-Disc Drive (200 Mbyte)

DEVELOPMENT OF INFORMATION TECHNOLOGY IN THE UNIVERSITY OF EDINBURGH

1. Introduction

The University established a Committee on Information Technology as a joint Committee of Court and Senatus in March 1982 "to promote the study of Information Technology within the University of Edinburgh and such other institutions or organisations with which effective collaboration can be achieved". Edinburgh University already had considerable expertise in Information Technology (IT); the aim of the Committee has been to coordinate and focus the activities taking place in a variety of departments. The Committee, under the Convenership of Professor J H Collins, Department of Electrical Engineering, includes representatives from the areas of the University most involved in IT, and external advisers from Government, industry and commerce.

This report outlines the developments which have taken place under the auspices of the Committee on Information Technology.

2. National developments in Information Technology

1982 was officially designated 'Information Technology Year' and there was a national campaign to increase awareness of the importance of IT. Knowing that there were significant developments in other countries, notably Japan, the Department of Industry and the SERC initiated a debate with representatives of Government, industry and academe on a major development programme in IT. This led to the formation of a Committee under the chairmanship of Mr J Alvey, Technical Director, British Telecom which reported in October to the Minister responsible for IT, Mr Kenneth Baker. The report recommended a five year national programme for Advanced IT costing £350M which would be a collaborative effort between industry, the academic sector and other research organisations.

As far as the academic sector is concerned, there will be, over the three years from 1983-1984, a significant expansion in student numbers in IT in universities and colleges; extra staff for research and for teaching of IT, particularly for postgraduate conversion courses; and special SERC research grants and fellowships.

The impetus given through the programme of Government support to research and development in industry, although less than recommended in the Alvey report, will nevertheless have an impact on University research through collaborative projects. In Scotland, which has a highly developed electronics industry, the Scottish Development Agency has established an Electronics Division to promote development in this area. In two of the three critical technologies identified by the SDA, Very Large Scale Integration (VLSI) and Artificial Intelligence, the University of Edinburgh is pre-eminent in Scotland and indeed has centres of expertise of world importance. Similarly, the University has expertise in all the main enabling technologies for the Alvey programme - VLSI, intelligent knowledge based systems (IKBS), software engineering (SE), and man-machine interface (MMI).

3. Education and training

One of the first goals which the Committee set was the introduction of an MSc programme in IT. The basis of such a programme already existed in the MSc/Diploma courses in Computer Systems Engineering and in the Design and Manufacture of Microelectronic Systems. By the summer term of 1982, the preliminary discussions with the SERC on developing the programme had already begun. Before the Alvey report was published, a detailed academic programme had been submitted in draft to the SERC. Thus the University was well prepared for the Government's announcement of support for advanced postgraduate courses in IT.

The new MSc/Diploma programme was introduced from October 1983 with the support of the SERC. The two existing MSc/Diploma courses were widened in scope and entirely new streams in Knowledge Based Systems and Intelligent Robotics have been added. The programme allows graduates from other disciplines to convert to IT. Each of the courses is divided into modules which can be combined into a programme tailored to an individual's needs. The modular structure also makes it easier for the courses to be taken part-time. The University has obtained three additional lecturing posts from the UGC to support the programme and additional support from the SERC. The SERC is providing 40 postgraduate studentships for 1984-1985. Discussions are also being held on expanding the existing MSc/Diploma in Cognitive Science and integrating this programme with the IT courses.

Edinburgh also obtained ten SERC postgraduate research studentships in IT and seven studentships under the SERC scheme for postgraduate research work in cooperation with industry (CASE) in 1983/1984.

An undergraduate programme specifically in IT has not been seen as such a high priority as the postgraduate programme although of course full Honours programmes in Computer Science, Electrical Engineering and Microelectronics already exist and numbers on these courses are growing. The possibility is being considered of an undergraduate degree in IT involving the development of undergraduate courses in Artificial Intelligence.

With the encouragement of the Committee, the University continues to be active in providing post-experience courses, principally under the auspices of the Wolfson Microelectronics Institute. With SDA backing the ERCC has established a training programme for industry in the use of ADA which is likely to be the main software tool for defence work in the next few years.

4. Research

The Committee realised that funds for research were going to become available and that there were likely to be considerable benefits from early investment by the University in developing research projects to the point where they could attract external income. At the request of the Committee on Information Technology, and with the support of the Edinburgh Computing Committee, Resources Committee agreed to allow up to £100,000 from ERCC's reserves to be used to 'pump-prime' interdisciplinary collaborative research in IT. The funds are being used for one year to bring in researchers from outside the University and to free University staff to begin work on research programmes which should then be capable of obtaining support from external funds.

There has been a significant increase in the number of posts for staff engaged mainly on research in the main IT Departments. The University has obtained eight UGC funded posts primarily for research in IT. With the three UGC posts for the MSc programme this makes a total of eleven UGC funded IT

posts, more than any other University. Also some of the University's 'New Blood' posts are in the area of IT, and Systems Designers Ltd, ICL and Sinclair have each funded lectureships or fellowships in IT. The University has also been very successful in obtaining grants from the SERC for research in IT since the Alvey proposals were submitted.

A series of workshops is being held on the theme of VLSI research and design involving leading experts in the field.

5. Collaboration with industry

An Artificial Intelligence Applications Institute has been established in association with the Department of Artificial Intelligence. The purpose of the Centre is to promote the transfer of technology from the Department of Artificial Intelligence by undertaking research and development work under contract or in collaboration with industry and by mounting courses for industry and commerce.

A second project initiated with the Committee's encouragement was the establishment of a VLSI Systems Centre. As has already been noted, Edinburgh is a centre of expertise in VLSI design, with research and development work in the Departments of Electrical Engineering and Computer Science, and the Wolfson Microelectronic Institute. There is also a major SERC funded microfabrication facility in Electrical Engineering. The Centre coordinates VLSI research in designing systems in silicon and provides a valuable VLSI design service for industry.

6. Promotional activities

The Committee has seen it as one of its functions to promote the awareness of the importance of IT, both within the University and in the community. Largely at the instigation of a member of the Committee, Mr K Grover, British Telecom, with the assistance of the University, mounted a three-day exhibition, INFOTEX, in August 1982. INFOTEX was held in the Appleton Tower and was open to the public and to the IT industry, Twenty-three University departments participated in the exhibition. The exhibition also attracted a large number of industrial exhibitors and was very well attended.

During Christmas 1982, a conference on computing and electronics for pupils and teachers, Concept 82, was run with SDA support jointly in Edinburgh and Glasgow. The Chairman of the organising committee for Edinburgh was another member of the Committee, Dr G E Thomas. It is hoped that similar events will be run in future.

The Committee has established a working party to promote the University's activities in IT. Brochures are being produced illustrating the work of University departments and the possibility is being considered of involvement in an annual event along the lines of INFOTEX.

7. School of Information Technology

A working party of the Committee encouraged the establishment of an academic School of Information Technology involving, in the first instance, the Departments of Artificial Intelligence, Computer Science and Electrical Engineering. The School, which is a federation of the three Departments, coordinates teaching and research in the departments at a more detailed level than would be appropriate for the Committee. Other departments will be able to join as associate members.

8. Communications Networks

If the University is to maintain its strong position in IT, then it must develop the capacity to communicate within the University to modern standards. The ability to transmit speech and data cheaply and easily throughout the University is important not only to IT based subjects but to all the University's activities. The Committee on Information Technology views the development of communications as of vital importance to IT, and has given its support to moves to improve the University networks, and in particular to introduce digital telephone exchanges which can transmit both speech and data.

APPENDIX E

REFERENCES RELATING TO THE COMPUTER BOARD'S LIST OF TOPICS

See section:	For information on:
1	History of the Centre in outline but with the last 5 years in detail.
2	Use and growth in computing, locally, remotely and at National Centres.
2.3, 8.6	Use of Research Council central facilities and grants for local projects.
1	Use of Minor Facilities Grant.
8.3, 8.4	Contribution to computing facilities from the University's general income.
2.4	Effects of computing facilities based at departmental level.
4	Local and wide area communications and networking.
3	Activities, projects, research, etc., where the university is regarded as a centre of excellence or as one of the leaders in the field.
2.1, 2.2, 2.3, 3	Requirements of user departments showing historical expansion and projected demands.
Appendix A	Staff and student numbers to allow the review of demand units over the last 5 years and estimated demand units over the next 5 years.
6, 7	Projected requirements in terms of facilities indicating what might be needed in the next 5 years and, in the way of enhancements, the following 5 years.
8.1	Running costs of the Centre; actual costs over the last 5 academic years, projected costs for this year.
8.5	Dependence on remote Centres in terms of financial contribution towards running costs/usage charges and the need to fund capital equipment at those Centres.
5	Procedures used for resource allocation and control.
8.1, 8.2	Use of Computer Board and university funds over the last 5 years.
2.5	Current use of Computer Board funded machine compared with OR for that machine.