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REVIEW OF INFORMATION SCIENCE AND ENGINEERING IN SERC

Report of the Panel chaired by
Sir John Fairclough FEng

April 1992

SERC

Science and Engineering Research Council
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ISBN 1 870669 18 5

FOREWORD

To review our activities in information technology was one of the objectives in the third SERC Corporate plan, of September 1991. The Council is very grateful to Sir John Fairclough, former Chief Scientific Adviser to the Cabinet Office, and the members of the panel that undertook the review and produced this report.

The report has been considered by Council in the light of reactions to it from all relevant bodies. We are naturally pleased at the overall finding on the quality of UK academic research in the subject; SERC's significant increase in investment in IT research and training during the 1980s was directed to just this end.

The recommendations of the panel appear in section 8.3 of the report, labelled A to K. The Council has reached the following decisions on these:

A, B, C and F. Accepted and passed to the Information Technology Advisory Board (ITAB) for implementation.

D. Accepted for investigation by the Engineering Board of the Council.

E. Agreed that a study of industrial needs should be undertaken by ITAB.

G. Council felt that more extensive justification for a move out of work on devices was needed and has asked ITAB to provide it.

H. Council does not accept that single-institution centres of excellence are the only mechanism to be considered in pursuit of the objective here; dispersed teams or networks may be equally valid. The overall aim must be to support the best work whatever its organisational details.

I. Accepted for discussion with the Department of Trade and Industry.

J and K. Accepted for consideration when these matters next come before Council.

Sir Mark Richmond FRS
Chairman, SERC
March 1992

1. BACKGROUND TO THE REVIEW

1.1 Following the completion of the Alvey programme, SERC and Department of Trade and Industry decided to continue their joint sponsorship of information technology research within a new programme titled the Joint Framework for Information Technology, JFIT. (JFIT is operated under the joint DTI/SERC Information Technology Advisory Board, ITAB.) JFIT was launched in 1988; after three years it is timely to make an initial assessment of progress.

1.2 The Council of SERC decided to undertake a series of major programme reviews as part of the commitment in its third Corporate Plan to reassess priorities. The urgency of an assessment of IT within SERC was emphasised by the decision of the Engineering Board, within whose remit the support for IT currently lies, to make a significant reduction in the funding to JFIT. Members of the IT community felt such a reduction was precipitate ahead of a review of the programme, and had been made without adequate consultation with the DTI or due consideration of the important links of IT into the other parts of the SERC programme (particularly within Science Board).

1.3 The terms of reference for the review, and the membership of the Review Panel, are listed in Annex 1. DTI had an assessor on the Panel; it had been agreed in advance that the review would not be a joint one. Before SERC implements any of the recommendations of this review, consultation with the DTI is required.

2. THE DEFINITION OF INFORMATION SCIENCE AND ENGINEERING, AND THE JOINT FRAMEWORK PROGRAMME

2.1 The Panel much prefers the description 'information science and engineering', ISE, for the research supported by SERC, rather than 'IT'. The term 'technology' usually refers to the exploitation of existing knowledge; yet information science and engineering research contains novelty and intellectual challenges to match any area of scholarship. The Panel recognises that 'IT' is now part of the lexicon of UK science; but at the risk of appearing pedantic has chosen to work with the title 'Information Science and Engineering' from this point on in the report.

2.2 The Panel has taken the following as the definition of ISE –

> 'Information science and engineering is research relating to the creation, collection, storage, manipulation, processing, transmission (including encoding/decoding, encryption, error detection/correction), display, and interpretation of information for use by people and machines.'

Many of the research areas falling within the Joint Framework fit awkwardly into such a definition; for example, a major component of the programme is in electronic materials, silicon and compound semiconductors. While electronic devices make an important enabling contribution to ISE their applications extend well beyond the bounds of the above definition. While some device work is required within the programme as a linkage to architectures and system requirements, the basic electronic materials research should be left to the SERC Materials Commission. Control and instrumentation lies within the Joint Framework – but this is merely one of a multitude of important applications of ISE research, and might more logically be placed within the Engineering Research Commission of Engineering Board or within the ACME Directorate. Although we were asked to review the SERC component of the ISE programme as we found it, it needs to be appreciated that this includes activities beyond the conventional boundaries of ISE research.

2.3 The word 'use' in the definition of ISE is enormously important. ISE research should eventually find a user. Any research activity must recognise the needs of users and allow ready transfer of ISE advances to other disciplines. Novel applications of ISE are as likely to be in medicine or astronomy as in 'mainstream' engineering. This presents something of a dilemma for SERC; the Council's ISE programme formally falls within the remit of the Engineering Board, with no organisational ISE interface into other Boards. One path to the 'user' will be the 'direct' path out of the Joint Framework to industry; another will be an 'indirect' path via other academic disciplines (within and without Engineering Board). If in this review we pay particular attention to the indirect path, it is because this should be of particular concern to SERC.

2.4 Recognising the importance of the 'user' of ISE, it is helpful to define who this is. often the 'user' is envisaged to be the next person along the supply chain – thus a simplified representation of users might include:

researcher	→	developer (user of research results)	→	manufacturer (user of demonstrator)	→	purchaser (user of product)

The panel much preferred a modified version of a definition of 'user' provided in one of the submissions made to it, namely:

> 'The user is anyone who gains a direct competitive advantage through applying the results of ISE research.'

Under this definition a 'user' might be a person in an unrelated field whose research benefits from an advance in computing; or a systems developer who makes use of a new device; or a manufacturer whose throughput is improved by ISE;... or indeed the next person in a supply chain leading to the production of a profitable product.

3. PRIORITIES FOR ISE RESEARCH

3.1 ITAB (or should it be ISEAB?) has well publicised priorities for its support of ISE. The Review Panel debated these at considerable length and concluded that the principal priorities and their ordering had particular merit. The Panel has reworded these priorities slightly, and added some qualifications – but in essence they remain those established by ITAB soon after its formation. The priorities (in order) are:

A. **To maximise derived benefit from the use of ISE.** With limited resources in a highly competitive world the first priority is to maximise the effectiveness with which the results of ISE research are used through the improvement of techniques, tools and methods oriented towards all kinds of users.

B. **To maintain an academic core to ISE.** It is critically important to maintain a vigorous capability in fundamental research in ISE as the essential prerequisite to grasping new opportunities as they arise.

C. **Selective reinforcement of competitive advantage.** UK industry cannot achieve a leading position in all technologies, but there are significant opportunities to reinforce selected areas where the UK may achieve or maintain international competitive advantage. In addition there needs to be a link between exploiter and innovator to avoid losing advantage.

3.2 The target percentages of funding to each of these areas is:

A 55%
B 30%
C 15%

(These percentages are under review by ITAB.)

The SERC funding to the Joint Framework programme goes principally to B, and in part to A. DTI funds cover the balance of A, plus C. (When account is taken of the provision of postgraduate training, the funding is split approximately 50:50 between SERC and DTI.) In funding research, it will not always be obvious which of the criteria A B C are being addressed. But the difficulty of classification aside, the Panel certainly saw merit in providing about half of ITAB's support to the area of utility/usability. How well this can be achieved depends on interfaces to other programmes and the methods deployed to encourage technology transfer.

3.3 Technology transfer is an important element of the overall strategy; it is not obvious that the best methods to achieve this are yet in place. In part, industrial collaboration with higher education institutions (HEIs) is promoted through the collaborative programme; in part through several related programmes under LINK; expansion into the use of the Teaching Company Scheme is being undertaken. There seems to be no coherence to the approach to technology transfer; a problem being readdressed by ITAB.

3.4 We will return later to many of the issues embraced within the above priorities; but at this stage we express a few general concerns.

A. **To maximise derived benefit from the use of ISE.** While derived benefit is relatively easy to orchestrate along the direct path to users, it is less easy along the indirect path via researchers in other disciplines who can benefit from advances in ISE research. The Engineering Board has attempted to promote the indirect path in its 'IT into Engineering' programme; this initiative appears to have got off to a rather uncertain start. But SERC should be promoting 'ISE into Everything'; a concept which the rather rigid Board structure of SERC finds difficult to accommodate.

B. **To maintain an academic core to ISE.** The best HEI ISE research is of very high quality; the SERC system of Peer Review does an excellent job in identifying outstanding research proposals. Although ISE research benefits from close coordination and a sensible level of direction, there must always be sufficient flexibility in the system to allow the responsive funding of proposals of particular merit or novelty even if they do not fall conveniently into stated priority areas. This flexibility should exist in both the academic and collaborative components of the programme. In addition, there must be scope to provide support for young researchers seeking to establish a track record. During the Alvey era, of relatively generous funding for ISE research, many research teams were built up and established recognised competence. That funding era is over, and tough decisions have been made; and must continue to be made to concentrate limited resources into the very best HEI groups whose research is genuinely world leading.

C. **Selective reinforcement of competitive edge.** A competitive edge can rarely be achieved based on 'me too' research; 'catching up' research has very little to commend it. Where a research lead has already been attained, then results must be fed rapidly to UK industry (where it exists) – although what constitutes 'UK industry' (or indeed European industry) is a moot point. (our observations and recommendations regarding 'UK industry' refer to companies with a local production and comprehensive research capability.) Where a competitive edge does not exist then one must have the courage to 'leap-frog', or else bow out of the field. This latter option requires tough decisions, but it is foolish to pretend that the UK can be pre-eminent over the whole of ISE research. Collaboration within Europe does allow some scope for collective pre-eminence. The fact that UK industry does not always exist to take-up research results should not by itself preclude research investment in such fields – although it should limit the scale of such investment to research of unqualified excellence. In the absence of a UK indigenous industry, a European outlet might be possible; in addition local expertise might attract inward investment to (re)create a local manufacturing capability (but research should not be supported with this the prime objective).

4. CONDUCT OF THE REVIEW

4.1 The terms of reference given to the Panel essentially covered:

Quality
Relevance
Organisation and resources

4.2 QUALITY

Assessment of quality in a review spanning less than six months was always going to be a difficult task. The Panel felt the best way was to solicit the help of the research community itself. The following evidence was collected:

Each of the committees of ITAB, and ITAB itself, were asked to submit self-assessments; emphasising particular strengths of the research programme, confessing to any weaknesses, and identifying the opportunities for the future.

To leaven the views of the committees, UK experts were asked to write independent assessments. The general topic areas chosen for these assessments, and the individual experts were:

Devices	Mr Clive Foxell
Control and instrumentation	Dr David Clarke
Computer science	Professor Roger Needham
Systems architecture	Professor David Wallace
Communications and distributed systems	Professor William Gosling

These assessments from the UK community were then sent to overseas referees for comment, before the Panel attempted an overall evaluation of quality.

4.3 RELEVANCE

The best people to comment on relevance are the 'users'. In the context of this review three groups of users were approached:

- Industry and commerce (40 individuals were invited to submit evidence)
- Government departments (the following departments were approached: Trade and Industry, Environment, Transport, Health and Defence)
- The committees within the SERC Engineering and Science Boards.

An important component of 'relevance' relates to the substantial investment in post-graduate training. This has three distinct elements; the one-year taught conversion courses, specialist (vocational) Masters-level courses, and research training leading to the PhD/DPhil qualification. The first two of these were the subject of a 1989 study by the Institute of Manpower Studies, and the Panel commissioned an update of this work to take account of the changing needs of industry (the executive summary of this review is at Annex 2). In the time-scale of the review it was not possible to survey industry on their needs for manpower with research training; but it is suggested that a survey be commissioned by ITAB to report at a later date.

4.5 Following the gathering of all this evidence, and an initial assessment, the Panel held a Friday/Saturday meeting (on 11/12 October 1991 at Cosenors House, Abingdon) with 30 key members of the community (including many of those who had submitted evidence). This meeting, which proved to be of particular benefit, allowed the panel to discuss its preliminary conclusions and discuss options for the future.

4.6 The Panel found the evidence presented from the community, referees, committees, and users of enormous value; it wishes to thank all those who offered expert advice.

5. ASSESSMENT OF QUALITY AND RELEVANCE

5.1 DEVICES

Devices research currently spans electronic and optical technologies, with both areas depending heavily on associated high quality materials research. The Alvey programme supported a wide range of electronic device technologies at a time when the UK industry started pulling out of this field. With hindsight, a more focused approach should have been adopted although it has also been argued that the existence of this technology base contributed to the inward investment of international semiconductor companies. The design expertise in application specific integrated circuits and the development of specialised silicon on sapphire technology were notable. The on-going scale of devices research, although substantially more focused, still seems somewhat inconsistent with the exploitation potential in the heavily restructured UK industry.

The corresponding position in optoelectronics has been quite effective. The early work on optical fibre communications was world class, well focused and led to international exploitation by British industry. We remain very strong in this field, partly through special initiatives such as JOERS. However, major investments in display manufacturing have already occurred in Japan and significant manufacture is not expected in Europe, except through inward investment.

5.2 COMPUTING SCIENCE

Computing science is the core discipline of ISE, embracing research in algorithms, programming languages, software engineering, artificial intelligence, data structure and

databases, as well as the hardware architectures and systems on which the software is executed. Computing science grew rapidly during the 1960s, and received a further impulse during the Alvey programme. UK research is of world class in theoretical aspects of computing science, particularly software, and in certain areas of distributed computing and networking, artificial intelligence, and computing systems hardware. World leading research in theory is concerned with program correctness and specification, concurrency, functional programming, and programming language design (including LCF, ML, HOL, occam, and BCPL, which led to C after implementation at the Bell Labs). There is little doubt that such research is highly relevant to technological development, albeit not always in the short term. Pioneering research in networking includes the Cambridge ring and related work on cryptography. In artificial intelligence, UK research is of world class in logic programming, computer vision, and natural language understanding.

5.3 COMMUNICATIONS AND DISTRIBUTED SYSTEMS

This topic covers a very wide range of activities, from satellite communications through to multimedia systems. The evidence submitted to the Panel suggests that the centre of gravity of work lies towards the communications/hardware end of the spectrum rather than the distributed computing/software end. Areas of strength and quality include mobile radio, signal processing and coding, small satellite systems and networking. Mobile radio, which displays a full cycle of benefit, was initiated by a Specially Promoted Programme in Radio Communications, leading to a focus on microcellular systems.

5.4 NOVEL ARCHITECTURES

The UK has an excellent record of innovation in novel architecture computing, achieving a depth and diversity comparable with the best in the world. Significant hardware developments include the Manchester machines, dataflow architecture, and parallel systems such as supernode which have all influenced and had relevance to product development (despite the lack of indigenous industry). The theoretical base is exceptionally strong; there is a good track-record of implementation, including the transputer-based machines and ICL (AMT) DAP; and an outstanding record of innovation in service provision has enabled a good level of applications expertise to be established across a wide range of user departments. There is a natural cross-fertilisation between much of this work and the requirements of the strong scientific community supported through other SERC programmes, particularly in physics and mathematics. The new Parallel Applications Programme is focused on four UK centres with high international reputations, but there is also strength in a number of other centres. In declarative architectures the UK has a world lead, albeit currently weighted towards theory. Collaborative programmes funded by Alvey and Esprit have attracted international attention. UK work in novel architecture aspects of neural networks and intelligent filestores has reasonable visibility in the European context, but these areas are currently very much dominated by the US.

5.5 CONTROL AND INSTRUMENTATION

This is an area of research which has benefited from having a relatively clear definition, and from a succession of successful initiatives such as a clear 'centres of excellence' policy. The combination of innovations in the theory of control with developments from ISE has enabled more complex systems to be controlled, and led to novel products (such as active car suspension and 'fly-by-wire' aircraft). Software control is central to these developments as they allow nonlinear decisions to be made on sensed system state, and allow for systems to be distributed and networked around a complex plant. Mechatronic devices are a currently fashionable and significant development of advanced control and instrumentation (C&I). The UK has made significant contributions to the theory of multivariable control, robust control, self-tuning and adaptive control, and in theoretical contributions to optimisation. In addition, UK groups were among the first to explore and exploit expert systems and neural networks to control plants that are difficult to model mathematically.

C&I research has been a major beneficiary of ISE research and it continues to pose challenging applications. On the whole, however, the ISE used in C&I tends to be conventional rather than pushing the state of the art. To remain relevant, research will need to cover not only control and manipulation of the physical aspects of production, for example pressures and temperatures, but also of management data associated with it, material yields, batch quality records etc. This would indicate that it is necessary to take positive steps to encourage applications-oriented collaboration which would be facilitated by a relocation of C&I within either the ACME Directorate or alongside the EMEC and Process Engineering Committees in the Engineering Research Commission.

5.6 TRAINING

One of the Panel members did an assessment of the quality of a sample of one-year taught courses in ISE, compared with those in mathematics. The conclusion was that the specialist vocational courses were of very high quality; however some of the conversion courses seemed below what was expected at the Masters level. ITAB must ensure that the standard of all conversion courses are genuinely at the Masters level. At Annex 2 is the executive summary of a valuable study undertaken for the Panel by the Institute of Manpower Studies. This revealed the value of conversion course graduates to industry – especially when they were enhancing business and management skills. The survey also revealed a dramatic decrease in the demand for IT graduates, which ITAB should take into account.

6. FOCUSING THE PROGRAMME

6.1 In making recommendations on focusing the programme, we start with the following basic tenets (some of which have been alluded to in earlier sections):

(a) The role of the HEIs in the Joint Framework is paramount; not only because much of the national creative talent resides in the top HEI departments, but because research and postgraduate training flourish in harness with one another. The 'rules' for the collaborative research programmes must therefore encourage maximum involvement of the academic partner(s).

(b) One of the most important of the contributions the HEIs can make is the provision of trained manpower, and this must include retraining for professional development; care must be taken that graduate training is well matched to national needs.

(c) The Joint Framework should continue to constructively reinforce activities promoted through the EC. International partnerships other than through the EC should also be encouraged. In all such partnerships the importance of safeguarding intellectual property needs to be stressed.

(d) ISE is highly interdisciplinary, and its applications pervade the whole scientific, technical, economic, and social environment. User requirements are therefore all important.

(e) Where economic arguments are being used to justify research in ISE, they should take account of the ability of UK-based industry to take-up the results. (It is recognised that fundamental research can be justified merely on the basis of scholarship.)

(f) There should be some clearly defined programme goals ('grand challenges') to help stimulate the community and inspire young researchers; although adequate flexibility must be retained to respond to new opportunities of particular merit.

6.2 In order to achieve these tenets the following actions to (re)focus the programme are proposed:

(a) The rigid adherence of the collaborative programme to the LINK '50:50' funding rule can discourage the optimum level of academic participation. While the panel accepts that there is no prospect of changing the basic LINK funding framework, there is scope for enhancing collaboration through other mechanisms (such as the increased use of industrial 'uncles' in SERC-only projects and of the Teaching Company Scheme, companies subcontracting academia, etc). Greater use should be made of the flexibility available to maximise HEI involvement in collaborative programmes.

(b) Postgraduate taught courses currently used for 'conversion' of those lacking ISE skills, should be used for ISE 'enhancement'. (It should be recognised that graduates should retain their basic discipline, but enhance its usefulness through the acquisition of ISE skills). It is recognised that the best courses already do this; but to emphasise its importance, this mode of advanced training support should be called 'enhancement' rather than 'conversion'. Greater emphasis must be placed on mid-career retraining and professional knowledge enhancement. The quality of courses must be kept under review.

(c) All the committees of ITAB should be asked to take account of EC programmes when formulating their own programmes; this will mean deciding where to place UK support on the basis of how the UK responds to EC programmes, which may vary between science and technology areas.

(d) Utility/usability can only be achieved if potential users are aware of what is on offer, and can share in research advances. Further thought needs to be given to how to improve mechanisms for technology transfer. One of the main barriers to the sensible permeation of ISE within SERC is the rigid Board structure and the sole custodianship of ISE by the Engineering Board. The present organisational arrangements need to be changed.

(e) The reduced capability of UK industry in the devices area suggests a further significant shift of research resources out of devices and into other ISE programmes where the UK retains an active industrial presence. Silicon-related research should be reduced further, although the 'niche' potential for compound semiconductor research is recognised. It must be for ITAB to decide how the resources should best be redirected from devices into systems engineering and novel architectures – but the shift we are proposing should be 30-50% of the current devices budget.

(f) The SERC ISE programmes need some 'grand challenges', while retaining a sensible level of flexible funding (in both the academic-only and collaborative programmes) to respond rapidly to new opportunities. The Panel has not sought to identify the 'grand challenges' – this needs to be left to ITAB. There should be half a dozen 'centres of excellence' with a broad range of ISE research, including devices, software, novel architectures, and systems. Coordination of the ISE programme will be important at such centres for them to be recognised as international centres of excellence. Other HEIs will work in only selected areas of ISE. But ITAB must concentrate its resources to only the very best groups; the temptation to spread resources thinly so as to allow at least some support to as many groups as possible is not an effective use of limited research funds.

6.3 The successful running of the programme, and the implementation of our recommendations given below to (re)focus parts of it, requires reasonable stability of funding. The general pressure on research budgets is well understood, and ISE research will need to make tough decisions on funding (including greater selectivity and

concentration, as argued above). The Panel has not been able to establish a case for some absolute level of funding for ISE – and comparisons with funding to other areas (eg by using demand or unfunded alpha statistics) is fraught with problems. However, there seems to have been no obvious basis for the selective funding reductions imposed on ISE research by the Engineering Board. While it is correct that the funding Boards should be able to alter the balance of their programme based on the perceived quality of research, national needs, patterns of demand, size of community and the 'unit of resource' etc, it is widely felt among the ISE community that such arguments were not applied when the reductions were made to ISE research funds. The Panel does not wish to make a judgement on these selective cuts on ISE, other than to suggest that the budget should be held at the 1991/92 level for at least the next three years while the recommendations of this report are implemented. The Council should then review the refocused programme.

7. OPTIONS FOR ORGANISATION

7.1 Four options for organisation were considered:

- the status quo;
- a return to the arrangements of the Alvey programme;
- a new Board structure;
- a shared programme with other Boards (along the lines of the Materials Commission jointly sponsored by Science and Engineering Boards).

7.2 STATUS QUO

Because of the pervasiveness of ISE, the panel would not favour the continuation of the present arrangements.

7.3 THE ALVEY ARRANGEMENTS

During the Alvey programme, academic-only research was supported within SERC by peer-review bodies within the Engineering Board, and the academic-industry collaborative programme was funded by the Alvey Directorate (with little resort to peer review). The Joint Framework has shown that academic-only research and collaborative research are comfortable 'bed-fellows' within a single peer review structure, and the Panel has rejected a return to Alvey arrangements.

7.4 NEW BOARD STRUCTURE

The Panel was alerted to the discussion taking place within the Council on a revised Board structure, based on an options paper produced by an internal 'ginger group'.

Generic model: In this model, systems engineering and systems architecture fall within a Computing Science and Mathematics Board, and devices and control and instrumentation within a Materials and Manufacturing Board.

Integrated model: In this model, computing science falls within a fundamental Sciences Board, electronics within a Materials and Manufacturing Board.

Both of these models split the ISE programme, and for that reason the Panel opposes them (a view reinforced by participants at the Cosenors House meeting).

The Panel was informed that its reservations were fed into the Council discussions, and a modified version of the Integrated Model is being developed, with the whole of the ISE programme within an Information, Materials and Manufacturing Board. This would certainly be a better arrangement than the initial models – but would still require close coordination with ISE-related activities in the proposed Boards in Molecular Science and Processing, and Physics and Mathematics.

7.5 AN INTER-BOARD ACTIVITY

The Materials and Biotechnology programmes, jointly sponsored by the Science and Engineering Boards, have each been successful in highly interdisciplinary activities of key importance to both sponsoring Boards. Should the present Board structure remain intact then ISE should be supported through an inter-Board commission. There are a number of reasons why such an inter-Board approach to ISE would have merit:

- the pervasiveness of ISE;
- the strong input of basic underpinning science (for example physics/chemistry in materials aspects; biology in cognition; mathematics in logic etc);
- the need to encourage collaboration with a wide range of ' users' from basic science (eg astronomy and particle physics), engineering, and external to SERC (eg medical research).

The DTI connection would remain intact in such an arrangement, which would be likely to involve all the Boards of Council providing an appropriate level of support. Certain responsibilities would be delegated to an inter-Board ISE Commission by the participating Boards, such as the main Science Board initiatives relating to ISE. Should such an approach be favoured, a great deal of work would be required to work out the details.

7.6 In any arrangement, the Council and all Boards should include people with a background in ISE.

7.7 As the debate on a revised Board structure continues, the pervasiveness of ISE must be taken into account. ISE contributes to all areas of science and engineering; but in turn ISE must be directed to the needs of users in science

and engineering. Academic 'users' in all disciplines should help define the 'grand challenges' for ISE.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 The Panel believes that in the time available to it a thorough and realistic assessment of the SERC ISE programme has been made. Despite the short time-scale for the review, the degree of cooperation from the research community, committees, users, and referees provided the Panel with a wealth of information on which to reach a collective judgement. The HEI ISE community is producing research of very high quality; but in attempting to do too much SERC is in danger of significantly under-funding the truly world-class ISE researchers in the UK. Although professing a commitment to utility, industrial and commercial 'users' perceive the research community to be inward looking and 'talking to themselves'. There is significant scope for (re)focusing the programme. No one declared any degree of satisfaction with the present organisational arrangements.

8.2 The overall conclusions of this review can be broadly summarised as follows:

- The quality of the academic ISE research in the UK is high, as judged by the panel, and UK and international referees;
- but greater account must be taken of the needs of users, and the current potential of UK industry.
- Although ISE should not expect to be protected from the general strictures on funding, in terms of its intellectual content and strategic importance it is deserving of continued SERC support at the 1991/92 level;
- nevertheless, there is scope for increased concentration of support and selectivity in identifying priority areas.
- The present organisational arrangements for ISE within SERC are far from ideal;
- however the collaboration with DTI is important and must be maintained.

8.3 The specific recommendations of the Panel are:

A. ITAB should retain the strategic emphasis on utility of ISE using the definition of 'user' as anyone who gains a significant competitive advantage through the application of ISE. SERC should be promoting the ideal of 'ISE into everything' – not merely 'ISE into engineering'.

B. ITAB should display greater flexibility in using the spectrum of academic-only to collaborative research, in respect of its academic funds. It should not limit itself to the extremes of sole-SERC funding or LINK rules. Options include the use of industrial 'uncles', increased use of the Teaching Company Scheme, and industry subcontracting work to HEIs.

C. Increased emphasis needs to be placed on technology transfer. This should not be limited to transfer of concepts, but should include the transfer of people. A proposal worth further investigation is that a research assistant employed on a SERC research grant within the collaborative component of the programme should spend a final 6 to 12 months working in the collaborating company rather than spending the full period in the HEI.

D. The emphasis of taught courses needs to be acknowledged as 'enhancement' rather than 'conversion' – including the professional development of ISE personnel in employment through part-time study. The ITAB Education and Training committee needs to check the quality of all taught courses to ensure they are genuinely of Masters standard.

E. Greater emphasis must be placed on the needs of industry in research training. One way of achieving this would be to make the majority of ISE research studentships CASE awards (although it is recognised that protecting the academic core of ISE research means that many research studentships would not be well-matched to CASE). ITAB should commission a study of the needs of UK industry for research training in ISE.

F. ITAB must continue to take full account of the EC programme when establishing its own priorities.

G. There should be a significant shift of programme priorities, out of the devices area and into systems engineering and systems architecture. Savings on devices research should remain with ITAB for deployment to the other ISE areas. The number of rolling grants and facilities needs to be reviewed, and the impact of their rationalisations assessed. Much of the support for devices research is through major rolling grants; there needs to be a move away from the use of the 'heavy roller' to the use of the 'light roller'; namely a basic infrastructure grant which can be used as the foundation on which groups of particular merit can attract funding from industry, the EC, and elsewhere, as well as collaborative project grants under the Joint Framework or LINK.

H. ITAB should identify several (say six) HEI 'centres of excellence' which cover an integrated range of ISE activities. While other HEIs could specialise in specific fields of ISE, ITAB must further concentrate its resources so that the best groups are supported at a realistic level (albeit that this will mean tough decisions will be required to discontinue support for many established groups).

I. The position in the organisational structure of the programme in control and instrumentation should be

reassessed by ITAB and the Engineering Board. A more natural home for it than in ITAB may be within the Engineering Research Commission or within the ACME Directorate. There is important research SERC should be promoting in C&I, and it is deserving of a higher profile than being slotted somewhat awkwardly into the Joint Framework.

J. The new Board structure of SERC should retain ITAB as an entity (albeit embracing the changes specified). This requirement would be met by the proposed Information, Materials, and Manufacturing Board. The pervasiveness of ISE demands close interactions of ITAB with all Boards in any revised structure. If the present Board structure is retained, ITAB should become an inter-Board activity (like the Materials Commission).

K. There needs to be an increased representation from computer science and engineering on Boards and on the Council.

8.4 Following consultation with DTI on the recommendations within this report, it should be passed to ITAB to implement recommendations A to H, the Engineering Board for discussion and a decision (in consultation with ITAB) on recommendation I, and Science Board (and the Materials Commission) for information. The Council needs to take account of recommendations J and K.

ANNEX 1

Terms of Reference and Membership of IT Review Panel

Bearing in mind the need to support the science base and to satisfy user requirements, and recognising that SERC's role in IT falls within the DTI-SERC Joint Framework for Information Technology, the role of the review is:

(i) to evaluate the international standing of the UK academic IT research community and the impact of Council's support over recent years, and the contribution it has made in the provision of trained manpower and of skills and tools in support of industry in Britain;

(ii) to consider the size and priorities for the Council's future IT programme of research and education and training, against the background of the resources in the 1991 Forward Look;

(iii) to consider the desirable relationship between the Council's IT programme, the Council's other programme areas, the programmes of other government departments, in particular the Department of Trade and Industry, the programmes of the Commission of the European Communities and the supply and user industry;

(iv) to consider the Council's future structural arrangements for support of IT;

(v) to make recommendations to the Council.

MEMBERSHIP

4. The membership of the review panel is:

Sir John Fairclough FEng – Chairman
Professor A F M Smith (Imperial College of Science, Technology and Medicine, London)
Dr N Kingsley (Eurotherm Systems Ltd)
Professor D E N Davies CBE, FEng, FRS (Loughborough University)
Dr K Gray CBE(Thorn EMI plc)
Professor M Brady (Oxford University)

Assessor:
Dr K Shotton (DTI)

In attendance:
Dr D H Clark (SERC)

ANNEX 2

Executive Summary

1. The research was commissioned at IMS by the SERC to investigate how demand for IT skills may be changing, as part of a SERC review of their IT 'conversion' courses. In particular, it sought evidence to substantiate a perceived view that requirements were shifting away from generalists with fairly basic IT skills towards specialists with combinations of advanced IT skills and skills from other disciplines. A sample survey of 50 major IT employing organisations, covering both the IT provider and user sectors, eg manufacturing, banks, public services (but not the academic sector), was undertaken in September and October 1991.

2. It is clear that a sudden and dramatic change has taken place in the overall demand for IT skilled staff. After almost a decade of virtually continuous upward growth, demand has begun to level off: less than one in three employers in the survey have increased their IT staffing levels in the last two years. Growth in the user sector has held up better than in the provider sector. The current economic recession is the main cause of the downturn: some of the IT provider companies have also been affected by organisational change in the form of mergers/takeovers.

3. Any new or evolving skill requirements are a continuation of previously identified trends. Overall, there is a greater need for software skills; more network communications expertise; more experience of using 4GL, CAD tools, structured programming methods, artificial knowledge systems and relational databases: more 'all round' IT skills, more business awareness and better interpersonal skills. There are a growing number of 'hybrid jobs' – jobs requiring combinations of advanced IT and other specialist knowledge/skills. Around half of the companies in the survey have them, but generally numbers are very small. The majority of hybrid jobs are ones which require functional/IT skill combinations eg finance, or people/IT skill combinations eg project management, consultancy skills. The few examples of technical/IT skill combinations included construction engineering, aerodynamics and manufacturing specialists. No examples were found of scientific/IT combinations eg biologists.

4. There are major difficulties getting employers to estimate the level of future demand because of the current uncertainties surrounding the economy and its effect on business activity and investment in IT. The general impression is a continuation of present trends in terms of the balance of skill needs rather than any significant new or different need emerging. It is likely that more attention will be given in the future to meeting needs from within their own resources through training and development of existing staff and improvements in efficiency and utilisation.

5. Most of the sample had experience of recruiting IT staff within the last 18 months, including graduate recruitment. However, only two out of three are recruiting in the 1991 graduate round, and intakes in IT have reduced by 36% on average since last year. Graduate intakes in the user sector have fallen back further than in the provider sector. Postgraduate recruitment remains small in comparison, and few employers seek out MSc or PhD students; between 1990 and 1991 postgraduate recruitment has also fallen down by 30% slightly less than for first degree graduates.

6. One in three graduate recruiters are only interested in graduates from IT and related disciplines; the majority recruit from a broader range of disciplines. The latter include some who prefer to recruit from maths, science or business backgrounds rather than any discipline. This pattern of recruitment has changed little in the last few years. Just over half of recruiters expect the non-IT graduates to have some basic IT skills, and more are expected to in the future.

7. Problems of shortages in the graduate market have virtually disappeared: only 6% are experiencing any major difficulties in recruiting graduates for IT functions compared to 46% two years ago. Difficulties continue to exist for those looking for 'the best' and there were criticisms about graduates' poor personal skills and lack of business/commercial awareness. The main reason for the easing of recruitment difficulties is the economic recession.

8. There is general satisfaction with the output from postgraduate 'conversion' courses, and evidence of an increased awareness about them among large employers. With a few exceptions, the conversion course students continue to supplement the general intake of graduates for IT functions, and their first degree is not usually very relevant to the decision to recruit them. They all tend to go into similar jobs as first degree graduates, and any shortfall in skills or knowledge can be made up by in-house development and training. They are particularly attractive to many recruiters not because of what they have done on their first or higher degree course but because they have demonstrated their commitment to an IT career by taking the postgraduate course, and often display more maturity, better personal skills and have more experience of the world of work than first degree graduates. While most employers say they will continue in the future to use the postgraduate courses as a potential source of recruits, their main preferences are likely to continue to be for first degree graduates; just over half would prefer IT first degree graduates and a similar proportion would prefer graduates from non-IT disciplines.

9. Only one in five employers in the survey use any short courses in IT at universities or polytechnics, and slightly fewer use any postgraduate modules for their employees. Most did not see a need to because they have well developed in-house training set-ups to meet their needs, and viewed provision in higher education

institutions as being not specific enough for their needs.

10. In conclusion, the survey has highlighted the downturn in demand for IT specialist staff which will undoubtedly affect the employment prospects of this year's graduates from conversion courses despite the general satisfaction of most recruiters with them. Economic conditions are too uncertain at present to get a useful perspective from employers about future staffing trends. There has been little significant shift in skill requirements but a continuation of previously identified trends in new and evolving technical skills and more emphasis being put on personal skills and business/customer awareness. The survey has not provided evidence of a significant shift away from generalists with fairly basic IT skills towards more 'niche specialists' with combinations of advanced IT and other technical skills. Employers will continue to resource their major requirement, which is for IT generalists, from graduate intakes (both IT and non-IT first degree, and conversion courses), but they will also need more specialist people with IT and non-IT skill combinations, though usually in fairly small numbers. The specialists in greatest demand are more likely to be those from business related disciplines, eg finance, business development, marketing, than from science or engineering.