MAN and TECHNOLOGY

The Social and Cultural Challenge of Modern Technology

Discoveries International Symposium
The Fellowship of Engineering

MAN AND TECHNOLOGY

This book is based on papers given at a Symposium organized in London in 1983 by the Fellowship of Engineering in the DISCOVERIES series sponsored by the Honda Foundation.

MAN
and
TECHNOLOGY

The Social and Cultural Challenge of Modern Technology

Edited by Bruce M Adkins

Cambridge Information and Research Services Limited

First published in 1983 by Cambridge Information and Research Services Limited

ISBN 0 905332 30 X

MAN AND TECHNOLOGY
Editor: Bruce M Adkins

Publishers: Cambridge Information and Research Services Limited
PO Box 147
Cambridge CB1 1NY
England
Tel (0763) 838615/6

Printed in England by
The St Edmundsbury Press, Suffolk

Foreword

Text of Inaugural Address by His Royal Highness
The Prince Philip, Duke of Edinburgh,
The Senior Fellow, The Fellowship of Engineering

Mr President, ladies and gentlemen. I have to say that every time I come into this hall my heart sinks. The first time I came here—I have just worked it out—was 45 years ago to sit the Civil Service examination to get into the Navy. And I have never quite got over it!

As you have heard, I have been a great supporter of the Fellowship of Engineering ever since it came into being in 1976. I attended the Privy Council meeting the other day at which the Charter was approved, and that gave me a great deal of pleasure. As a matter of fact, I was promoting the idea of such a body at the time that I was President of the late—I am not so sure how lamented—Council of Engineering Institutions, back in the late 1960s, so I am delighted to find that the Fellowship is in a sufficiently flourishing state to be made responsible for organizing this important Symposium, sponsored so generously by the Honda Foundation.

However, I am sure you will have noticed that a Symposium on Technology is being organized by a bunch of engineers, which makes me wonder what is the difference between engineering and technology. Or is it that some people prefer to use the word technology because they still think of engineers as grubby-handed men in blue overalls carrying a spanner and an oilcan? In that case I can say that I am very glad to see that the fellows have put on their Sunday best for this occasion! Mind you, the academic ones are always in these clothes, I think.

Anyway, I am sure that the papers to be read will provide a great deal of interesting material, the speakers are highly distinguished in their fields, and I expect their contributions to stimulate a lively debate.

The title of the Symposium says 'Social and Cultural Challenge of Modern Technology'. This could be taken to mean that modern technology poses a threat to society and culture, and by implication that technologists need to be more responsible and considerate. Equally I suppose it could mean that the challenge is to society to make the best use of modern technology in the long-term interest of human civilization. However, I notice that most of the speakers are a bit wary of the word challenge. Instead they appear to prefer such words as effects and impact of technology on society and culture. One title refers to regulation and control while others speak of potential and future possibilities. And of all the titles, the only one that refers to regulation and control implies that technology poses some sort of threat to modern society.

Of course there can be no doubt that technologies do change social and cultural patterns, but then, for example, so do crimes, or wealth. However, it is worth bearing in mind that technologies are not developed with the express purpose of changing society or culture. The primary object is to meet perceived practical human needs. Vastly improved standards of transport and communications, public health and hygiene, housing and household gadgets inevitably change ways of life. All these can raise material standards of living, and they certainly make it possible to increase the quantity of human inhabitants of this earth, but there is no evidence to suggest that they improve the quality of human behaviour or stimulate greater artistic talents.

Quite apart from the social and cultural consequences of modern technology, there is another area that is very significantly affected by technologies and which in turn influences the living population of the world. Modern technologies have created a growing demand for the earth's resources, and they have also developed the means to acquire those resources at an ever-increasing rate. And in the long run, that is if there is to be a long run, common sense suggests that demand will have to be balanced against the sustainable availability of renewable resources. In that sense the success of modern technology poses a very important challenge to human ingenuity, and an even greater challenge to the present generation for the future of all life on earth.

I do not think that any discussion about modern technology can ignore what is certainly the most important challenge of modern technology to mankind; namely the development of the generation of power from nuclear reactors and of nuclear weapons. Both these products of technology pose baffling dilemmas. Evidence suggests that conventional power stations, together with some of the industries they supply, plus vehicle emissions, are mainly responsible for the acid rain which is destroying forests and killing life in rivers and lakes throughout the Northern latitudes. Nuclear power stations may pose other problems but they do not produce acid rain. Then again, all the evidence points to the successful deterrent effect of nuclear weapons. Although they do not stop small wars or the invasion by stronger powers of their weaker neighbours, they have prevented escalation, and they certainly appear to have discouraged armed conflict in Europe. Yet many people still seem fervently to believe that wars are created by weapons. The trouble is that any weapon capable of killing is dangerous the moment it gets into the hands of anyone with the intention of using it. For nearly a hundred years Britain had a naval fleet more powerful than those of the rest of the world put together, but it was not called upon to go to war until 1914. What is known to the Jewish people as the Holocaust was perpetrated without the use of any military weapons at all. More people have been killed by motor cars or by terrorism than by bombs.

Everybody, I think, knows that the destructive power of nuclear weapons is vastly, almost immeasurably, greater than that of conventional weapons. Therefore in all logic there is really no point in having any more of these weapons than the bare minimum to provide a credible deterrent. What really matters are the scruples of their possessors, the character of those individuals with the ultimate power to unleash them. People are far more dangerous than inanimate objects.

Many years ago Albert Einstein said that nuclear power had changed everything, and added significantly 'except our way of thinking'. It is tempting to suggest that nuclear weapons are the ultimate social and cultural challenge of modern technology, but it would not be quite accurate. The challenge is not to such abstract concepts as society or culture. The challenge is directly to our human nature and to the way we think and the way we use our brains. The question is whether the threat of cataclysmic disaster can possibly bring those traditional origins of conflict, human greed, ambition and good intentions, under some sort of rational restraint and control.

Contents

Preface

The DISCOVERIES Project was launched in 1976 by the Honda Foundation under the personal sponsorship of Dr Soichiro Honda. Its main objective is to promote a combined occidental-oriental interdisciplinary approach to world problems, and thus to harmonize the rapid development of very advanced technologies—especially in the fields of information processing, communication and automation—with ecological considerations on which the survival of world civilization (perhaps even of the world itself) must depend.

In pursuance of this objective DISCOVERIES has sponsored a series of international symposia, under the general title 'The Humane Use of Human Ideas', the sixth of which was held in London from 26 to 28 April 1983.[1] This sixth meeting, under the title 'MANTECH, the Social and Cultural Challenge of Modern Technology', was organized by the Fellowship of Engineering and took place in the historic and adjacent headquarters buildings in Westminster of the Institution of Civil Engineers and the Institution of Mechanical Engineers. The first morning's sessions benefited from the personal presence of His Royal Highness the Prince Philip, Duke of Edinburgh, who had given powerful support to the Fellowship since its creation seven years previously, and who as the Senior Fellow delivered an opening discourse which undoubtedly set the very high standard of communication and discussion throughout the three-day meeting.

The Symposium was made up of six main sessions in addition to the opening and closing ones (see Programme, Appendix I), all but the first and last comprising several 'keynote addresses' followed by discussion and interventions from the floor. The sixth session began with reflective comments from a panel chaired by the Fellowship's President, the Viscount Caldecote, followed by further discussion ranging over—and in some cases beyond—the many matters raised previously. This structure enabled very many of the participants (some 200: see Appendix II) to contribute to what could well be called a continuous three-day debate on the impact and problems of advanced technologies, a debate which continued between sessions and during the several social events in the programme.

Participants in previous (particularly the first three) DISCOVERIES symposia may perhaps have felt MANTECH to be somewhat less interdisciplinary than the earlier meetings, doubtless owing to a preponderance of engineers, and in consequence to have rather fewer representatives from other branches of science.[2] Nevertheless the participants as a whole demonstrated in full measure the remarkable versatility of practical comprehension that characteristically equips the engineer to deal with things as they are in real life, rather than as they might be in the scientific ideologist's (or philosopher's) utopia.

Two outstanding impressions persisted throughout–and after–the Symposium. The first was that an inevitable result of ever-expanding automation and 'robotization' (a word whose unfortunate ugliness tends to emphasize its societal disadvantages rather than its benefits) must be the gradual elimination of traditional labour-intensive work. Furthermore this result was not to be dismissed as accidental or incidental: it was in fact the intended purpose of the new technologies–in the same sense that the gradual elimination of the use of people as pack-animals was the intended purpose of the wheelbarrow, the horse-drawn cart or in due course the fork-lift truck and the motor-lorry. Nor therefore should the displaced labour force be surprised or complain when relieved of the burden of long, arduous or tedious work, regarded until recently as one of the evils of industrialization. If the new-found freedom to expend more personal effort on enjoyable activities rather than drudgery should be proving unwelcome, the cause must surely lie in the structures of society, and the remedy in the modification of those structures.

The second outstanding impression was that, however hard-hit by recession the advanced industrial countries (AICs) might be, the plight of much of the Third World (late developing countries or LDCs) was far more serious. Despite the remarkable advances made by a few such countries–notably those endowed with large oil reserves and a few others which had successfully exploited their low indigenous labour costs–the wider picture in southern Asia, central Africa and much of central and south America was of inadequate agriculture, even more inadequate industry and above all chronic lack of the financial resources essential for an amelioration of their plight. As in earlier DISCOVERIES symposia, considerable lip-service was paid to the principle of technology transfer, and indeed some concrete examples of such transfer were reported, but in general these seemed to concern 'second-hand' technology already discarded by the AICs rather than promising new technology as yet incompletely exploited.

Clearly a major obstacle here was finance, and despite the efforts of the International Monetary Fund, the World Bank and the International Development Agency, not to mention many 'private' institutions in the field, trends in the real-world game of Monopoly (as in the original pretend game played for amusement only) once established were extremely difficult to halt or reverse.[3]

If the foregoing impressions from MANTECH were predominant, there were of course many others, ranging from the almost runaway esotericism of computer applications in very advanced information processing to the more mundane but vitally important questions of providing education and training in the many rapidly developing branches of science and engineering. Training or retraining at lower levels was also discussed, for clearly this must play an important part in adapting so-called redundant labour forces to meet the social and cultural challenges of modern technology.

A few remarks on the structure of this book may be helpful to the reader, to whom various approaches are possible according to the amount of time available and/or the level of interest evoked by the subject matter.

For a comprehensive but not too lengthy summary of any session individually, or of all the sessions as a whole, the summary/ies at the start of each chapter may be read without reference to the full texts of the various 'keynote addresses'. In these summaries the sections headed 'Discussion' may be omitted by readers wishing no more than short résumés of the keynote addresses so as to decide rapidly whether or not to peruse the full texts which follow.

However, for those with both more time and the inclination, the 'Discussion' sections are recommended as presenting an assessment of the general feeling among participants (rather than just the views of the main speakers); while of course the fullest value from the book may be obtained only through a complete reading of all the keynote addresses *in extenso.*

It is not essential to read the book in page order. Each session report is a self-contained account, and the occasional cross-references to other sessions may be ignored by those in a hurry.

Finally, a most convenient very short summary is given in the 'Symposium Review' by Sir Francis Tombs which begins on page 270.

The footnotes are of three kinds. There are footnotes which were integral parts of the speakers' addresses, which are referred to by asterisks but not by numbers. The other two kinds of footnote are both by the editor, and are numbered consecutively. They comprise firstly cross-references, principally to page numbers on which the various integral texts of addresses begin; while the remainder are remarks and comments by the editor which seemed inappropriate for inclusion in the main body of the text.

As will be seen, and in conformity with the Proceedings of previous DISCOVERIES symposia prepared by this editor, the present book is neither a full verbatim record nor a simple summary. Rather is it an appreciative review (with an occasional though rare word of criticism) by a privileged participant whose brief included both reporting and a degree of interpretation. He has made every effort to discharge these duties with accuracy and fairness, but has to recognize that his interpretations, which must by nature be subjective, may not always be entirely coincident with those of others. Should this be the case it is his earnest desire that divergent opinions may, as in all fruitful discussions, lead eventually to fuller understanding and benefit.

bma, Summer 1983

EDITOR'S NOTES

1 The five previous meetings, which like the London one had the general theme 'The Humane Use of Human Ideas', were held in Tokyo (1976), Rome (1977), Paris (1978), Stockholm (1979) and Columbus, Ohio (1982).

2 This is not an attempt to reawaken perennial controversy as to the relation between engineering and science (which in fact received some passing attention, notably in Session 6). Rather is Science (with capital S) a convenient word to embrace all forms of knowledge and academic discipline, at the same time encouraging their consideration as interdependent and basically indivisible.

3 According to recent World Bank estimates, over the period 1981 to 1982 lack of finance forced non-oil-producing LDCs to reduce their imports by some 25 billion (10^9) dollars, and with the future of WB and IDA funding by no means assured the situation is getting worse. It is hardly surprising that the whole monetary system, originally devised as a more convenient basis for trading than barter (of which it could be regarded as a sensible development), is now criticized in many quarters as an impediment rather than an aid to worldwide participation in the earth's munificence.

Chairmen and Principal Speakers

Umberto Agnelli
Vice-Chairman of Fiat and Chairman of Fiat Auto SpA. Vice-Chairman and Managing Director of Istituto Fianziario Industriale, Chairman of Piaggio & Co, Vice-Chairman of the Fondazione Agnelli and a member of the Board of the Banco di Roma. He was a Senator of the Italian Republic 1976-79 and is a Grand' Ufficiale al Merito of the Italian Republic and Chevalier de la Légion d'Honneur.

Professor Shuhei Aida
Professor of Systems Science, University of Electro Communications, Tokyo and lecturer in Bio-Engineering Tokyo Institute of Technology. Director of the Honda Foundation, Vice-Chairman of Committee on Social Effects of Automation, International Federation of Automation Control. Awards: Decoration of Cavalier Ufficial, Italy, 1981, 23rd Mainichi Cultural and Publication Award and 1976 Pattern Recognition Society Award. Author of *Introduction to Cybernetics, Robot, Introduction to Ecology, Science of Prediction, Interdisciplinary Study, Systems Engineering* and others.

Professor Kazuhiko Atsumi
Director, Institute of Medical Electronics, University of Tokyo, since 1974. President of the Japan Society for Bio-Medical Thermography, for Laser Medicine, for Artificial Internal Organs and for Bio-Medical Engineering and Vice-President of the International Society for Artificial Organs and of the International Society of Laser Surgery and Medicine. Author of publications in the field of futurology, artificial organs, biomaterial, thoracic surgery, medical informatics, medical thermography, medical lasers, ultrasonic medicine, etc.

Royal Professor Ungku A Aziz
Vice-Chancellor of the University of Malaya, Kuala Lumpur and Royal Professor of Economics (Rural Development). He is a member of the United Nations

University Council, the Joint Advisory Committee FAO/UNESCO/ILO and other international bodies and a past Chairman of the Association of Commonwealth Universities. Holder of the Tun Abdul Razek Foundation Award (1978) and the Japan Foundation Award (1981).

Viscount Caldecote
President of the Fellowship of Engineering, member of the Engineering Council, Chairman of Finance for Industry plc and a member of the Advisory Council for Applied Research and Development. Former Chairman of the Design Council. Holder of the Distinguished Service Cross.

Sir Robert Clayton
Technical Director of the General Electric Company plc, member of the Advisory Council on Energy Research and Development. Member of the University Grants Committee and President of the Association for Science Education. President of the Institute of Physics, a past President of the Institution of Electrical Engineers and Vice-President of the Fellowship of Engineering. He is a Commander of the Order of the British Empire and was knighted in 1980.

Professor Herman Feshbach
President of the American Academy of Arts and Sciences 1982-85, Fellow of the American Association for the Advancement of Science and member of the National Academy of Science. Professor of Physics, Massachusetts Institute of Technology. He is the author of many articles and contributions to conference proceedings on aspects of nuclear and particle physics.

Professor Sir Hugh Ford
Emeritus Professor of Mechanical Engineering, University of London and Senior Research Fellow, Department of Mechanical Engineering, Imperial College. Director of Sir Hugh Ford & Associates Ltd, Ricardo Consulting Engineers Ltd. He was Chairman of the Science Research Council 1969-72 and President of the Institution of Mechanical Engineers 1977-78 and is President Elect of the Welding Institute. A Fellow of the Fellowship of Engineering and of the Royal Society, he was knighted in 1975.

Dr Robert A Frosch
Vice-President of General Motors in charge of Research Laboratories. He was Administrator of the National Aeronautics and Space Administration 1977-81. Previous posts include Deputy Director of the US Advanced Research Projects Agency, Department of Defense; Assistant Secretary of the Navy for Research and Development; Assistant Executive Director of the United Nations Environment Program. He is President of the American Association of

Engineering Societies. Holder of the Navy Distinguished Public Service Award, the Defense Meritorious Civilian Service Medal and the NASA Distinguished Service Medal.

Professor Toshiyuki Furukawa
Professor, Institute of Medical Electronics, University of Tokyo, Council Member of the International Federation of Medical and Biological Engineering and Council Member of the Japanese Societies of Ergonomics, of Behaviometrics, of Biometrics and of Medical Electronics and Biological Engineering. Author of *Computer-aided Medical Diagnosis* and *Guide for the Application of Multivariate Statistical Analysis.*

Sir Peter Gadsden
President of the Ironbridge Gorge Museum Development Trust. Mining and marketing consultant. He was Lord Mayor of London 1979-80 and is a Governor of the Imperial College of Science and Technology. A Fellow of the Fellowship of Engineering, a Knight Grand Cross of the British Empire, Knight of the Order of St John of Jerusalem and Officier De L'Etoile Equatoriale De République Gabonaise.

Barry M Grime
Director, English Clays Lovering Pochin & Co Ltd, Deputy Chairman of Horizon Exploration Ltd and Director of International Drilling Fluids. He is a Fellow of the Fellowship of Engineering and a member of the Institution of Mechanical Engineers and the Institution of Electrical Engineers. His major concern is the equipping of minerals extraction and processing plants worldwide.

Professor Gunnar Hambraeus
Professor and Chairman, the Royal Swedish Academy of Engineering Sciences. Consultant, International Atomic Energy Agency, Vienna, 1968-69. Chairman, Swedish Technical Attaché Board. Chairman, IIASA Advisory Committee for the Management of Technology. Member Royal Swedish Academy of Sciences. Member Royal Swedish Academy of Military Sciences. Member Finnish Academy of Technology. Member the National Academy of Engineering of Mexico. Member Royal Society of Edinburgh. Chairman, DISCOVERIES International Symposium, Stockholm, 1979. Awards: Seraphim Medal, The Order of the Northern Star, The Legion of Honour, The Grand Cross of the Order of Merit. Author of *Progress in Swedish Research and Technology* and other publications.

Professor Harold W Lawson Jr
Professor of Telecommunications and Computer Systems, Linköping University, Sweden and head of the Computer Architecture Laboratory. He has previously held positions with Sperry Univac, IBM and Standard Computer, participating in

the development of the first COBOL compiler and the development of the PL/I programming language. His current research fields include graphical methods for software and hardware algorithm design and computer-aided design of VLSIs. He is the author of many articles and several books on computers and computing.

Dr Roger E Levien
Principal, Corporate Strategy Office of the Xerox Corporation. He was previously Director of the International Institute for Applied Systems Analysis (IIASA) for six years and prior to that was Deputy Vice-President of the Rand Corporation. Holder of the Austrian Ehrenkreutz First Class in Science and Arts and co-author of *The Emerging Technology* and *R & D Management.*

Professor Brian A May
Dean of the Faculty of Agricultural Engineering, Food Production and Rural Land Use of the Cranfield Institute of Technology. A Chartered Engineer, Fellow of the Institution of Agricultural Engineers and Member of the Institution of Mechanical Engineers, he has extensive consulting experience with national and international bodies concerned with agriculture and rural industrial development, particularly in the developing countries.

Lord Nelson of Stafford
Director of the General Electric Company plc and Chairman 1968-83, having previously been Chairman of the English Electric Group. Director of the Bank of England and President of the Sino-British Trade Council. He is a Fellow of the Fellowship of Engineering, the Institution of Civil Engineers, the Royal Aeronautical Society and a past President of the Institution of Electrical Engineers.

Surendra J Patel
Director of the Technology Division, UNCTAD (United Nations Conference on Trade and Development) in Geneva. He was on the Secretariat of the Economic Commissions for, successively, Europe, Africa and Asia and the Far East. He is the author of several works on economic transition, with particular reference to India.

Moeen A Qureshi
Senior Vice-President, Finance, the World Bank. After government service in Pakistan he served with the International Monetary Fund from 1958 to 1970, including a period as IMF resident representative in Ghana. From 1970 to 1979 he served as, successively, Economic Adviser, Vice-President and Executive Vice-President with the International Finance Corporation.

Sir Denis Rooke
Chairman of the British Gas Corporation since 1976. He has served on a number of government bodies, including the National Economic Development Council

and the Advisory Council on Research and Development, and was a part-time member of the British National Oil Corporation. He is Chairman of the Council for National Academic Awards and past President of the Association for Science Education. He is a Fellow of the Fellowship of Engineering and of the Royal Society, Commander of the Order of the British Empire, and was knighted in 1977.

Dr Shinroku Saito
Professor Emeritus, Tokyo Institute of Technology and President, Japan Fine Ceramic Association. He is a member of several committees within the office of the Prime Minister, the Agency of Science and Technology and the Ministry of Education, Science and Culture and is Chairman of the National Space-Shuttle Utilization Committee. Holder of the Purple Ribbon Medal and author of *Physical Engineering of Extreme States of Solids, Characterization of Ceramic Materials, General Technology of Composite Materials* and *Factors in the Densification and Sintering of Oxide and Non-Oxide Ceramics.*

Dr Günter Schuster
Former and Honorary Director-General of the Commission of the European Communities (CEC), co-ordinator for bilateral co-operation of the German Federal Ministry for Research and Technology, in particular for India, special adviser of the CEC. Doctor of Science at the University of Bonn and former holder of appointments in the German Federal Ministry of Science and Education and within the CEC.

Lord Sherfield
Deputy Chairman of the House of Lords Select Committee on Science and Technology, member of the Energy and Finance Sub-Committee of the Lords Select Committee on the European Community. Chancellor of Reading University, Chairman of Wells Fargo Ltd. He was HM Ambassador to Washington 1953-56 and Chairman of the United Kingdom Atomic Energy Authority 1960-64. Knight Grand Cross of the Order of the Bath and Knight Grand Cross of the Order of St Michael and St George. Created first Baron Sherfield in 1964.

Dr Reikichi Shirane
President of NTT Telecommunications Science Foundation and Counsellor, Science and Technology Agency, office of the Prime Minister. Member of the Information Processing Society of Japan, the Japanese Society for Quality Control and the Institute of Electronics and Communications Engineers of Japan. Author of *Operations Research, Theory and Practice, Perspective of the Intellectual Civilization, Information Society, Technology Assessment, Medical Information System, Network Society.*

Professor Ithiel de Sola Pool
Professor of Political Science at Massachusetts Institute of Technology and Director of the MIT Research Program on Communications Policy. Fellow of the American Academy of Arts and Sciences and a Foreign Visiting Fellow of Churchill College, Cambridge (England). Author of *American Business and Public Policy, Talking Back: Citizen Feedback and Cable Technology* and other works.

Sir Francis Tombs
Chairman of The Weir Group plc and of Turner & Newall plc and Director of N M Rothschild and Sons Ltd. He was formerly Chairman of the Electricity Council. He is a member of the Science and Engineering Research Council, a Fellow and Vice-President of the Fellowship of Engineering and is immediate Past President of the Institution of Electrical Engineers and a Fellow of the Institution of Mechanical Engineers. A member of the Commission on Energy and the Environment. He was knighted in 1978.

Sheikh Ahmed Zaki Yamani
Minister of Petroleum and Mineral Resources, Saudi Arabia, since 1962 and member of the Council of Ministers of Saudi Arabia. He is a Director of the Arabian American Oil Company (ARAMCO) and was Secretary-General of the Organization of Arab Petroleum Export Countries in 1968-69. Chairman of the Saudi Arabian/Sudanese Joint Commission for Exploitation of Red Sea Resources and President of the Supreme Advisory Council for Petroleum and Mineral Affairs. Author of *Islamic Law and Contemporary Issues.*

Professor Toru Yoshimura
Professor of Policy Science and Dean of Graduate School for Policy Science, Saitama University. Adviser to the Science and Technology Agency, office of the Prime Minister, since 1971 and member of many Japanese Government Departmental and Agency committees. Member of the Japan Committee for IIASA. Publications: *Philosophical Foundation of Behavioral Science, Policy Science, Introduction to Policy Analysis.*

Chapter One

INTRODUCTION

Chairman of the Session:
The Rt Hon Viscount Caldecote DSC FEng
President, The Fellowship of Engineering

Editor's Summary

The MANTECH Symposium opened under the chairmanship of the Viscount Caldecote, President of the Fellowship of Engineering, who after greeting the Senior Fellow and welcoming all participants was able to announce that Her Majesty Queen Elizabeth had just granted the Fellowship the honour and distinction of a Royal Charter, so recognizing the great contribution of the engineering profession to the advance of technology in service of society. Lord Caldecote then invited the Senior Fellow, HRH the Prince Philip, Duke of Edinburgh, to address the opening session.

After expressing his own special pleasure at the granting of the charter, His Royal Highness turned to the theme of the Symposium,[4] noting that 'the challenge of modern technology' might be taken to imply either a threat to society and culture, or a challenge to use the technology to the best possible advantage of society. But irrespective of interpretation, there was no doubt that technology was constantly becoming more powerful, and so able to bring more and more important changes to everyone's life. Such changes could certainly affect societal cultures although technology had rarely, if ever, been developed with this in mind: almost always the primary objective had been 'to meet perceived practical human needs'. There was no evidence that resulting (incidental) cultural changes had produced any improvement in the quality of human behaviour or had stimulated greater artistic talents.[5]

The undeniable increased potential of technology for improving the material quality of life therefore demanded ever greater care to avoid, and if possible eliminate, its destructive uses. His Royal Highness cited in particular nuclear weapons, the destructive application of a new source of energy which could also prove the key to future prosperity combined with environmental security owing to its non-polluting character.

It was appropriate to recall the words of Albert Einstein, commenting many years ago on the 'arrival' of nuclear power. Nuclear power, said Einstein, had changed everything except our way of thinking. 'The challenge of modern technology,' concluded the Senior Fellow, 'is directly to our human nature and the way we use our brains.'

A challenge indeed for every participant in MANTECH.

Speaking on behalf of all participants in the Symposium Ambassador Takeso Shimoda, President of the Honda Foundation, thanked His Royal Highness for his distinguished presence and stimulating remarks. Ambassador Shimoda also wished to thank most profoundly the Fellowship of Engineering and its President, the Viscount Caldecote, for hosting the meeting, and the Organizing Committee under Sir Henry Chilver for its substantial and clearly successful planning effort.

The mission of the Honda Foundation and its DISCOVERIES Project, said Ambassador Shimoda, was to try to help resolve some of the very severe problems now confronting mankind ... problems whose solution would be essential to enable the world to survive in face of predicted 'megacrisis'. He was therefore particularly pleased that this sixth DISCOVERIES Symposium was taking place in England, '... where the industrial revolution first began, and since then so many new ideas and inventions were introduced in the fields of industrial science and technology'. It was the Honda Foundation's hope and belief, he concluded, that the London meeting would mark further progress towards the creation of a civilization with high respect for humanity–the basic concept of the Foundation.

1.1 The Challenge of Technology

Chairman, Sir Denis Rooke, Senior Vice-President, Fellowship of Engineering

In a profound and inspiring development of the theme 'Technology, Master or Servant', Viscount Caldecote opened the first working session by surveying[6] the growth of improved technological approaches to solving the everyday problems of food and energy supplies, shelter and a continual improvement in the standard of life, and the parallel growth of fear, in some parts of society, that these improved technologies were inseparable from new and severe dangers for the future. The classic case was that of nuclear energy, where the necessary development of a new and exceptionally significant source of electric power had been equated by some with severely increased risks of disastrous war. Very few could recall without astonishment, said Lord Caldecote, that less than a century ago there were virtually no motor cars, no refrigerators, no television, and only very elementary medical defences against diseases such as tuberculosis, diphtheria and cholera. Here were the very real benefits of science and technology, and few would now deplore such developments on the grounds that the same science and technology could well have been used disastrously.

In this context Viscount Caldecote drew attention to some of the arguments often used by opponents of advanced technology, for example concerning pollution from motor car exhausts or the damage which could result from nuclear weapon explosions. But urban pollution today would be far worse if horses still provided the main motive power for transport, and an 'average size' hurricane could release an amount of energy equivalent to that of tens of thousands of H-bombs. Moreover, compared with an estimated ten million tons of man-made pollutants in the atmosphere, there was an annual discharge of 1,500 million tons of methane from the world's natural swamps. Viscount Caldecote concluded with some cogent remarks for those who deplored the social effects—notably on employment—of increasing technological advances in industry. Such advances were essential, he said, if industry were to remain competitive in world markets; and no healthy purpose could be served by resisting such changes in order to bolster employment in obsolescent or obsolete sectors. Re-education and retraining were essential for economic survival, and opposition to such advances could only lay up greater problems for the future.

Viscount Caldecote was followed by Mr Moeen Qureshi, Senior Vice-President (Finance) of the World Bank, who was equally determined that technology should be mankind's servant and never master.[7] Not surprisingly, his address concentrated on the problems of developing countries and the various ways in which these countries could acquire and exploit technologies which—at least until recently—had been mainly developed by the more advanced and more wealthy nations. Mr Qureshi pointed out that only 12 per cent of the world's scientists and engineers were currently working in the developing countries, and that these developing countries accounted for only 3 per cent of the world's investment in research and development.

'Technology transfer' was generally acknowledged as essential if the developing countries were to achieve reasonable equality with the rest of the world, not only as users and consumers of goods and services but also as their producers. Mr Qureshi made clear the interdependence of these two categories of country in the development of world trade and world prosperity, and explained the processes by which the World Bank was assisting that development both by direct financial aid and by aid precisely to facilitate the transfer of technology. However, there were many difficulties in these processes: both funds and equipment might be employed inefficiently or even in a manner harmful to the society concerned (whose internal divisions could be aggravated by an uneven distribution of benefits). Moreover it was by no means established that the greater efficiencies in industry or agriculture made possible by advanced technologies were necessarily beneficial: they could well lead to increased unemployment in communities with populations still expanding rapidly. However, such expansion must also lead to increasing demand for goods and services, although these demands would no longer be at the elementary end of the technological scale: the developing countries, said Mr Qureshi, were in the market for word processors, not pencils.[8]

Mr Qureshi gave considerable attention to problems encountered by the World Bank (and by other institutions) in encouraging these developments without causing unacceptable internal stresses—either in the source or the recipient countries and organizations concerned with technology transfers—and incidentally paid a substantial compliment to the United Kingdom which, he said, had pioneered so many of today's technological innovations that were now being adopted throughout the world. In 500 major technological developments during the 20-year period 1953-73, the British contributions had exceeded those of Germany and Japan combined, although both these countries had achieved greater technology exports to the developing countries than had Britain. The speaker did not need to explain in detail the implications of these facts, which indeed no more than confirmed information and declarations heard in the United Kingdom for decades.

Concluding this opening session, at the invitation of the Chairman, His Royal Highness Prince Philip offered some remarkably penetrating 'instant comments' on what he had just heard and which he believed (others were well convinced) could be helpful.[9]

First, he was puzzled by the considerable opposition to re-education for new jobs: we did not, he noted, still have an industry for making bows and arrows, for the skilled tradesmen had turned to other things.

Second, he felt that although improved living standards were highly desirable, it was necessary to avoid these leading to further population increases: otherwise the extra people would soon bring standards back to their former levels.

Third, His Royal Highness wanted to warn against over-rapid consumption of the world's finite resources, and improved technology had valuable contributions to make in increasing efficiencies of such use. But there were real limits—as also there were for the so-called renewable resources, for if consumption were at a greater rate than renewal, these resources were also finite. Expenditure, in fact, should not be allowed to exceed income.

Fourth, His Royal Highness had been much impressed by improvements in communication, and there was no doubt that technology could and would bring further improvements. But, he pointed out, there was no indication at all that 'technology will improve the rubbish put out on these systems of communication'.

Finally on pollution, His Royal Highness had noted the remark by Lord Caldecote concerning polluting discharges from horse-drawn transport of the last century, and the fact that today's motor vehicles discharged far less. But, said Prince Philip, the former pollution could at least be used for ground fertilization and growing mushrooms: the pollution from modern transport (carbon and nitrogen oxides, lead, and often sulphur derivatives) had no such useful applications.

However, the Senior Fellow was in no way calling for a return to the nostalgic but unreal world of 'the good old days'. Today's world problems were of a magnitude then inconceivable, and their solution called for the fullest possible employment of the best efforts of advanced science and technology.

EDITOR'S NOTES

4 For the full text of the Senior Fellow's inaugural address see page v.

5 Many of the world's greatest artists have in fact produced their best work while living in the most appalling personal circumstances.

6 For the full text of this address see page 9.

7 For the full text of this address see page 19.

8 A rapid glance round the auditorium at this point established that about half those present were nevertheless using these elementary but remarkably cheap and efficient devices to record, presumably, not simply what was being said but their own 'instant interpretations'.

9 For the full text see page 27.

1.2 Technology, Master or Servant?

Viscount Caldecote, President,
Fellowship of Engineering

There is nothing new about the interaction between the growth and application of scientific knowledge and the cultural and social progress of mankind. Thousands of years ago the process of extracting and purifying metals was applied to making tools and other useful products, as well as to creating works of art in gold, silver and bronze. And we all benefit from the creative skill of the early builders of great religious and secular buildings.

From the earliest times too man has worked to unravel the laws of nature and, as far as his understanding allowed, to make practical use of them. That indeed was the motivation behind the founding in 1660 of The Royal Society. The early Fellows of the Society, famous men like Christopher Wren, Robert Hooke and Isaac Newton, attached great importance to experimental work to broaden the boundaries of knowledge in what would now be called the natural sciences.

But the road to discovery and verification of knowledge about the natural world was not always a smooth one and there were many people then, just as there are today, who wondered whether this new knowledge was a beneficent force or something which would only cause trouble and upset the established social pattern.

Indeed these feelings were so strong that some scientists were persecuted, like the astronomer Galileo, who was imprisoned for asserting that the earth moved round the sun.

But now we can look back on the three centuries which have passed since The Royal Society was founded and we can see clearly the vast improvements in the quality of life which the application of scientific knowledge has achieved for millions of people, although there are of course still large communities for whom the growth in scientific knowledge has made little difference. Probably the most significant developments affecting everyday life have been in the areas of public health and medicine, in food production and in transport and communications generally. But in spite of these and other obvious benefits which have stemmed from technology, which is the art of applying scientific knowledge to useful purpose, there are many today who fear its accelerating influence on our lives. So I have chosen the title 'Technology, Master or Servant?' for my introductory address.

The theme of this Symposium, 'The Social and Cultural Challenge of Modern Technology', is surely very topical and since engineers are much involved in the art of applying scientific and technical knowledge in a useful and practical way, or, in the words you may have seen in the entrance to this building,[10] 'to harness the great sources of power in nature for the use and convenience of man', our profession of engineering must accept a large measure of responsibility for ensuring that the forward march of technology is indeed applied to purposes which benefit mankind. So the Fellowship of Engineering is very pleased to have had the opportunity and privilege of organizing this Symposium with the generous support of the Honda Foundation.

The number of people still alive who can remember what living conditions were like at the beginning of this century is rapidly decreasing. Then, even in our relatively advanced Western society, there were very few cars—the horse and train still dominated the transport scene: electricity was in its infancy—gas, paraffin and tallow lightened the darkness: coal and wood warmed our houses, and steam and water provided the power for industry. Letter writing was the principal method of communication, supplemented by a telegram service based on the Morse code. The few telephones were connected through manually operated exchanges and Marconi had just succeeded in sending a wireless message in Morse code across the English Channel. But for many people probably the greatest differences from today's scene were in the standard of medical care and conditions in the home, where all the dreary household tasks were manually performed, by an army of servants for the fortunate few, but mainly by the housewife and her family. Such were the conditions in this country less than 100 years ago and they were not so very different within the memory of many here today. For most younger people it must be hard to imagine a home without a refrigerator or television set, and much of the drudgery of living replaced by a wide variety of domestic appliances. Even more important, diseases like tuberculosis, diphtheria and cholera are no longer major killers in our society and many lives are saved every year by the use of antibiotics.

In industry too there have been vast changes. New methods of production have done away with millions of dull repetitive jobs and much of the hard and dangerous work in such industries as coal mining is now done by machines. So in industrialized nations we have been able to produce the wealth we need to increase our standard of living, with fewer people working shorter hours and with the tragedy of child labour eliminated.

Through all this change the number of people in full time employment steadily increased through expanding demand for new products, and through the growth of service industries and other administrative jobs, so that by and large the levels of unemployment did not rise to unacceptable levels except in times of world recession as occurred in the 1930s.

Such has been the effect of advancing technology in the industrialized nations. Apart perhaps from some concern about its effect on the environment and its contribution to arms production, technology has been seen to be almost wholly beneficial in enabling most people to live a fuller and more satisfying life.

But of course over wide areas of the so-called Third World millions of people have been largely unaffected by advancing technology and life goes on much as it has for hundreds of years, with much poverty, disease and illiteracy. And as the Brandt Reports have pointed out, the gap between living conditions in the industrialized countries and others is still growing.

Recently concern has been growing within the industrialized countries themselves that the application of modern technology is creating more problems than it solves. New methods of production, dominated by the computer, seem to be creating permanent unemployment on a vast scale and to be increasing the gap between the quality of life for those in employment or able to benefit from the new technology in other ways, and those who are unemployed or unable to benefit perhaps through inadequate education.

Dr Schumacher wrote in his book *Small is Beautiful*, 'In the subtle system of nature, technology, and in particular the super-technology of the modern world, acts like a foreign body, and there are now numerous signs of rejection'. 'Can we,' he asked, 'develop a technology which really helps us to solve our problems–a technology with a human face?'

How to achieve this and to avoid a growing disparity between the haves and have nots, whether within industrialized countries themselves or between nations, is I believe a major part of the challenge which we are discussing in this Symposium and on which we must hope our meetings will shed some light.

Before we can start to form a judgment on the true value of technology and on the strength of its balance sheet, whether its assets do indeed exceed its liabilities or whether it is, as some seem to think, almost irretrievably bankrupt, we need to seek an objective against which its achievements can be judged. In doing so it is tempting to stray into the realm of philosophers, who have been debating the meaning of life from time immemorial. But that is a field where engineers, like angels, must fear to tread.[11] To our more practical minds the objective must surely be to ensure that advancing technology helps people to live a fuller, richer life, though of course I accept that each of us will interpret what that means in very different ways. It is, I believe, much easier to agree on what must be avoided if life is to be enjoyable and satisfying. Grinding poverty and lack of food and water, which require every working minute to be spent on a fight to keep body and soul together, to survive another day, cannot lead to a full life; neither can disease and malnutrition or lack of elementary sanitation, or adequate shelter and clothing for protection from the elements. At a slightly higher level child labour and back-breaking drudgery in the house, especially for women, which destroy family life, are abhorrent, as are conditions of employment in factory or mine which degrade human dignity. Loneliness for the old, lack of care for them and the sick, and of education for the young are all tragedies which detract from the achievement of a full and rewarding life. Thus it is not in doubt that nature in the raw with no leavening of even simple technology is at least as oppressive as the unrestrained advance of modern technology.

Today we are much concerned with pollution and damage to the environment, but does it ever occur to those who make a fuss, for instance, about urban pollution from motor car exhausts how much greater the pollution would be if horses were still the main method of transport? It has been estimated that for every gramme of pollution emitted per mile by a car some 150 grammes of pollution are emitted by a horse. And, to put some other accusations against technology into perspective, an average size hurricane releases an amount of energy equivalent to that of tens of thousands of H-bombs. Again, an estimate made a few years ago that the atmosphere contains some 10 million tons of man-made pollutants should be compared with more than 1,500 million tons of methane gas emitted by natural swamps every year. Truly nature is both a polluter and a self-cleansing system on a gigantic scale.

But the paradox remains that amongst us, the fortunate ones, criticism of technology is growing at the same time as we see much of the less fortunate Third World in a similar state as our society was before the great transformation brought about by the scientific and agricultural revolutions from the seventeenth century onwards. There, human and animal muscle still produces much of the essential power of everyday life, and it is inadequate to lift the standard of living of these relatively primitive societies much, if at all, above the subsistence level of survival. It is only where technology has provided people with new sources of power that it has been possible to create real wealth out of nature's raw materials on a sufficient scale to enable society to rise above a survival existence and to provide spare time and energy to devote to improving the quality of life. But lest we should assume that such major improvements are peculiar to the fully industrialized countries, we should note the great advances made in India, particularly in the Punjab some 15 years ago where, for instance, wheat production more than trebled between 1967 and 1971, and the rice crop increased by a similar percentage, through the application of more scientific methods to farming. And we should remember too that mechanical power is no recent development, for water and wind power have been used for centuries.

What is surprising is that in some parts of the world these power sources formed the basis for an accelerating wealth creation process whereas in others very little progress was made. But we have to tackle the problems as we find them today. So I would like to spend a few minutes looking a little more closely at some of the current problems and attitudes to which I expect we shall return later on in this Symposium.

Current Problems and Attitudes

Although we are fortunate in welcoming many friends and visitors from overseas to this Symposium, it is, I fear, inevitable that these comments are slanted towards conditions and problems in the UK, partly because a worldwide survey would be impossible within the time available, and partly because I can only speak with any first-hand experience of conditions in this country, although I have been fortunate in having visited many other places. In any case others far more experienced in conditions elsewhere will be speaking in later sessions.

In Britain we are still suffering the long-term effects of losing a tied market for the products of our industry within a worldwide British Commonwealth and Empire, where British standards reigned supreme until some twenty years ago. Although we still export more per capita than the USA and Japan, increased competitive pressures in world markets for British products have accentuated the downturn in our share of world trade which started in the nineteenth century.

As a result of memories of the hardship and suffering experienced by the unemployed in the recession of the 1930s, post-war British governments have until recently given the top priority to a policy of maintaining a high level of employment. But the achievement of this policy was at the expense of substantial reductions in productivity and so of competitiveness of British industry. A related factor has been slowness in the introduction of new technology into the production process.

However, since 1979 there has been a major and effective drive to reduce manufacturing costs and so improve competitiveness through higher productivity, even if this resulted in increasing unemployment as it has done. When this process started most people thought that the major unemployment was a temporary phenomenon which would disappear once the recession ended and demand increased. But now there is a growing realization that—through the application of new technology to the whole process of design, development and production—productivity, in the sense of real wealth created or value added by each person employed, can be so dramatically increased that in future far fewer people will need to be employed in manufacturing industry to satisfy the demands of our home and export markets. In this sense it is asserted that technology creates unemployment and the forward march of technology is therefore much feared by many people.

On the other hand it is clear that if our industry fails to take advantage of new technology, such as computer aided design, flexible manufacturing systems enabling a wide variety of products to be made with extensive use of robots and the minimum of human labour, together with computer control of the whole manufacturing process from customer's order to delivery, we shall not be competitive in quality, price or service. This must result in a further loss of share in world trade, rising unemployment, and lower standards of living. So the phrase 'Innovate or liquidate' has been coined.

Yet other groups believe that advancing technology engenders a materialistic, selfish outlook in which the welfare of the individual is largely ignored and the interests of the financier and multi-national company dominate the scene. They feel an urge to return to the 'good old days' of a simpler life, but often seem to forget that they were 'good' for relatively few and fail to give credit to technology for its great contributions in, for instance, health, medicine and communications which have benefited so many. There is, I suggest, no evidence that a no-growth, stagnant economy is likely to lead to a more humane, more tolerant or more rewarding life in a more satisfied society. As Edward Heath said ten years ago, 'The alternative to expansion is not, as some occasionally seem to suppose, an England of quiet market towns linked only by trains puffing slowly and peacefully through green meadows. The alternative is slums, dangerous roads, old factories, cramped schools, stunted lives'. And in any case it is impossible to put the clock back and dam the flow of increasing knowledge. But we can channel it into ways which will benefit mankind and that is one of the challenges we face in this Symposium.

Taking Advantage of Technology

Technology is concerned with the application of scientific knowledge to the creation of useful things, processes and services. Its most basic function is its contribution to the creation of real wealth, and it is unfortunate that the word 'wealth' is widely thought to imply a big bank balance and all the trappings of luxurious living. But of course money is simply a means of transferring real wealth; and luxurious living or indeed any living is only possible if real wealth has been created, which we accomplish when we add value by brain and muscle power, and through machines, to the raw materials found in nature.

In many countries—in Europe and the USA for instance—we have been doing this successfully for quite a long time, and thereby we have been enabled to raise our own standard of living, and pay for the import of raw materials through exporting to other countries which provided them. To the extent that we were employing technology more advanced than was available elsewhere we prospered and it is only comparatively recently that this dominance has been challenged by newly industrialized countries becoming very effective competitors, partly by making use of advanced technology themselves and partly by accepting lower rates of pay and hard work while they grow.

To counter this competition manufacturing costs have had to be reduced, as I have indicated, by the use of more and more advanced technology leading to greater output per employee. As long as demand for the products of manufacturing industry grew, as it has in Japan through massive exports, employment did not suffer, but over wide areas of the developed world demand has not kept pace with potential supply and large-scale unemployment has resulted. And it appears that employment on the scale and in the form to which we have become accustomed is unlikely to return even when the world economy expands again. A more fundamental structural change has occurred, stemming from our ability to produce what we need with far fewer people employed.

Must we then accept that the advance of technology will condemn large numbers of people in one part of the world to a life of boredom and inactivity, and elsewhere to a life of continuing poverty and malnutrition, with an ever-widening gap between the richest and the poorest? If that were to be the outcome then indeed technology would have become our tyrannical master. So we must seek alternatives and again I hope these may form the basis of some of our subsequent discussions.

There are those who do not accept that big increases in productivity are the cause of unemployment. They quote as evidence the rise in employment in, for instance, the automotive and textile industries where new technology greatly increased the market: and its more recent contribution to the expanding demand for computers and consumer goods, such as domestic appliances and HiFi equipment. The gist of the argument is that advancing technology creates new products and services which generate new markets and jobs which more than replace those which are lost.

This has certainly been true in the past but will markets expand at a greater rate than productivity in future? If they do there is a risk that the expansion will come mainly in industrialized countries and little benefit will go to the Third World, because of lack of buying power.

Others claim that the growth in service and leisure industries will provide employment for those no longer required in manufacturing. To some extent this must be true, and these activities also generate demand for manufactured products, such as sports gear, office and communication equipment, but they create no real wealth themselves and the ability to pay for the services they provide comes from the wealth created in manufacturing industry, whose contribution to every country's prosperity will remain, whether its industry is producing manufactured products or raw materials. Again, if the new wealth is simply diverted to expanding service and leisure activities for a fortunate few, there will be minimal effect in helping to alleviate poverty and to care for the old and sick whether in the Third World or nearer home.

Yet others, including many in our trade union movement, maintain that the solution to these employment problems lies in work sharing in industry by, for instance, the reduction of working hours. Unless individual productivity increases proportionately (in which case no new jobs are created) or lower rates of pay are accepted, this solution will inevitably increase unit costs with resultant damage to competitiveness and sales and so to job creation. Thus this solution poses many inconsistencies, but apart from these is it really sensible to restrict wealth creation, when so many people are desperately in need of its benefits? No doubt shorter working hours will come and leave time for different constructive, perhaps more congenial, activities but they are certainly not a panacea for society's problems today.

All these ideas for matching demand and supply in circumstances created by the great increases in productivity which are now possible seem to me to accord too little significance to tasks unfulfilled in, for instance, health and education and to the needs of the poor and the old throughout the world. For many years our objective should surely be to distribute more effectively the great wealth we can and should create. This is a much more constructive policy than to seek ways of restricting wealth creation, and if, as I am sure is possible, advancing technology makes a major contribution towards the achievement of this objective, it will certainly be acting as our servant.

But the creation of unemployment is not the only evil blamed on modern technology. Pollution and damage to the environment is another, although, as I have already suggested, this is much easier to refute. The fact is that technology is at least equally adept at controlling pollution and protecting the environment, as witness the disappearance of 'pea soup' fogs in London, which in my young days caused many deaths; and the cleansing of the Thames and other rivers and of the Canadian lakes where fish now flourish after many years of absence. It is not technology that causes pollution but society's failure to use it effectively and its reluctance to pay the price of so applying it. Those are political and economic problems, to which practitioners of these arts should pay much more attention.

Similarly technology is accused of encouraging greed, materialism and the breakdown of family life. If it is greedy to want a supply of pure water, or materialistic to seek a weatherproof house and control of disease, or cowardly to enjoy the use of anaesthetics, or lacking in moral fibre to rejoice in the restoration of mobility through artificial joints and limbs, or the availability of the family car, then technology must plead guilty, but no-one in their senses would argue thus. Much of this sort of criticism in reality stems from resistance to change, or perhaps more accurately to the rate of change, which technology has stimulated over the last 100 years. It has powerful social and political overtones and it is also part of a much bigger ethical, religious problem—involving selfishness and love for your neighbour—for man cannot live by bread alone.

So to sum up I believe there are two great cultural and social challenges which modern technology presents to us today.

The first is that we make up our mind that technology is no different from any other powerful force; if wisely and firmly directed it can do much good but if it is not well directed it could run riot and sweep all before it into a morass of selfish materialism. Technology is not unlike water power which this long established and distinguished Institution of Civil Engineers has done so much to contain and to direct to useful purpose from its natural, often wasteful and destructive channels. The great dams which the engineering profession has designed have brought enormous benefit to countless millions of people: there are many well known examples, such as the Churchill Falls project in Labrador, the dams at Aswan on the Nile, and at Mangla in Pakistan, where with support from the World Bank the waters of the Indus have been harnessed to provide power and irrigation. Perhaps the closest analogy is the Snowy Mountains scheme in Australia. There before they were tamed the rivers from the Great Dividing Mountain Range flowed in useless torrents eastwards to the sea. But then dams were built, and in tunnels driven westward through the mountains the water has been diverted into turbines driving electric generators, some in large caverns carved out of the rock. And when it has done its work the water flows calmly into the great rivers like the Murrumbidgee to irrigate the once arid plains to produce much-wanted food.

But when water power runs riot as in the floods which devastate the land and kill thousands of people from time to time all over the world, or when very occasionally some great dam bursts and a wall of solid water uncontrolled sweeps all before it, great suffering and damage result. The moral surely is clear; where the principles are understood and scientific knowledge properly applied the forces can be usefully directed and the power harnessed for the benefit of mankind. But where, through ignorance or inaction, natural forces are allowed to take command disaster follows. Thus it is with technology.

So the second great challenge is to understand the principles which lay behind technology and the means of harnessing it to good purpose. In that task we engineers have I believe an even greater responsibility than we have for successfully designing and making useful things. For we have had the good fortune to acquire the knowledge and experience on which alone full understanding can be based. But, although engineers worldwide have made and will continue to make massive contributions to the progress of mankind towards a more rewarding, satisfying life, we have in the past been too introverted, and given scant attention or effort to explaining ourselves, our skills, and our responsibilities to our fellow men who have followed other callings. We see this issue in a particularly stark form in this country, for our culture has in the past been ill-tuned to the constructive use of technology in wealth creation.

As Martin Weiner has written in his book *The Decline of the Industrial Spirit*, 'The dominant collective self-image in English culture became less and less that of the world's workshop. Instead, this image was challenged by the counter-image of an ancient, little-disturbed green and pleasant land geared to maintenance of a status quo rather than innovation, comfort rather than attainment, the civilized enjoyment, rather than the creation, of wealth.' Alas, in the real world you cannot have your cake and eat it, but thank God at last we are appreciating the significance of that truth.

But there have been faults on the other side of the culture gap as well. Politicians have been too obsessed with how wealth is to be distributed, and others too absorbed in financial and economic juggling rather than in directing financial resources into wealth creating channels. There has been far too little concern with the creation of real wealth itself in terms of adding value to make things, including food, which people need.

So the second great challenge is really one of communication, and the paradox is that technology itself is more and more providing the means to communicate quickly and effectively. What great benefits have come in communication and in education in the broadest sense from our 'Open University', through documentary television programmes and up-to-date news of events brought to us via satellite, soon to be further extended by direct reception in our homes of satellite transmissions. The means to communicate are there in abundance and all we need is the determination to apply them more constructively towards a better understanding of the significance of wealth creation, and to bridge the gap between those who understand technology, with all the great changes which it brings, and those who fear it through ignorance or bigotry.

In Clough's challenging poem starting 'Say not the struggle nought availeth . . .', he goes on 'If hopes were dupes—fears may be liars'.

Certainly we must not hope for more benefit to mankind from advancing technology than it can provide, but equally I am confident that fears about its future are much more likely to be liars than to be justified by events, particularly if we engineers face up to our responsibilities, as we shall.

EDITOR'S NOTES

10 The Institution of Civil Engineers, Great George Street, Westminster.

11 Some readers might ask why.

1.3 Technology in a Developing World

Moeen Qureshi, Senior Vice-President (Finance),
The World Bank

It is a great honour and privilege for me to participate in this distinguished Symposium.

This morning's programme has certainly been thought-provoking, and I am sure everyone has been as impressed as I have by the address just given by Lord Caldecote, particularly his remarks about making technology the servant of humanity. He rightly highlighted the technology needs of our societies: raising the living standards of people around the world may be the most worthwhile technological project of the next generation or so.

In my own remarks I want to stress the economic and commercial benefits that can flow to all concerned from the transfer of technology to the developing countries. It is very important to emphasize the practical incentives that can help to get this important job done. With the United Kingdom and other industrial nations struggling to revive their economies, it is urgent that they recognize their stake in the Third World progress, otherwise the prospects of reducing poverty, and welfare around the world, may be crowded aside by domestic economic concerns.

So this morning I shall argue first that the developing countries are a rapidly expanding market for technology exports. Second, that the World Bank is and can be an effective catalyst for the transfer of technology. And finally that for the United Kingdom, as for the major industrial countries today, the supply of technology to the developing countries is the emerging area of business growth over the balance of the twentieth century.

The developing countries achieved faster economic and technological progress between 1950 and 1980 than at any previous time in their history. The whole world enjoyed a period of unprecedented economic growth, and on average the developing economies expanded even faster than the industrial economies. During this generation of economic expansion, some nations outperformed others. Among the industrial nations Japan more than quadrupled its share in global output. But the improvements have also been impressive in less rapidly growing economies such as the United Kingdom.

Among the developing countries, even most of the poorest countries enjoyed broad-based improvements in literacy and life expectancy, and several groups of developing countries emerged as new poles of dynamism within the global economy. About twenty developing countries like Yugoslavia, Korea and Brazil are economies that have approached the industrialization stage. The oil-exporting developing countries comprise a second exceptionally dynamic group, and in some respects, food production for example, the largest nations of Asia, China, India and Pakistan, have also made remarkable progress.

Economic progress in both the industrial and the developing countries has been spurred on by the rapid development of new technologies and their quick diffusion to the newly developing countries. Studies from various countries confirm that one-third to one-half of economic growth is normally derived from combining capital resources and labour more productively; in other words, from technology. Our generation has witnessed revolutionary improvements in transportation and communication technologies. As a result, one-fourth of everything produced in the world is now traded internationally. The rapid growth of international commerce has made the world economy more efficient, and in the process pushed incomes upward everywhere.

And the breakthrough in transportation and communication technologies of the last generation—air travel, telecommunications—has been specially suited, not to bulk transport, but to the movement of people and of ideas; in other words to the transfer of technology.

The developing countries still depend on the industrial countries for virtually all the modern technology they use. Only 12 per cent of the world's scientists and engineers work in the developing countries, and the developing countries account for only three per cent of the world's investment in research and development. The Third World pays the industrial world as much for licences and knowhow as it spends on indigenous research and development.

The dualistic character of developing societies is often aggravated by improved technologies and by imported technologies. Elaborate medical equipment is installed in urban hospitals while most of a country's families do without the basics like clean water and adequate food. Scarce foreign exchange is used to buy modern, capital-intensive equipment for a few factories while thousands of small enterprises struggle on with the most rudimentary methods of production.

But there are also some advantages for the developing countries in this situation. They can draw on the technical knowledge which the industrial countries have accumulated over the generations. A good part of this knowledge is available to anyone without charge, and in today's global economy virtually all industrially significant technologies can be obtained from competing suppliers around the world.

What does the rapid economic growth of the developing countries and their continuing need for technology imports mean to suppliers in the industrial countries? An important, dynamic, and sometimes difficult market. The industrial countries sell one-fourth of their merchandise exports, and one-fifth of their exports of licences, knowhow and related services, to the developing countries.

During the seventies, the middle-income developing economies as a group grew twice as fast as the industrial economies. Exports of capital goods and equipment to the developing countries, one form of technology sale, increased 10 per cent per year in real terms. Direct foreign investment and payments for licences and knowhow, the other commonly used indicator of technology sales, grew less dramatically during the seventies, but still by about four per cent in real terms. Just now the developing economies are struggling because of very high interest rates and slack demand in the global economy, but their under-utilized resources, their population growth, almost guarantee that the rapid growth of technology exports to the developing countries will continue again in the future. The main unmet technological demand of the developing countries is still for technology adapted to the limitations and needs of poor people, but the most successful developing economies have moved well up the scale of technological sophistication so that the Third World today is buying a much more diverse range of technologies. Half a dozen developing countries have in fact become significant exporters of technology.

The competitiveness of some developing countries in certain lines of manufacturing has accelerated the decline of these activities in the industrial countries, but it is impossible in today's world for any nation to retain its competitive edge by restricting technology exports, and in any case the industrial countries get better value for money in international trade, and the benefits on balance from the increasing productivity of the developing countries in manufacturing. Then, too, as the more dynamic developing economies progress, they are also increasing their imports of technology from the industrial countries. They are less likely to need a foreign consulting firm to do routine design work, but they still contract with top rate foreign engineers for particularly difficult or innovative work. They are in the market for word processors, not pencils.

The increasing sophistication of some of the developing countries is also one reason why institutional arrangements for the transfer of technology are in a flux. During the 1950s and 1960s, the transnational corporations greatly extended their global reach. They brought technology to the developing countries in a package, together with organizational skills and financing. But many developing countries became suspicious of transnational corporations, and to some extent suspicious of foreign technology. Developing country governments imposed conditions on international business that often made technology transfer, and especially direct foreign investment, difficult. At times they appeared to pursue a concept of autarchy, which proved very costly and wasteful. Many of those who are personally involved in the sale of technology exports could cite instances in which developing countries have blocked technology sales to their own detriment. In the seventies, developing countries more often imported technology, organizational skills and financing separately. Their imports of capital goods and their commercial bank borrowing both expanded rapidly, while direct foreign investment grew less rapidly. Gradually transnational companies have learnt to adapt themselves to national policies, and some Third World governments have become more adept at guiding direct foreign investment without killing it. The debate about whether or not to import foreign technology is fortunately fading as developing countries come to recognize that there is often no viable alternative to importing technology.

At the same time as more developing countries become sophisticated shoppers for technology and finance, we are likely to see yet more diversity in the institutional arrangements for technology transfer. Countries will pick and choose among the many ways they can get finance and technology: borrowing, direct foreign investment, consultancies, licensing, equipment purchase, training, research—selecting whatever mix seems most appropriate for a particular project. And active government involvement in technology transfers in both the selling and the buying countries is likely to remain a permanent feature of policy.

Within this important changing and institutionally difficult process of technology transfer to the developing countries, the World Bank has proved to be a useful catalyst. The World Bank's objectives are much broader than the transfer of technology. The Bank's objectives are to help raise living standards and to promote development, but towards the achievement of that objective we also assist countries in their technological development, and our work as a technological intermediary is built on the World Bank's more basic function as a financial intermediary.

The Bank depends on financial backing and contributions from the industrial governments. It raises most of its funds by borrowing in the world's capital markets. And the Bank's lending to the developing countries is supported by a much deeper relationship of co-operation with them on development projects and economic analysis. But in a unique way the World Bank gets the industrial and the developing countries together, and the public and the private sectors together, all working jointly.

Because of the World Bank's broad developmental perspective and its success as the financial intermediary, the Bank can and does finance a wide range of Third World development activities that commercial investors could not or would not finance on their own. The Bank also provides financing for needed improvements in public infrastructure, in social sectors, and in specific areas such as contracts, training, construction and so forth. The Bank's projects usually incorporate technological improvements, as well as reforms in development policy and institutions. Most projects include a technical assistance component, mainly domestic and international consultants. The World Bank financed $1 billion in technical assistance last year. In the end, the technological, institutional and policy improvements embodied in the Bank's lending almost always have more far-reaching effects than our financial contribution.

The World Bank is involved in a wide range of technological development activities. Two-thirds of the Bank's education lending, for example, has been for science and technology. Our first loan to the People's Republic of China is helping to re-equip scientific and technological universities. Five of the agricultural projects our Board approved last year are totally devoted to research and extension. The Bank also serves as a secretariat for the Consultative Group on International Agricultural Research. In the energy sector the Bank is systematically assessing the energy prospects of 60 developing countries.

Let me give you a sense of the Bank's involvement in technological development by discussing our experience in three areas:

–industrial technology, which involves relatively straightforward transfer of established technologies
–computers–a fairly high-technology area
–urban shelters–an area where the developing countries need low-cost, appropriate technologies.

About a fifth of the World Bank's lending is for industry, and one of the Bank's affiliates, the International Finance Corporation, operates mainly in the industrial sector. The clearest lesson that can be distilled from the experience of the Bank and IFC in the transfer of industrial technology is that technology cannot be neatly packaged or effortlessly bought and sold. The IFC has found that the most successful way to get the necessary effort from suppliers of technology is to give them an equity share in the developing country enterprise they assist. I would hope more companies might consider joining as technical partners in IFC projects.

The transfer of industrial technology also requires effort at the receiving end. Case studies show that the developing country firms that successfully introduce new technologies normally budget time and money for training and research. They integrate new technologies into their operations through a series of small changes over a period of years. The initial transfer of technology normally adds less to productivity than the sum of these adaptive efforts. Therefore our advice to developing countries is that they buy the industrial technologies they need, but they also upgrade their own technical capacity.

Japan is a model of rapid technological development, and Japan's approach when it was a developing country was just that. It bought technologies that were already in the market and dedicated its creative energies to adaptation and improvement. The lesson that successful technology transfer depends on such follow-up effort is important to remember as developing countries now turn their attention to more novel technologies, such as information technologies. I cannot but recognize in that connection the great contribution that many of the great Japanese firms have made to the field of technology.

As I listened to Lord Caldecote I thought he was on the verge of making an apt, if somewhat inadvertent, slip when he referred to the fact that Mr Honda's name might go down to posterity. Instead I thought he was going to say to prosperity. But I really did wish at that particular point that he had made that inadvertent slip, because as goes Honda, so goes technology. I do really think that technology will in the end lead to prosperity.

The World Bank has often financed computer purchases, mostly by public agencies, and we are participating in efforts to use satellite mapping to improve weather forecasting, for example, for vulnerable countries that are affected by climatic difficulties. But information technology, for all of its sparkle and for all of its future potential, offers no painless or immediate solution to the problems of developing countries. Over and over we find that the inefficient organization that installs a computer remains inefficient. Unless the organization itself becomes better organized, its computer will probably be under-utilized. Initial experiments in the use of satellites to broadcast programmes directly into Indian villages proved technologically successful, but because nobody paid attention to the quality of the information that was delivered through the system,[12] the result of the experiments as a whole was disappointing. Villagers around the world already have transistor radios, and we could vastly improve the quality of information available to them, through better programming, at a tiny fraction of the cost of computers. Again, technological advance can seldom be reduced to a single or a discrete transaction. It almost always depends on a development process.

Let me turn now to one of the most serious social aspects of technological change, its impact on employment. In industrial societies, high worker displacement has been experienced by industries which have switched from mechanical or electromechanical components for their products to microelectric components. Similarly, in the service sectors, office automation looms as a major threat, especially to the employment of women who predominate in that area. This danger of creeping unemployment as a result of technological change seems bad enough in industrial societies which are currently suffering from economic stagnation and high degrees of unemployment. How much worse is it likely to be, one wonders, in the developing world, with its heavy population pressures and endemic underemployment. Is the introduction of new technology in the developing countries worth the social cost? There is no doubt that the application of many new technologies, let us say microcomputers in industry, will displace labour. It is equally true, however, that avoiding their use may condemn industry to low productivity and a loss of international competitiveness. It is perfectly feasible, although frequently painful, to take care of unemployment generated by technological innovation when industry is profitable and expanding, and new job opportunities arise because people can be retained and redeployed. There is unfortunately no way to take care of unemployment that is the result of technological obsolescence in a shrinking industry. So also with the developing countries. The introduction and transfer of new technologies to them cannot be a mechanical or an overnight process. It must be done in steps consistent with their comparative advantage and their stage of economic development, and without unduly disrupting their social and cultural values. However, technologies that do make economic and social sense in their situation hold the promise of exploiting enormous untapped potential, unleashing latent human energies, and creating vast new employment opportunities. This in the final analysis is what economic and social development is all about in both developing and developed countries.

Those familiar with the history of agricultural development in the United States will recall that over the last half of the nineteenth century the agricultural labour force was reduced to about three per cent from about 50 per cent as a result of mechanization of farming. It seems to me that the technological revolution of the second half of the twentieth century will generate even more rapid change. We must therefore learn from the experience of countries such as Japan, which have shown such remarkable facility in organizing, retraining and redeploying labour, in maintaining the stability of their social fabric and their cultural identity, and thus avoiding the negative social effects of technological change.

I should like to say a few words about the overall trends in consultancies financed by the World Bank. We find that architectural and engineering firms still top the list, but the trend has been towards technical assistance in areas like slum improvement, agricultural and rural development, and energy development and conservation. Technology transfer requires ongoing relationships and gradual learning, and it is perhaps for that reason that the World Bank, which is so deeply and intimately related to the developing countries, has proved to be a useful bridge for the transfer of technology.

Each of the industrial countries has its own strengths and weaknesses for the task of putting technology to work for our developing world. The difficulties facing the British economy and its industry in particular have been the subject of national debate and policy initiatives for decades. But perhaps I can contribute an observation or two regarding one particular area of the British economy: its technology-related exports to the developing countries. Over the last two decades while the share of exports in Britain's national income has grown, the share of exports to the developing countries in Britain's total exports has fallen, but this relative decline in exports to developing countries seems to have bottomed out, and by every indicator the export of technology-related items to developing countries is still proportionately more important to the United Kingdom than to any other industrial country. The British share in consultancy contracts with the World Bank is very high, and growing. It is now about a sixth of the total.

As I see it, the United Kingdom has two advantages in the competition to supply technology in developing countries. First, the United Kingdom is an exceptionally open trade-oriented economy with deep historic ties to many developing countries. The other clear advantage of the United Kingdom is general technological excellence. The latest issue of Columbia Business School's *Review of World Business* reported a study of 500 leading technological innovations between 1953 and 1973. Even though both Germany and Japan now exceed the United Kingdom in technology exports to the developing countries, the UK's share in leading technological innovations was more than the shares of Germany and Japan together. The United Kingdom's leadership in science and technological innovation in the nineteenth century is widely known, but it is less widely recognized that it has also pioneered major technological advances over the last 50 years. I refer not only to the path-breaking work of scientists such as Rutherford and Chadwick, who helped usher in the nuclear age, or of Fleming in medicine, or more recently of Milstein in genetic engineering, but also to the type of basic material and product development, and industrial engineering, which has fuelled the growth of modern engineering. It was Morris Motors of Coventry which first developed the engine block machine, and it was the Austin motor car that inspired small car development throughout the world including, if I may remind my Japanese friends, that of Datsun in Japan. Television was first demonstrated by Baird of Scotland, and it was the London telephone system that first installed the automatic exchange and the first direct dialling system. The first upright vacuum cleaner was a British product, and the first use of quartz crystal for time measurement, which is now revolutionizing watchmaking, was in the Greenwich Laboratory. I would hope that more of the United Kingdom's vital capacity for technological innovation could be turned to its own needs and to the needs of the developing countries. Few fields of technological endeavour have more social or cultural value, and few fields of technological endeavour hold more commercial promise for the United Kingdom itself.

It was Professor Toynbee who wrote that the most powerful change of our epoch is the awakening of the hitherto depressed three-fourths of the world's population to the possibility of improving their way of life through technology. Toynbee adjudged atomic energy and the exploration of outer space to be trifles by comparison. And it was Corbusier who said that there is no such thing as a primitive man, there are only primitive needs. As every corner and cranny of the world is hooked into one jet and electronics network, the demand for better ways of doing things continues to swell in the developing countries.

In conclusion, as we discuss how technology interrelates with society and culture, I would ask you to remember how rapidly the world has been developing, and to remember something that a former prime minister of a developing country once said: 'Of what use is putting the first man on the moon if we cannot reach the last man on earth?' This indeed is the greatest challenge that faces our societies; to take full account of the immense energies of those people around the world who now know about, but do not yet fully participate in, the benefits of technology.

EDITOR'S NOTE

12 Cf. HRH Prince Philip's remarks.

1.4 Comments by The Senior Fellow

This is slightly unexpected. My trouble on these occasions is that I keep thinking of what is wrong with what people are saying, and not necessarily what is right with it, because that is usually self-evident.

But among the things that went through my mind is this business of the developing and industrial countries. It seems to me that it has now become almost a cliché to refer to the two, because it is only too evident that every country is developing in one direction or another. And although the technologies may be more developed in one country than another, the fact is (and the British situation is very typical) that we have to go through continual development in order to retain or improve our share of world markets, and the competition for markets nowadays is the thing that seems to matter more than anything else.

Then we have been hearing about the transfer of wealth to the so-called developing world. It is a very difficult situation. Do you just transfer money? It seems to me that that has been largely discredited. If you make a loan you end up with a debt, and debts seem to have reached such enormous proportions that now nobody knows what to do with them except sell them to each other! You can always rely on commercial people to find something to deal in!

But it seems to me that one area of transfer is a very difficult area: the transfer of employment. As soon as people become too expensive, the manufacturers will move the production somewhere else. That is very unpleasant for the employed people in the country who have in a sense opted out, but in fact transferring employment is a very good way of transferring wealth. It is also transferring technology, the technology of using machinery to make things. I think there has been a tremendous amount of wealth transfer in that respect, but it is a difficult thing to refer to because of the unemployment created in the countries that have exported employment.

Another thing. We were talking about Britain as the world's workshop and all the reasons why it is not the world's workshop any more. It seems the simplest reason is a very natural one; that anybody who has made a pile sits back and uses it. He does not go on working. And I think that nationally we have been simply enjoying the wealth that we created a hundred years ago, and taking advantage of it. Now I think that wealth is beginning to run out, and like any family who sees its savings being whittled away, it is scratching its head to see how it can recover some of the income. Well, we have got to go back through the period of realizing that we have got to earn our living.

I think there are a lot of other reasons, but I think that seems the simplest one; to me, anyway.

We were talking about raising living standards. I am all for the raising of living standards of people, provided of course that it does not raise the numbers of people. Because it seems to me so much of development has resulted in increase in the numbers of the population, and of course the growth in the population does prevent, in the end, the improvement in living standards. It is inevitable, and it does a lot of environmental damage in a sense, because more people take up more room, and if they are better off they absorb more resources, and although this may generate economic development, on the other hand it is passing on the moment when life will become very difficult.

Another thing that struck me is how can we raise material standards by transfer of various kinds in the face of social unrest, revolution, civil war, administrative chaos. It is no good pretending these do not exist. There are an awful lot of countries in this world where there is a determination not to improve human standards. Well, perhaps not a determination, but the way in which they are handling their internal social and cultural activities is such that in no conceivable way are they going to raise the standards of their people. And this problem is a very difficult one. I do not think one should simply pretend it does not exist. You cannot lump all these people into what is called the developing world because some of them are certainly of themselves preventing any development. And you cannot necessarily blame international finance or commerce for the situation.

I referred earlier on to renewable and non-renewable resources. Perhaps my economics are not very good, but I cannot think of any other way in which you are actually going to create wealth unless you exploit the world's resources. The danger, of course, as we all recognize, is that there are many resources that are non-renewable, but it seems to me we ought also to be worrying about the renewable resources which are being exploited faster than they can renew themselves. Take for example the tropical forests. They are a splendid resource. They are a source of wealth in so-called developing countries, and modern technology has made it possible for those forests to be cut and exploited at a rate far greater than they can be replaced. That is not just speculation, that is a fact, and I regret to have to say that a great deal of that exploitation of those resources is actively financed by the aid organizations. It is another thing we should not ignore. It is a dilemma. I am not blaming anybody, it is simply a dilemma. There are the resources, and they could be converted into wealth: we have got the machinery to do it, so let us go and do it. But the fact is we are creating very serious problems.

There are other serious problems about development or the financing of development. For instance, there are two cases being argued about hydroelectric dams. One involves the World Bank directly, which is about to finance a dam in Thailand, a hydroelectric dam and an irrigation dam. But the site happens to be in a forest area which happens to be in a national park. Now, in no civilized country would a development of that sort be allowed to take place, but it is being actively financed by the World Bank. This is a dilemma.

The other case, of course, is the great argument about the dam on the lower Gordon, as it is called, in Tasmania. That is a somewhat different problem. It is not entirely different, but there the argument is within Australia and Tasmania. The area of South-West Tasmania has been declared, believe it or not, an international heritage site, or whatever it is, and in spite of that it is possible to build a dam. I am not arguing whether the dam is necessary or not. The fact is these are the dilemmas of development. These are things that we should not ignore. They are there.

We were talking about means of communication. There is no question that technology does improve means of communication. But no amount of technology will improve the rubbish that is put out on these systems of communication.

Here is another point, about employment. We tend to hear a lot about the disappearance of employment. If an industry dies, we add up all the people who are put out of work. But we seem to forget—we do not have a lot of out-of-work makers of bows and arrows: somehow or other they have found something else to do.

Viscount Caldecote suggested that horses created a lot of pollution. Strangely enough it never caused a problem at the time. The great thing about horse pollution is you can use it to grow mushrooms, whereas acid rain has the opposite effect. So I do not think they are exactly comparable. And do not forget that in the days before the motor car there were enormous numbers of people directly employed because there was horse transport. Having done away with that—why do we not have large numbers of unemployed grooms running about? Why not a lot of unemployed drivers? A lot of unemployed farriers? The fact is they have transferred.

I would very much like to know what state the economy would be in in Japan but for electronics. After all, 50 years ago there were no such things, or at least nothing like what they are today.

So there is a tremendous amount of transfer of employment.

To take another very good case. I cannot remember exactly what it is, but I think a hundred years ago—I looked it up—15 per cent of those employed in the UK were in domestic employment. The figure today does not even come into the statistics, it is so small. What happened to all those people? Somehow or other they have transferred. And I think you will find, if you look at the statistics, there are more people employed today, in spite of the unemployment, than there were 40 or 50 years ago.

So something is going on and I do not think we should ignore the dilemmas as well as the consequential changes. Let us not jump to conclusions that because an industry is dying, or because a country cannot produce, this is necessarily always a debit side. There is a positive side to it.

On the other hand I think, as I said before, that we should take into account the dilemmas that are caused not only by improved technology but simply by the existence of technology, and not only by technology transfer but particularly by the transfer of wealth in various ways, and trying to improve standards in countries where the standards are low.

Chapter Two

MODERN TECHNOLOGY IN THE CONTEXT OF WESTERN EUROPE

Chairman: Professor Sir Hugh Ford FEng FRS
Vice-President, The Fellowship of Engineering

Editor's Summary

The next four sessions of the MANTECH Symposium were devoted (at least by designation) to examination of the social and cultural challenges of modern technology in four main areas of the world: Western Europe, North America, the 'Developing Countries' (without further definition) and South-East Asia and Japan. While coverage of the first two and last areas seemed entirely adequate, if the relative extent—and population—of the third area is taken into account its two representatives[13] might have seemed to some to be a little thin on the Symposium ground. Doubtless quality compensated for numerical deficiency.

However that might be, the second working session benefited from a series of particularly stimulating keynote addresses which, not surprisingly, provoked some profound and penetrating discussion.

The scene was set by one of Western Europe's most involved industrialists, the Vice-Chairman of Italy's huge Fiat organization (and Chairman of Fiat Auto SpA) Dr Umberto Agnelli, who was clearly no less aware than others in motor manufacturing of the great difficulties facing his industry.[14] However, while evidently championing innovative development in transport (in many respects today's cars, trucks and trains were very different from their counterparts of only a decade ago) there was perhaps a tendency to assume without proof that all these changes were necessarily for the better. The large stocks of unsold vehicles which may be seen 'stored' at disused airfields and similar places in most European countries certainly indicate a disparity between demand and supply, and although the basic reason may be financial rather than technical, it is none the less real. (Asked to choose between sophistication and cheapness, a great many would-be customers will opt for the latter, sometimes because the alternative is out of their practical reach.[15]) But very advanced electronic technologies have certainly become an established part of motor vehicle design, and have enormous contributions to offer in securing optimum efficiencies combined with minimal environmental pollution.

Dr Agnelli stressed the vital role of engineers in applying the developments of advanced scientific research to practical ends—in, as he said, transferring new technology from the laboratory to the shop floor. This process had always been much faster in Japan than in Europe, which doubtless was not unconnected with the success of Japanese industry in creating new markets for many products, as well as supplying those already existing. Dr Agnelli also called for more 'engineering realism' in research, which otherwise could rather easily follow modish trends with insufficient regard for the real needs of industry.

However, his main message, entirely in keeping with the subject of the Symposium, concerned public attitudes to technology, to new scientific developments, and particularly towards the young people who, faced with a wide choice of education and career, were often influenced by social trends and attitudes based on emotion rather than reality. It was undeniable that an advanced technological future could not be assured without a continuing supply of advanced technologists, and there was still a widespread feeling that technology was for others, while the real problems of life were the domain of social scientists and others whose hands never got dirty. 'The general public,' said Dr Agnelli, 'must be better educated in the real facts of technological innovation which, like it or not, is going to make far-reaching changes to the daily life and work of everyone.'

But more and better understanding of modern technology was needed in all sectors of society and at all levels, and not least in circles connected with employment and labour relations. At a time of high unemployment in most countries, it was not surprising that technology capable of reducing the demand for manual labour (even 'skilled') caused apprehension to trades unionists and others. But some of the countermeasures proposed, such as a general and standardized reduction in working hours–which meant paying more for less production–could only lead to cultural retardation. In this field Dr Agnelli felt that both governments and trades unions rarely understood the true significance of technological change, and both seemed 'readier to produce studies and White Papers than to develop long-term strategies'.

Perhaps it was inevitable that an industrialist should display so little confidence in the administrative establishment, and there is no lack of evidence that the establishment (in general) equally lacks confidence in industry. If one principal conclusion is to be drawn, it is surely that this persistent mistrust, and the persistent misconceptions on which it is based, must be eliminated if the very real social benefits promised by advanced technology are to be realized.

The next speaker was Dr Günter Schuster, a former Director-General of the Commission of the European Communities (CEC), now co-ordinator for bilateral co-operation in the German Federal Ministry for Research and Technology.[16] Dr Schuster was anxious to convince his audience of the very substantial benefits to be gained from international research projects, often involving investments (both of money and technical personnel) which participant countries individually would be unable to find. As examples he cited several of the better-known European inter-governmentally sponsored projects: in particular the CERN organization in Geneva for research into the fundamental nature of matter; the European Space Agency (ESA) which had developed the Ariane launcher vehicle; the French/German experimental high-flux nuclear test reactor at Grenoble; and the most important technical project of the European Community, the Joint European Torus (JET) for the development of nuclear fusion. All these had demonstrated the clear advantages of international co-operation in science and technology, but had also shown where problems could arise, for example in connection with the commercial exploitation, under patents, of knowledge acquired. But overall these problems were insignificant compared with the benefits offered, which in Dr Schuster's words included an 'added value element' well beyond the simple sum of the individual contributions. In the interaction with other people, he said, 'with other ways of thinking, other cultural backgrounds, different approaches to solving problems, good people and even the best people became better'.

Dr Schuster made special mention of the comparatively recently established European Science Foundation, a non-governmental European organization based in Strasbourg, France, which comprises representatives from the research councils and academies of most Western European countries, and which provides scientific guidance and surveillance in many of the newer fields of modern technology. This body might one day lead to the creation of a European Advisory Committee to make priority recommendations for large science tools and provide facilities for basic research, a body which Dr Schuster strongly advocated.

Concluding, Dr Schuster noted some of the difficulties and obstacles which could be encountered in the establishment or operation of joint collaborative projects. They included difficulties due to the involvement of industry (particularly, as already mentioned, the exploitation of patentable knowledge and processes); difficulties due to differing national policies, norms and standards in the participant countries, as well as problems of choosing a research site which often had necessarily to be in one country only; and difficulties due to the greater complexity of international management. Sometimes these difficulties could be extremely severe, yet considerable hope could be derived–and not only for the future of scientific and technical collaboration–from the INTOR (International Torus) fusion research project under the auspices of the International Atomic Energy Agency in Vienna, which had recently produced a design for a new large 'Tokamak' fusion machine.

Would that such co-operation should spread into other fields, even beyond technology! Would that all the countries of the world should work together for the future benefit of all, rather than against one another and towards mutual disaster!

Discussion

At this point there was a break for discussion,[17] and the first intervention, from Mr Frank Sims (a Yorkshire local government engineer), usefully brought the meeting back to its principal subject, namely the social and cultural challenge of modern technology.[18] Mr Sims wanted to discuss unemployment.

Neither he nor others present believed that high unemployment levels, especially in Europe and even more especially in Britain, were more than partly due to the impact of advanced technologies. However, it was to be expected that the introduction of machines to increase individual productivity in any sector would, unless the market expanded to absorb a greater output, leave some in that sector with less or even no work to do. True, as His Royal Highness Prince Philip had said earlier, these people could in principle turn to alternative occupations, as had the former makers of bows and arrows or the farriers of the age of horse-drawn transport. But was this still generally practicable? Mr Sims pointed out that Britain was not a poor country, or short of indigenous energy. The workforce was capable, there was a well-established and well-known capacity for research and invention, agriculture was efficient and effective. Yet 14 per cent of the population available for work was unemployed.

To counter this Mr Sims called for a long-term 'co-ordinated view of people', so that sudden step-changes in requirements for labour and production might be smoothed out and so cease to be the violently disruptive factors of the current social era. This was the first mention of a point to be made several times later in this Symposium, namely that gradualness could make acceptable—even unnoticed—changes which would be highly disruptive if introduced too rapidly. Many of today's social problems could in fact be attributed to over-rapid change (often for entirely sound reasons). There were tremendous differences between the working life of today and that of a century ago, and very few would dispute that today's was incomparably better. The probability was that the 2080s would compare similarly with today.

Mr Sims ended with a plea that countries should study the technological and social relationships in other countries, particularly those (such as Japan) where the introduction of advanced technologies had been most successful. He called for more international co-operation, at all levels, between practising engineers and technologists.

This led another practising engineer, Dr G S Hislop, to raise the subject of collaboration in defence projects in which, particularly in a closely knit community such as Europe, conflict frequently arose between the desire to move forward rapidly with uniform and co-ordinated strategies and that of most countries to ensure that their national industries benefited as much as possible from the resulting contracts. Dr Hislop thought the current collaborative framework in Europe was inadequate.

Dr Schuster did not disagree, but pointed out the considerable differences between public spending on defence research and development in the countries of the European Community: some 50 per cent in Britain, 30 per cent in France, 10-12 per cent maximum in the German Federal Republic. For comparison, the Japanese percentage was much lower still. These different levels of commitment made collaboration difficult, and in addition defence was still an area where exchange of information and technology was strictly regulated and often limited. It was entirely excluded from the 'framework of the European Community'.

Dr Agnelli pointed out that reticence over technological exchanges was not confined to the defence field: collaboration between national telecommunications systems (the advantages of which might be thought self-evident) was still impeded by 'reluctance to give up sovereignty in many crucial areas which will be fundamental to the future of our wellbeing'.

Mr J S Solbett had noted that most of the European co-operative efforts described by Dr Schuster were government sponsored (and funded) in one form or another. He wondered whether the more 'elementary' collaboration which took place in non-governmental bodies, such as the European Federation of National Engineering Societies (FEANI),[19] was being exploited as fully as possible, and felt that participants 'in the work of such bodies . . . who meet and then go home the better for it' could perhaps find ways of passing on the betterment to the memberships at large of their national professional institutions; to the tens of thousands of individual members of these societies, so that they as engineers and technologists in general can benefit, and then perhaps do something for their fellow citizens.

Dr Schuster, having already spoken in support of the European Science Foundation, was strongly in favour of Mr Solbett's ideas, which could represent an important step towards a public better informed of scientific and technological progress, and hence (he believed) less hostile towards that progress. The FEANI, which in fact was both a European and a worldwide association, was now bringing together engineers from very many countries, but there was a tendency for these contacts to remain a closed society. What was now needed, as Mr Solbett had said, was more dialogue with 'modern youth, the new generation, who speak a completely different language and have a completely different way of thinking'. This view was supported by the President of the FEANI, Dr José Maria Coronado Valcarel, who mentioned that a forthcoming meeting of his federation, in Paris in September 1983, was being organized on an interdisciplinary basis with a hoped-for attendance of societal groups other than engineers, so as to get a 'cross-fertilization of ideas with the purpose of improving life, and for the service of mankind'.

Unhappily these ideas provoked a somewhat negative comment from Mr Donald Glower (Ohio State University), who reported that the National Science Foundation in the United States, despite expenditure of some thousand million dollars per year on activities rather similar to those of the FEANI, had been shown to have little influence on either the development of technology or its understanding by the public.[20]

Finally in this discussion, Dr Robert Frosch of the (US) General Motors Corporation echoed the doubts of several others present by questioning Dr Schuster's suggested $\sqrt{N}$ relationship between the numbers of participants in an international project and its complexity in comparison with a purely national project (see Dr Schuster's text, page 53). Without a precise definition of observation' would easily show the relationship to be of the exponential form 2^N. Dr Schuster replied that it depended on whether one was an optimist or a pessimist.

That is probably true, although it is hard to imagine (at least as yet) any attempts at international co-operation being sponsored other than by determined optimists.

There then followed two further 'keynote addresses', the first by Professor Gunnar Hambraeus, Chairman of the Royal Swedish Academy of Engineering Sciences, who had long associations with the DISCOVERIES Project, had been Chairman of the Project's 1979 Symposium in Stockholm and in November 1980 was the first recipient of the recently established Honda Prize.

Professor Hambraeus began by describing[21] an activity of his academy in Stockholm which he called horizon gazing, which in fact comprised attempts to foresee the future well beyond the immediate horizons of the next election (politicians), payback time for investment (industry) or simple self-interest in living today without regard for tomorrow (the general public). In all these cases a principal characteristic was inertia: technological inertia, which 'tends to slow the modernization of our industries'; social inertia, in education and training, markets, research and development; and psychological inertia, or natural resistance to change. 'People are reluctant to change habits,' said the professor, 'or to learn anew, to move to new locations and to acquire new working habits. They resist changes in production methods, in product and distribution patterns: they stick to old markets and traditional methods.'

Some of this inertia was of course tied to capital and market investments, to research and development that had been expensive and must now be exploited to the limit, and to education, which could be similarly regarded as investment in those both already within and just entering an industry. Declining economic activity, such as much of the world was currently experiencing, also encouraged inertia. Nevertheless most people recognized that change was largely inevitable, and had only to look to the newly industrialized countries where it was being fully exploited to see that, in the end, it could pay good dividends. This applied especially to changes involving the newest and most advanced technologies, although here there was a danger that non-experts (politicians and their advisers, some industrial and most financial directors) could be attracted to the 'fashionable' rather than to the more promising opportunities recommended by their scientific peers.

Professor Hambraeus drew attention to the considerable and increasing imbalance between demand and supply of young qualified scientific and technical personnel, gently chiding those who found it 'much easier to go into social science, the humanities or languages'. This is certainly a dilemma in a democratic society, which is supposed to guarantee liberty to pursue any career chosen (though without guarantee of a paying job in that career).

What may sometimes cause greater distress is seeing brilliant brains turning in an unproductive (even in the most liberal interpretation of the word) direction because the exact sciences are passing through an 'unfashionable period'. Perhaps, as was suggested in subsequent discussion, education might be extended somewhat so that all technologists could have some training in 'liberal' subjects, and vice versa.

The professor also believed that many people, particularly politicians and administrators, did not fully understand 'what was happening in the world around us'. The universality of advancing science and technology meant that no single country could any longer resist or isolate itself from the advance: either it must be accepted and exploited, or ignoring it would lead to societal decline. Its misuse for 'breeding white elephants' was no less dangerous, while resisting its consequences (e.g. by protectionism in the face of saturated and over-supplied shrinking markets) could lead to disaster.

Concerning the problems of unemployment raised in the previous discussion period, Professor Hambraeus hoped to see an end to the idea that fixed and regular working hours were to be championed, whatever variations might occur in work to be done. This was acceptable in the past, but changing circumstances could now make it a very inefficient approach. It had to be recognized that a completely new work pattern was appearing, where 'perhaps five per cent of the total population will be employed in agriculture, and the manufacturing of all basic industrial goods will be taken care of by another 10 to 20 per cent'. The rest of the population would have to find employment in service, information and other 'soft' trades.

The professor concluded with a rather profound and by no means uncalled-for reflection on a particular social consequence of advanced technology, which he called electronic loneliness, or even electronic solitude. 'Our youngsters in Europe and the United States,' he said, 'spend several hours a day in front of the television screens, and further substantial amounts of time playing video games of various types. They do it alone with the machine, without contact with other human beings, and we are now in a new phase of adding (further) to the electronic entertainment options in the home.' Certainly all this offered important attractions and even advantages, but it must not be allowed to kill the joy—the great joy and the necessary fulfilment of life—that came from co-operation and togetherness between people.

The last address on this very full first day of the MANTECH Symposium was a nostalgic look into the past by Sir Peter Gadsden, formerly Lord Mayor of London and now President of the Ironbridge Gorge Museum Development Trust. No summary could do justice to Sir Peter's fascinating account of some of the monuments in his museum to the past prowess of British engineering: his paper[22] should be read in full. If there were lessons to be learnt for the present day, they were perhaps that the first Industrial Revolution was due to co-operation between all sorts and levels of devoted workers, all giving of their utmost because they believed in, and derived great personal satisfaction from, what they were doing. 'We must make sure,' concluded Sir Peter, 'that our measures of social control over industrial activity (however desirable in themselves) do not fail to allow room for personal satisfaction.'

No one could disagree, and at least some were left reflecting that provision for increased personal satisfaction, if that could be achieved, must surely go a long way towards restoring lost confidence and happiness in the millions who today can be heard questioning their very *raison d'être*, the reason for their existence in a none too friendly society and (apparently) a none too welcoming world.

Discussion

Sir Peter Gadsden's closing remarks had clearly inspired much of the discussion which followed, and several interventions called for greater attention to the human element in an increasingly automated, computerized and now robotized world. Because they were overwhelmingly a gathering of engineers, the moral and humane role of these specialist members of society came under particular scrutiny, first of all from the viewpoint of education.

The first intervention, from Mr F E Ireland, drew attention to a UNESCO study some years previously (following the 1972 Stockholm Conference on the Human Environment) which had examined the impact on society of a large number of professions, and concluded that engineering (and hence the engineer) had more impact than any other.

However, most engineers were unaware of this, and many tended to regard their engineering as an end in itself rather than a means to an end (in broad terms a better world). The reason appeared to be that engineering training was so vigorous and time-consuming that it left insufficient place in university curricula for 'broad and cultured education'. Yet precisely because the engineer's work could have such an enormous (and ever-growing) effect on the whole of society, his need for a broad and cultured education was vital, and more vital today than ever before. It should, said Mr Ireland, begin in schools, teaching children in their formative years about society and the environment. Then on to the secondary school, but the more so at universities. It should not be a series of lectures, but a part of the whole of an engineer's education and training, and brought into the major projects which the engineer studies.

In this way it might be hoped that engineers, whose contributions to society's fundamental decision-making processes[23] tended at present to be advisory only, would gradually take a more responsible role in controlling the use of the creations of their technical expertise for the greater general good–in the parlance of DISCOVERIES, *humanely*.

This somewhat concentrated attention to the education and role of engineers could be expected to stimulate thoughts on the relationships between them and their companion intellectuals, the scientists. Dr J H Horlock, both an

Engineering Fellow and a Fellow of the Royal Society (who declared that he was also presenting the views of Dr Robin Nicholson),[24] wanted to avoid too sharp a line between science and technology–the latter term including, or being included in, engineering. Dr Horlock went on to suggest (and no one would dispute) that scientific discoveries have been the origin of many industrial applications, so that in the end '. . . it is often difficult to distinguish between the contributions of the scientist and the engineer'. So why should there be 'divisiveness between science and technology'?

The speaker feared that this originated largely in education, where there was a tendency to favour 'the romance of pure science rather than the rough and tumble of engineering'. This artificial distinction was surely an impediment to the efficient development of any advanced technology, and Dr Horlock hoped the close co-operation between the Fellowship of Engineering and The Royal Society (the youngest and oldest of Britain's 'élite learned institutions'), together serving Science as a whole, would continue and expand, not only to their mutual benefit but above all to the great benefit of an ever more technology-based society.

The chairman of the session, Professor Sir Hugh Ford, also a Fellow of Engineering and of The Royal Society, as well as a past chairman of the British Science Research Council, added his powerful support to Dr Horlock's remarks, at the same time hoping that the Fellowship of Engineering would be able to develop additional co-operative links with other academies of engineering throughout the world.

Returning to the analysis and assessment of the role of engineering in the development (evolution) of society, Professor Harold Linstone of the Portland State University remarked that in the United States the professional engineering institutions seemed less concerned than the nation's central administration. For example the Office of Technology Assessment (OTA), which evaluated both the physical and social impacts of technology, was a creation of Congress, not of the engineering profession. It was funded entirely by the State. Moreover, interest in technology assessment was found more among, for example, business management students than among those of engineering, evidently for the reason already noted by Mr Ireland, namely that engineering curricula were so crammed that no space remained for 'marginal studies', often regarded by the engineers as comparatively trivial. It seemed in fact, from Professor Linstone's intervention, that even though the US situation might be regarded by some as less satisfactory than that in the UK, concern for improvement in the former country was also less than in the latter.

The session being devoted to Western Europe, it would have been interesting to hear about the administrative influence of engineers (and scientists) in other European countries, particularly, for example, France, Germany and Italy. But no offers of information were forthcoming. The next session, devoted to the North American scene, was to demonstrate that at least some professional technologists there were as worried as their British counterparts.

It was left to Professor Hambraeus (Royal Swedish Academy of Engineering Sciences) to summarize the dilemma which was clearly sensed by everyone present. 'On the one hand,' he said, 'I see a great need for a more profound [technological] education . . . which will allow no time and no room for a wider education in sociology or other things.' Yet there was an undoubted need for technologists with that wider education. The professor had a possible solution to offer: that those with personal preferences and evident ability for greater specialization should be able to follow this 'vertical' cause 'to the exclusion, or at least postponement, of wider education, which would in any event come later to these more intelligent youngsters'. But others should be offered a more general ('horizontal') education, which should include study of the social implications and consequences of their engineering. Effective engineering groups would then include some people of each type (horizontally or vertically educated), the one type complementing the other.

For all present it may have been comforting to reflect that this sort of solution seemed, in fact, to be evolving—in all but a very few highly specialized fields—as a result of 'natural' forces and influences. If this could give cause for restrained satisfaction, it was by no means a reason for complacency.

From education back to employment (or unemployment) and what Professor M W Thring (Queen Mary College, London University) referred to as 'the engineer's conscience',[25] namely his recognition of responsibility for the social consequences of his work. The professor himself clearly felt that responsibility personally and deeply, but he was also able to show that many of the unwelcome phenomena of current society, including unemployment, derived from a complex combination of circumstances, related more to political and financial policies than to modern technologies. Thus it was unacceptable to blame technology for the fact that, in the professor's words, 'the infrastructure of London is falling to pieces and we cannot afford to repair it, and yet we can afford to pay millions of people to do nothing'.[26]

Concerning the much-sought-after renewal of growth in industry, commerce and the economy generally (both national and international) Professor Thring reminded the meeting that 'every engineer knows there is no such thing as perpetual expansion',[27] and that a continuous growth rate of four per cent would mean a fiftyfold increase in a century. The logic of this is unquestionable; indeed today's many apparently saturated markets illustrate the inevitable ultimate result of continued over-production in relation to demand. However, some of those present with experience of less materially satiated communities were unconvinced that zero (or near zero) growth was yet desirable anywhere in the world. What was needed was a radically changed system for matching real demand (freed from political, financial or other restraints) with a similarly unconstrained production. If this seemed to some to go beyond the limits of technological discussion, it was surely still well within the scope of DISCOVERIES.

Professor Thring's reference to 'paying millions of people to do nothing' prompted a comment from Sir Peter Gadsden, who pointed out that 'having a job' was not necessarily equivalent to doing useful work. Sir Peter was against the commonly found relationships between pay and the precise work done, advocating instead that people be paid–or otherwise rewarded–according to their capabilities, but should then accept whatever work might be required of them, '. . . and if they did not take it that would be their fault and they would not get paid'. Sir Peter might have added that certain self-contained communities have long practised systems of this nature, apparently with success.

Professor Thring's remarks on 'the engineer's conscience' also prompted an intervention from Professor Gordon Wray, who gave a short but fascinating account of how the textile industries of the advanced industrial countries, to achieve lower production costs, were installing machines which could reduce the labour force required for a given rate of output to perhaps one-tenth of that needed ten years ago. The incentive to use such machines was the need to cut labour costs (which had become totally uneconomic) or go out of business. Professor Wray described how, as a developer of and counsellor on the use of the new machines, his usual brief was to automate operations and so eliminate as many operatives as possible. Thus his own work was putting others out of work, and he could certainly visualize the 'factory without workers' mentioned earlier by Dr Agnelli of Fiat.[28]

This led Professor Wray to what he believed 'should be the ultimate question for this conference on the social challenge of modern technology'. If high technology eliminated virtually all workers except those in the service industries (which would never be able to absorb so huge an additional part of the labour force), not only would there be an immense increase in unemployment, but in consequence there would be an immense decrease in the markets for the automatically produced goods, for 'who will have the money to buy the products?'

Would these products have to be given away, or would a completely new social structure have to be devised 'so that people could still have the products of industry'. In a certain sense, the alternatives might amount to very nearly the same.

With this in mind, and before leaving the subject of technology and unemployment, Professor Hambraeus injected an invaluable reminder that real wealth in a society was not dependent on the numbers of workers required to create it. It comprised quite simply the added value given to raw materials by the process of manufacture.

Given that manufacture, the wealth was there, and the same was true in agriculture. 'So,' declared the professor, 'even with rising unemployment in manufacturing and in agriculture, we have greater wealth to share.' And so back to Professor Wray's concluding comments.

The discussion also returned briefly to the earlier remarks of Dr Günter Schuster, when he had suggested a $\sqrt{N}$ relationship between the numbers of participants (N) in an international enterprise and the 'complexity' of that enterprise compared with a purely national one. Dr John F Coplin thought this a most important consideration in planning the transfer of technology from advanced industrial countries to those less advanced, where his own experience had suggested that the exponential relationship 2^N of Dr Frosch was probably the more correct. However, Sir Frederick Page, speaking from personal experience of European collaboration in the aerospace industry, believed Dr Schuster's $\sqrt{N}$ factor was appropriate for such a case, provided all participants were technologically competent and 'there was one strong central management'. Moreover, if the collaboration had a closely defined practical objective (for example, a particular aircraft) it would if successful almost certainly lead to a substantially larger market for the eventual product.

Finally, and again basically stimulated by Sir Peter Gadsden's insistence on the importance of 'job satisfaction', Mr John Derrington pointed out that much of the infrastructure of civilized life was still largely labour intensive, and was likely to remain so. Mr Derrington was of course referring particularly to the service industries, but he also wished to draw attention to the older 'craft' industries, which could still reward personal skills and so create satisfaction and even pride in work well done. He believed the preservation of these older industries was of growing importance as a counterbalance to the societal divisiveness of ultra-modern technology.

In Mr Derrington's words:

> We see the danger occurring of society being split into two extremes: the white-coated technologist in his ivory tower, and the rest of humanity, who are not provided with satisfaction for their normal human endeavours and who to a large extent, or to an increasing extent, do not even have the attraction of gainful employment. Thus we must, in spite of the growing attractions of and interest in high technology, devote an increasing effort to training craftsmen and recruits to some of our older industries. Otherwise we shall run the risk that high technology itself will wither away for the lack of an adequate infrastructure.

EDITOR'S NOTES

13 HE the Sheikh Yamani of Saudi Arabia and Dr Surendra J Patel of UNCTAD (UN Conference on Trade and Development).

14 For the full text of Dr Agnelli's address see page 46.

15 The commonest car to be seen on the roads of France is the 'Deux Chevaux', a brilliantly designed but extremely simple (hence reliable and cheap) transport machine.

16 For the full text of Dr Schuster's address see page 53.

17 The Symposium programme provided for two such breaks in each session, midway and at the end.

18 The tendency to digress from human and/or humane considerations, and to discuss instead ultra-sophisticated applied science (especially that related to electronic information and communications), has been a prominent characteristic of the more recent DISCOVERIES meetings as compared with earlier ones. While easy to explain, this is perhaps less easy to justify, particularly in view of the declared and unique 'theme' of the series, when conferences and symposia devoted to every form of high technology as such are legion.

19 After the Federation's title in French, Fédération Européenne d'Associations Nationales d'Ingénieurs.

20 In a particular technological field, that of civil nuclear power, there is ample evidence of minimal relationship between public understanding and acceptance and expenditure designed to encourage these through improved public information. Doubtless this is largely due to much publicized and often sensational misinformation, frequently promoted by opponent groups with little professional standing but a carefully cultivated public image. Scientists and engineers generally find difficulty in countering these groups, perhaps because as yet there is no recognized profession of 'psychological engineering'.

21 For the full text of this address see page 62.

22 For the full text see page 68.

23 Fundamental not only to the future of society but to the future of the whole world.

24 Dr Robin Nicholson, Chief Scientific Adviser to the Government's Central Policy Review Staff, whose unavoidable absence prevented him delivering an intended address on 'Science—the Base of Modern Technology'.

25 Professor Thring had published a book under this title, through the Institution of Mechanical Engineers, in 1981.

26 Professor Hambraeus had made the same point, in the wider context of 'urbanized Europe'—see page 66.

27 The universe might be considered an exception.

28 See page 49.

2.1 Managing Technological Change in Western Europe

Umberto Agnelli, Vice-Chairman, Fiat
Chairman, Fiat Auto SpA

The title of this session is 'Modern Technology in the Context of Western Europe'. It is no easy task to cover such a vast topic in all its national and sectorial variations in a twenty-minute speech. And there is a real danger of repeating what we have all heard before, or of falling into facile rhetoric. I shall try to base my remarks on my own experience, quoting examples I have encountered in my professional activities as a businessman.

At the same time, I am fortunate to have such a well-qualified audience and I shall be extremely interested to hear the first-hand experience and views of those who operate in other productions of the industrial and tertiary sectors. By pooling all our different experience we shall be able to give a much fuller answer to the question under discussion by the end of our meeting.

We can confidently assert that a great deal of technological innovation has been introduced into production processes in the engineering and mechanical industry, and especially in the transport sector.

In strictly technological terms, the development of robotization and its large-scale introduction on the shop floor have brought us more or less in line with the major Japanese car firms.

In technological terms, the machines are extremely up to date and, at least in Fiat, the company I know best, up to the highest international standard. This is true in both quality and quantity terms, given the widespread use of advanced technology in all areas: from body making to painting, from mechanical parts to assembly.

We find a similar situation in the large mechanical firms outside the vehicle sector. In most cases, conventional automation and technological innovations to the production process have reached satisfactory levels. The only exceptions are those firms who were in difficulty well before the recession and who just did not have the money for technological conversion.

The situation is more complex when we look at the smaller companies, which in numerical terms form the largest part of the mechanical industry's universe. In general terms, it is fair to say that the firms supplying the major companies have undergone or are undergoing wide-ranging technological change, often accompanied by organizational adjustments and business agreements with similar firms. The strategy adopted by the big companies makes competitivity essential. Most large firms are tending to search out the most competitive suppliers rather than relying on the suppliers they have always used. It is the need to enhance competitivity that has triggered innovation in the smaller supplier and sub-supplier firms.

The situation in other small firms is much less homogeneous. Some are a fair size, others are tiny, and their situations vary enormously. There are small extremely advanced companies side by side with others that are technologically twenty years out of date. And I think this is also true outside the engineering sector, indeed almost everywhere if we exclude the advanced technology sectors (electronics used in information processing or public services) and capital goods and part (but only part) of the chemicals industry.

Having spoken of modern technologies as applied to the production process let us see what effect they have had on the product.

Cars, trucks, trains and other transport vehicles only superficially resemble their counterparts of a decade ago. The fact is that the application of electronics and instrumental technologies based on the so-called 'artificial brain' families has thoroughly revolutionized components and is still doing so. Here too innovation is a major factor in European industry. In many cases I would say our technologies are the most advanced in the world.

It should also be noted that the technological revolution, whether it affects the production process or the product, is the result of massive research programmes conducted either by industry or in some countries by national industrial research councils.

The wealth of technological knowledge and capability this has produced in European companies (my own experience is primarily in the vehicle sector) was and is well up to the challenge presented by our international competitors.

Someone has stated that for companies the next ten years will be 'the age of the engineers'. True enough, but not in the sense of the 'technocracy' which was such a common topic in the early 1970s. Certainly the engineering experts, whose job it is to select and apply to production the innovations created by the research workers, will become increasingly relevant. It is they who will speed up the transfer of new technology from the lab to the shop floor, a process that has always been much slower in Europe than in Japan.

Obviously we have to strike while the iron is hot and fill in certain gaps. (In my own country, Italy, almost all industrial research is done by business, the national research organizations being underfunded and inefficient.) Above all we must avoid a one-track-minded approach in research. All too often such approaches are modish but disregard the real needs of industry.

From modishness to myths. Back in the late 1960s, when student protest formed the tip of a whole radical-utopian iceberg, technology was the enemy. Technology grew best in factories and the factory was the symbol of the system they wanted to destroy. Technology was the Americans' major weapon in

Vietnam and the US government was Public Enemy Number One. Not for the first time in history, logical thought gave way to strange cocktails of feeling, ideology and emotionalism even in educated and sophisticated circles. Technology was seen not as a tool but as an evil, a Moloch to be fought and beaten. Today, only 15 years later, the climate of 1968 feels like light years ago. The attitude to technology is totally different and, at least in Western Europe, a certain ambivalence is apparent. For some, technology is the new god, a totem to be worshipped by advanced societies. Others approach it with diffidence and a touch of incredulity. Some of the books and articles on the technological society to be expected in the 1980s and 1990s take a more or less science fiction line. In the last analysis, Servan Schreiber is confused with a new Orwell. Both attitudes show how little even the educated public actually knows about the complex reality behind the concept of modern technology.

The fact is that the public has not been educated in the 'culture of innovation', with practical results that are far from negligible. Information science for example is a typically innovative field. A great deal is still to be learned and much research is needed. The computer industry is extremely dynamic. But technological innovation and, more specifically, the application of electronics is a much bigger world, covering very much more than information processing. Just think of the numberless uses of electronics in robotics, in machine tools and consumer durable components, some now commonplace, others still to be applied on a wide industrial scale. It is quite wrong to emphasize only information processing and neglect other applications of electronics. I say this because, in recent years, government institutions in particular have often sponsored information processing research programmes that more or less uselessly duplicated work already done. At the same time, public funds for research into innovative applications of electronics in productive areas like the mechanical industry have been hard to come by.

Yet in the next few years it will be industry that produces the so-called 'ripe products' to make the greatest use of electronics-based technologies and of the research required.

I would like to go a little further into the question of technology-society education and not because I want to do the sociologists out of a job! I am convinced that the general public must be better educated in the real facts of technological innovation which, like it or not, is going to make far-reaching changes to the daily life and work of everyone in Western Europe. For another thing, if we fail to map out the positive benefits technology can bring to our societies, we are going to be faced with serious hold-ups; and industry will be the first to suffer, since it is here that technological change has the greatest influence. It is not enough to say 'Look at Japan and relax: the Japanese are far ahead of us in the field of technological applications, yet they have almost no unemployment and technology has brought positive advantages in both industrial production and social terms'. We have to find a way to understand more fully what is going to happen to our societies, without either facile optimism or frustrating pessimism. We have to foresee, prevent and adjust.

Toynbee's statement that a society's ability to cope with change is and will be in direct proportion to its ability to exploit its educational, technical and scientific assets is truer than ever. And here I come to the practical consequences of what I was saying. One of the most urgent problems posed by the technological challenge is educational. We need to produce workers with training to manage the complexity of automated systems. The drastic reduction in physical effort is counterbalanced by the need to master not only new techniques but most of all to acquire scientific, logical and linguistic skills. As someone very acutely said this involves training in the perception of essentials and constant observation.

It is therefore absolutely vital that the technological revolution be accompanied by a parallel and prompt effort to modernize our education and professional training systems.

Anyone who has seen the difficulty of reforming and strengthening our educational and training systems, especially after the demagogic disasters of the still recent past, will easily understand that this is no less of a challenge than technological innovation itself.

A fair amount has already been written about 'factories without workers'. Frankly I do not believe that this will ever happen, except in certain very special cases. Not because it is impossible, but because there are sound economic and social arguments against its widespread application. Nevertheless the skills required by the new technologies are bound to change the image and the substance—as well as the size—of the blue collar workforce.

This will have obvious repercussions on industrial relations and on labour regulations, which are usually so detailed and so ossified in Europe. We may as well prepare ourselves now, or in a very short time we shall be complaining about glaring inconsistencies between laws, labour and the facts.

I get the feeling that few in trades union or government circles have really understood the significance of technological change. We industrialists have had to learn faster than the general public, since we are living with these changes inside our companies. Governments, however worried about the social effects of technological innovation (with particular emphasis on jobs), seem readier to produce studies and White Papers than to develop long-term strategies.

I doubt for example if the union leaders and the politicians realize that the technological revolution creates the necessary basis for a more flexible society. Nor do they appear to see that bureaucratic constraints will have to be removed, that industrial relations based on the class war are outdated, that some bargaining machinery is useless and that much of the overgrown Welfare State organization is counterproductive.

I mentioned a more flexible society, rendered not only possible but essential by technological innovation. I am thinking for example of a society in which a growing number of workers will be able to do target-oriented work rather than sticking to rigidly programmed procedure, and working hours will be much more flexible and tailored to individual needs. These changes are likely to occur in the very near future. In some cases they are already being introduced. In this situation the almost general demand by European unions for a standardized reduction in working hours is a glaring example of cultural retardation. Quite apart from value judgments, such claims only make sense in major industrial areas with thousands of workers all tied to the same shifts, the same products, the same work procedures. They lose much of their relevance in the presence of widespread decentralization and a technology which permits the flexible organization of working hours and styles.

As I said at the start, facts not fantasy will help us to manage innovation properly. Only an innocent or a utopian will claim that technological progress in itself means freedom and quality of life. What is true is that technology can create a new context and new tools, which properly managed in technical terms and based on a thorough understanding of innovation can be used to improve the quality of life and enhance human freedom. To put it simply, a modern liberal society concerned with the real needs of individuals, as well as with economic development, is now easier to build than it was in the past. Because today we have the tools to reproduce in concrete form that flexibility which was an essentially cultural objective in the past.

A word of warning. The fact that it is now easier to improve the quality of life does not mean that this is in any way automatic or inevitable. As usual, what we get will depend on what we decide to do. More exactly it will depend on the choices made by the decision-makers, the leaders in politics, industry, trades unions and education.

Business has a great deal to contribute, having had first-hand experience of technological innovation before the rest of society. There are suggestions we can make, errors we can warn against. However, our messages will only be useful if our listeners can tune in to the same wavelength. Can the unions in Italy, France or Britain tune in to this wavelength? Can the politicians, who in the age of technological revolution persist in using languages, interpretations of society and tools of political action more appropriate for historical studies?

And yet the current technological transformation is bound to have an effect on political practice too. The new techniques introduce an ever-wider public to a mass of information destined to become the basis of every citizen's political opinions. Less and less will political consensus be based on pure ideology or sentiment. Even the form of elections may be revolutionized by the tools available. The long-distance electronic vote is already widely used in opinion polls.

Why should I be talking about politics, trades unions and the flexible society in a speech on European technology and industry? The reason is obvious. Technological progress affects society as a whole, so all groups in our society need to understand and channel it. If we can do this, technology, like the flooding Nile, will become a bearer of growth and fertility. If not, it may prove a Noah's flood drowning those who didn't get round to building their ark.

As I approach the end of my speech, there is one question we all want answered. What are the prospects for European industry in the face of the technological challenge of 1985-90?

One thing is certain. Industry will remain the driving power behind technological change even in what many describe as a post-industrial society. For several reasons. First, because now more than ever, the production of technological innovation is a business. Secondly, because innovation is infiltrating the entire range of industrial activity. Thirdly because the flexibility and adaptability of the new technologies opens new markets for the personal and intangible goods we may classify as services, but which are in fact a by-product of traditional industry. To take just one example: it's no accident that the best transport system engineering is produced by the affiliates of major vehicle producers.

The European problem is that we have many excellent sources of scientific and technological skills, many excellent business centres, but they often follow separate lines or have few direct links. There are several reasons for this. The first is unfortunately obvious. There is no common European policy aimed at developing a strategic approach to the mobilization of resources on a continental scale through research and incentives.

The second is that individual national policies vary so widely. Some countries invest massive human and financial resources in technological innovation. In others public spending is minimal and often frittered away.

I am not pretending that we shall overcome this handicap in the short or even the medium term. Still, co-operation between the most technologically advanced companies in each industrial sector would help to counteract it. This is already happening to some extent. Almost every day the media announce agreements between major industries producing true joint projects for research, component production, marketing or after sales servicing.

Today we can adapt the new technologies to various economic situations, different needs, varying levels of economic development and different social structures. This is important for the creation of new and more advanced forms of industrial co-operation with the developing countries. Another factor is widespread industrial decentralization in which the parent company is increasingly dedicated to strategic planning and assembly, sometimes fed by a whole constellation of supplier companies. This too enhances flexibility, enabling firms in the advanced countries to adapt their products to the consumer needs of their outlet markets and at the same time to become themselves the buyers of sub-contracted supplies produced in the developing countries. European industry is particularly well placed to grasp these new trade and co-operation openings, especially in Africa, the Mediterranean and the Middle East. We are fortunate in having a long tradition of adapting our products and technologies for a diversified market. Since the Common Market was born 25 years ago or more, our industries have been accustomed to operating on a continental scale, while at the same time adapting their products to the individual requirements of the separate national markets and the different tastes of the consumer in London or Rome or Brussels. Without falling into optimistic prophecy, I think I can fairly say that the new technologies are forging another tool with which it will be possible to narrow the gap between North and South. A tool, moreover, that may come to represent concrete business for industry in general and European industry in particular.

Obviously these processes will never develop coherently if they are just left to happen. Is it utopian to hope for a strategy of the OECD countries along these lines? Can we develop a policy offering not constraints but guidelines for the future?

That, at long last, would be a genuine response after so many inconclusive North-South debates.

But the question is one not even I myself feel capable of answering.

2.2 National and International Collaboration in the Development of Science and Technology

Günter Schuster, Co-ordinator for Bilateral Co-operation, German Federal Ministry for Research and Technology

Introduction

A lot has been said and will be said about collaboration in science and technology at national and international level. I should like to contribute to this important subject matter in drawing on my own experience as Director-General of the Commission of the European Communities for Science and Research during a period of ten years and in analysing particularly the situation in Europe.

When talking about international collaboration in science and technology it is appropriate to differentiate between the collaboration in the field of fundamental or basic research on the one hand and the collaboration in applied or technological and industrial research on the other.

Basic Research (National versus International)

I will follow this order and I will start with the field of basic research.

Let me first remind you very briefly of the tangible and intangible benefits of international collaboration in this field. The tangible benefits are well known to you. They arise when the countries share the cost of a scientific programme with one or more other countries, when one country uses research findings generated in another country to avoid unnecessary duplicating efforts, when it obtains access to unique foreign research facilities or when unique research facilities are constructed and exploited together in a common venture. Sharing knowledge means that research goals can be reached more quickly and cheaply. It allows the country to focus domestic scientific efforts in particular areas with a high potential and to rely in other areas on the participation in a collaborative project.

As important as the tangible benefits are the intangible benefits. These are

—the advancement of Science in general

—the strengthening of international relations, and what I might call
—the 'added value element' of international collaboration.

This last point is, to my mind, still largely underestimated and not fully realized by the politicians and the administrators. What do I mean by that?

Bringing together good scientists and researchers from different countries, working on bilateral or multilateral projects, gives a measure of cross-fertilization and mutual stimulation so that the result of research activity is not merely the arithmetical sum of their efforts; it is more. This 'more' is what I mean by the 'added value element'. In the interaction with other people, with other ways of thinking, other cultural backgrounds, different approaches to solving problems, good people and even the best people become better. The interaction of researchers of different countries in a research team increases the efficiency of the work. The result is richer compared with the result of a national team of the same size and working on the same subject.

Let me quote three examples taken from the field of basic research:

The design, construction, and exploitation of the high flux reactor of the ILL[29] at Grenoble, a bilateral French-German venture which started in the late sixties. French imagination and experience in designing research reactors and in making experiments with neutron beams combined with the German experience in engineering and in hardware fabrication have led to a unique research tool which turned out to be better than that which mere French or mere German teams would have produced.

The collaboration of teams of European researchers in the field of medical research, in the framework of a so-called 'concerted action' of the European Community, led to results which the national groups so far had not been able to attain.

CERN—the 'European Mecca' for high energy physics experiment—is another striking example.

International collaboration has in fact been a feature of basic research from its very beginning and by its very nature. All scholarship is international by the very fact that its findings are published and are available throughout the world. A new dimension in the development of basic research was reached when certain projects could no longer be funded from the research funds of the university budgets or by the research councils and not even within the national science budget. The only possibility then is to collaborate with other nations in order to share the financial burden; but this means that parliaments and governments come into the picture. Because of their importance, their prestige and their costs the international projects are of great interest to national governments and parliaments and the researcher must accept a closer involvement of the parliamentary and governmental institutions. The governmental participation is at the same time a time-consuming factor and a stabilizing factor: time-consuming because of the various legal, commercial, and political structures and interests in the different countries which have to be taken into account before an agreement is reached. It is a stabilizing factor because after the conclusion of the agreements the flow of funds and the continuity of the project are guaranteed. Pooling resources in certain fields of basic research was the only way for the European nations to keep pace with the two superpowers.

It stems from this fact that the West European region is unique in the world in having created new international organizations in the field of basic research which design, construct, and exploit large research facilities in common, e.g. CERN, the EMBOLAB, the ILL, the Radioastronomy Centre in Las Palmas.* Through these inter-European activities free Europe is able to contribute to science on the scale of a superpower.

Another specific European reaction was the creation of the European Science Foundation in 1974. This foundation is a non-governmental organization sponsored and supported by the research councils and academies of the West European countries. Its aims are to advance co-operation in basic research, to promote mobility of research workers, to assist the free flow of information and ideas and to facilitate the harmonization of basic research activities supported by member organizations.

So far the results of the ESF are not spectacular. Some people are even disappointed by it, but in my view they should not be. The permanent contact between all the participating organizations, the organized flow of information about their activities, plans, difficulties and problems, are already very important achievements in themselves, but in the last eight years or so quite a number of important and interesting joint activities in nearly all the fields of Science (here: *Wissenschaft*) were generated. The ESF is an important asset in inter-European collaboration in basic research. In the middle of the seventies one Italian researcher said to me: 'In the universities in Europe we know each other mainly through a mirror which is placed in the US. We meet in Stanford, we meet in Berkeley, we very rarely meet in Europe, and this is a rather strange state of affairs. We ought to do something about it.' The ESF will contribute to improving this situation.

It is very probable that basic research needs new and even bigger tools in several fields for its advancement in the future. What has to be done then to assure timely European answers to new problems? In the years after the Second World War, it was through the initiative and the influence of eminent scientists that joint European action was taken and that new inter-European organizations were created (Néel, Perrin, Amaldi, Maier-Leibnitz, Sir John Adams . . .). In the sixties, after the 'invention' of Science Policy (King, OECD), things were handled more systematically. Decisions were taken within the framework of the

* I should like to quote JET and Ariane in the field of applied research.

national science policies and their priorities. Some countries created advisory committees or councils at national level composed of leading scientists with a high reputation. They were to advise the governments on priorities among several proposals for large new scientific instruments and facilities in the different branches of science at national level. Priority-recommendations from those committees or councils were generally followed.

This system guarantees an orderly procedure in different European countries but it obviously lacks a corresponding body which could recommend priorities at European level, in order to avoid duplication at national level of research tools and facilities of nearly the same size, and to enable the European countries to pursue research on a scale big enough to keep up with the progress at world scale.

What is needed, in fact, is a European advisory committee that makes priority recommendations for major science-tools and facilities in the field of basic research, whose recommendations are taken into account by the national governments.

There are several possible solutions to this problem: I will suggest two. An advisory committee such as I have just proposed could be established by the four so-called bigger countries: the UK, France, Italy and Germany (which comprise nearly 80 per cent of the scientific potential of Western Europe), or the ESF could be mandated (or I had better say 'asked') to do this on behalf of the interested governments.

Applied and Technological Research: National versus International

I shall now deal with the field of applied and technological research. What I have said about the tangible and intangible benefits of international collaboration in the field of basic science is also true for this sector, but I have to add some more points:

In the field of applied and technological research inter-European collaboration

—will allow the European countries to undertake projects with high technical and high financial risks but at the same time with a high potential benefit (e.g. nuclear fusion research, space research)

—will secondly prevent divergent development trends in a given field which would hinder the conclusion of joint industrial ventures at a later stage (e.g. telecommunication, micro-processors).

Furthermore, the development costs and marketing opportunities of new technologies require large markets in order to guarantee the competitiveness and the survival of the European industries. Providing large markets through inter-European industrial collaboration is one way to meet this requirement.

Needless to say, some projects in this field of applied and technological research require transnational actions by their very nature, in the environmental field (lead content of the air, SO_2 and NO_x influences on our forests), or in matters such as transportation or the safety of nuclear installations.

But the implementation of joint projects and activities in the field of applied science and technology is much more difficult than in the field of basic research.

What are the additional difficulties?

Difficulties Arising from the Involvement of Industry

1 National governments believe that their first duty lies in sponsoring advanced technologies to improve the competitiveness of their national industries, so what they consider to be within the capability of a purely national activity will be done within a national framework.

2 In a given field of advanced technology a country has to have a certain amount of knowledge and experience before joining an international partnership. If European country A already has a certain industrial experience in a given new field, and another European country B does not have it yet, country B sometimes is inclined to seek first the necessary know-how in the US and to take licences from US firms instead of seeking it from a European partner. Obviously this attitude does not facilitate inter-European collaboration in this particular sector.

3 Projects with industrial involvement cannot evade the well-established rule that the nearer the markets are to the projects, the more difficult will be the creation of inter-European activities and projects, and vice versa. This means that inter-European projects which involve participation of industrial firms are mainly focused on the so-called 'precompetitive industrial research'.

4 A special problem arises from the requirement to safeguard industrial secrets and protect inventions. The question of patents and licences is of eternal delight to the lawyers involved.

Difficulties Arising from the Involvement of National Policy Interests

5 In some cases a given research and development activity is part of the national foreign policy, e.g. the activity may be part of a wider bilateral co-operation between two countries, or it may play an important part in relationships with a developing country. This normally excludes joint projects with a third European partner or more.

6 The European countries have, of course, different economic policies, different commercial and different legal systems, different legal requirements (e.g. the requirement for ratification of international agreements) and different norms and standards. Even the organization of research may often differ very considerably (e.g. centralized as opposed to decentralized or semi-centralized). All this makes the establishment of a joint venture or a joint activity rather complicated.

7 A too rigid application of the 'fair-return principle'[30] makes dealings very often difficult.

8 One special difficulty lies in the decision about the site for a big newly planned installation. There are obviously some advantages for the host country in both economic and prestige terms. The site decision for JET was a real drama, sometimes referred to as the 'JET-site story', and the whole project was on the point of collapse over this decision. Incidentally this is no less a problem for 'basic research' projects, the site decision for the first CERN extension being a good example.

Difficulties Arising from Management Problems

9 Another difficult problem is the establishment of an efficient management structure for big inter-European projects, such a structure being vital for the success of a given activity. The arrangement must guarantee a clear distribution of responsibilities, a capacity for making quick decisions, and proper control mechanisms.

10 The management of a bilateral or multilateral project is more complex in comparison with a purely national project and the difficulties clearly increase with the number of partners involved. The relation seems to be more or less a square root function of N ($\sqrt{N}$), N being the number of partners. The same is true for the cost of the project. The more complex the organizational structure, the greater the need for translation of meetings and papers into other languages and the higher the travel expenses; there is also the extra cost of achieving an equitable distribution of the production of components (in particular of the so-called 'noble' parts of the facility), all of which necessitates more money and again appears to entail a $\sqrt{N}$ relationship.

11 There are two other EC-specific difficulties of an institutional nature:

EC research programmes and projects have to be approved by the Council of Ministers of the EC by unanimity. One country can block the decision for a project which is acceptable to the nine other countries.

> Very often the decision-making process is aggravated by the so-called 'package deal' mentality, which means that the approval of a certain project is given by a certain country only if at the same time another project is approved in which country A is greatly interested but some of the others are not.

My listing all these difficulties may give the feeling that important joint inter-European projects may never be achieved. Fortunately we have achieved some already and I should like to mention a few.

The 'flagship' of the EC is the JET project (nuclear fusion). I have already mentioned the difficulties in deciding on the site for the JET machine. The same can be said of the whole project. It was terribly difficult to get it approved by the Council of Ministers. If you wish to learn more about it, you need only read Denis Willson's book *A European Experiment.* Other EC projects are the Eurelios solar power tower plant in Sicily (1MWe) and the construction of 16-19 photovoltaic pilot plants in the 100 kW range for electricity production with solar energy in different member states.

Successful and important examples of intergovernmental inter-European collaboration are: in the field of space research the Ariane Project and the Spacelab Project; in the field of nuclear research the centrifuge enrichment 'Troika' (UK, FRG, NL) and the fast-breeder collaboration (F, FRG, Italy, B, NL). These are examples of successful co-operation which has helped the European nations to make full use of their resources to keep pace with the superpowers.

In assessing these projects we find that most of them lie in fields characterized by high risks, high costs and high potential benefits, i.e. in fields in which no European nation could undertake and pursue the project alone. This state of affairs has to be seen against the difficult situation in which most of the West European countries will find themselves at the end of this century. On the one hand they are threatened by the quick innovative progress in the so-called high-technology countries (US and Japan), in particular in key technologies, and on the other hand by the increasing flow of imports of classical goods from countries with cheap labour forces. These developments may endanger the competitiveness of the European industries in several fields in the coming years.

One answer to this challenge is to make more and better use of the still existing big European potential by inter-European collaborative projects, with full involvement of industry in some key sectors or in key segments of certain sectors.

These projects with strong industrial involvement must be guided by common objectives and strategies aimed at keeping the European industries competitive at world level, at creating wider markets, and last but not least at furthering employment.

In different sectors or segments of some important key-technology areas–I am in particular thinking of telecommunications, electronics, microprocessors, bio-engineering, biotechnology, robots and certain energy technologies–European countries and European industrial firms will have to develop common objectives and corresponding strategies to define the actions and measures necessary.

These strategies will have to comprise elements of industrial policy, trade policy, energy policy and research policy. This is the new kind of collaboration which Europe needs now. But who is to develop this type of co-operation, who can and will take the initiatives, bearing in mind all the above-mentioned difficulties? One could consider the European Community a natural nucleus. The EC approach is policy-guided. It acts as a regional community and tries to evaluate the potential of its member states. EC research activities are conceived in order to facilitate the achievement of those policy goals.

But the EC machinery needs more flexibility. The rule that all ten member states have to approve unanimously the proposal for a certain action is not in harmony with the needs of this new approach.

The EC should develop a pattern of co-operation in which under common objectives and a common strategy (accepted by all its member-states) participation becomes possible only by those countries which are strongly interested and which have the appropriate industrial capacities and capabilities. This approach is not to be seen as an 'à la carte' approach, because it is part of a commonly accepted strategy.[31] So far the inter-European collaboration of industrial firms is concentrated on long-term precompetitive research. In the new concept the collaboration of some firms on short-term market research should become possible.

I hardly dare to forecast that the EC will find the possibility to develop this flexibility in its existing legal framework. But I should like to say that the so-called EXPRIT proposal in the field of informatics (which comes from Commissioner Davignon) seems to go in the right direction. If the EC should find itself unable to develop more flexibility in its activities, it will be essentially up to the countries and (or) the industrial firms to take the lead and to develop some of these sectoral or segmental collaboration projects of the new type.

Concluding Remarks

Collaboration between the Western-European countries is just one example of collaboration within a world region. There exist many other collaborative activities of this type in different regions in the world, e.g. in South America, in Africa, between the Arabian countries, the ASEAN group in Asia and the Comecon countries. Furthermore, there exist big cross-regional organizations like the OECD/NEA/IEA.

Finally, at world level it is the UN and the UN-system which takes care of the collaboration in research and development projects and of problems which have to be tackled at world level. Obviously it is impossible to deal with all these important issues in a short lecture.

But I should like to conclude by mentioning one new exciting example of collaboration at world level which is taking place in the field of nuclear fusion research. At present fusion research is being vigorously pursued by three countries, the US, the USSR, Japan, and by one group of countries, those of Euratom. All four are involved in the design, construction and exploitation of big Tokamak machines which should prove the so-called scientific feasibility of the tamed nuclear fusion process. The cost of each of these machines lies in the range of 500 million dollars.

The next step to be tackled is the demonstration of technical or engineering feasibility. A machine for this purpose would cost about two billion (1982) dollars. Such expenditure may be beyond the resources of any one of the four 'countries', and call for intercontinental collaboration or even collaboration at world level.

Three years ago teams of the four 'countries' met in Vienna–stimulated and hosted by the International Atomic Energy Agency (IAEA)–in order to establish collaboration on the design, construction and exploitation of such a big Tokamak fusion device, called Intor (International Torus). The design was finished in 1982. It was an enormously exciting exercise with an excellent result which none of the four groups alone could have achieved. Each partner learned from the others, each partner stimulated the others. Obviously the decision on a joint venture to construct and exploit the Intor machine is suffering under the current East-West tensions and no forecast is possible at present. But this first exercise in global collaboration on a major scientific project was a worthwhile one. It was a good example of the 'added value element' of international collaboration.

EDITOR'S NOTES

29 Institut von Laue/Langevin

30 By which participant countries expect to receive shares of a project's contracts approximately in keeping with their contributions.

31 A la capacité (capability)?

2.3 Modern Technology in Western Europe

Gunnar Hambraeus, Chairman,
Royal Swedish Academy of Engineering Sciences

One of the aims of the Royal Swedish Academy of Engineering Sciences is to try to find out in the world of science, technology and industry the true and important signals of coming change from among all the noise of day-to-day happenings. This seems to us to become more and more important as the majority of the decision-makers, as well as the great public, tend to shorten their views with regard both to physical dimensions and to time. Politicians tend to look to the next election. The high interest rates of recent years necessitate much shorter payback periods on investment and limit foresight in industry. And with a higher standard of living, short-sighted self-interest tends to fragment loyalties and to encourage increased parochialism.

To counteract this our academy has for ten years run a number of projects under a general theme of what we call horizon gazing, or early warning systems. Many of the issues that we have dealt with fit rather nicely under the heading of social and cultural challenges of modern technology. In this paper I intend to run through a few such issues.

The first is what we call the migration of industry, a movement of industry from the traditional industrialized countries to other parts of the world and the consequences of this movement. In our old industrial world a heavy inertia of technology tends to retard the modernization of our industries, and only a part of this can be attributed to capital conservatism as investments in buildings, equipment and inventories. Much is in non-material investments: in markets, research and development, education and training of staff. There is also a heavy psychological inertia to overcome. In most organizations, and industry is no exception here, there is a natural resistance to change. People are reluctant to change habits, to learn, to learn anew, to move to new locations and to acquire new working habits. They resist a change of production methods, of products and distribution patterns, and they stick to old markets and traditional methods. In all too many cases the trades unions support or even foster such inertia.

The situation is even worse in a stagnating or declining economy with under-employment and weak solidarity in industry. Then all parties tend to cling to what they see as a safe and basic vocation, trade and location. There is then a heavy pressure on the politicians to subsidize, and by artificial means prolong, the struggle of dying industries.

We can contrast this to the situation in the newly industrialized countries. They enjoy great advantages in being able to build their plant with the most modern technology that can be bought, and building at a size that brings economies of scale. Very often these new industries can also rely on their providers of machinery and capital equipment to receive products out of the factory as payment. Thus the marketing of the products will be assured over a certain period of time. In these countries, too, labour is cheaper than in our part of the world, and concern for the environment might be less pronounced.

In the developing world, in the newly industrial countries, in the oil-producing areas as well as in the planned economy states, we see much new investment in areas like mining, metallurgy, forestry, shipbuilding, automobile manufacture, petrochemicals and other basic industries. There now exists a world overcapacity on a grand scale, even in times of high prosperity, for very many traditional industrial products. In this situation the new installations can easily outprice the older factories. The result is a great migration of production resources.

At one time we in the old world believed that a country needed an age-long tradition to maintain industrial production at a competitive level. To our surprise we have found that this is not the case. New countries are able to bring the labour force to a higher level of competence in a very short time. There are certainly instances where old industries have been able to fight back, and bring back a substantial volume of business by using modern methods of production, investing in new equipment and redesigning their products, but these instances are rare compared to those where we see a deteriorating structure in our own part of the world.

The obvious solution is to move to the new high technology, and to place much greater emphasis and reliance on research and development and on innovation than we have done for the past few decades. This is now on the lips of almost all political parties in Europe and we have a prosperous applied science activity in very many countries. In many of them this is about the only favoured sector in their national budgets in situations where governments run heavy deficits and have negative balances of trade. As yet however these efforts are rather superficial. The politicians and their advisers tend to look more toward what is fashionable in the world than to where the real capabilities of their scientists and engineers lie and where the market opportunities will be found. Grand national programmes are being brought about in computer technology, new telecommunications technology, bio-engineering, space technology and other fashionable areas. Also politicians tend to think that there is an unlimited amount of basic knowledge from which we can draw new experience and facts on which to base new applications. Thus there is a grave risk that they overlook the need for basic research and for a wider education. It is highly worrying that in too many countries in Western Europe we see a decline in scientific and technical education in the schools. We have in many instances difficulties in recruiting high-quality intelligent people into scientific and technical education. For many of them it is far easier to go into the social sciences, the humanities or languages. Certainly these subjects are very much needed, but not to the detriment of an education in the exact sciences.

Coming as I do for this Symposium direct from South Korea and Japan, I am deeply shaken by the difference in attitude between our youngsters in Europe and the new generations in East Asia. There I find, as I found earlier in the Soviet Union and the People's Republic of China, an interest in and an enthusiasm for learning and study, especially in science and technology, that is largely lacking in Northern Europe. From our studies in the Royal Academy of Engineering Sciences in Sweden we attribute this to a degeneration in the affluent society which tends to take all the benefits of the industrial society for granted and thus fails to maintain and nourish the very base of its high standard of living. It seems to us obvious that a new cultural awareness is needed, which above all should be manifested in education at all levels.

We have also to foster in our ageing societies an open and realistic understanding of what is happening in the world around us. Contrary to all predictions, science and technology is moving at least as fast as ever if not faster. But this is only one of the several factors which continuously will expose us to new situations. There is no single country in the world that can isolate itself from change, least of all the trading nations of Europe. We have no choice. We must learn to welcome change, to actually create a demand for development and a preparedness for a new and different future. Several of the world's industries, foremost among them the Honda factories, have succeeded in making their workers active contributors in the process of continuous development. In our old, industrialized countries we must learn to foster a similar attitude; actually to take advantage of the opportunities of a constantly evolving world by the creation and use of new knowledge, instead of burying our heads in our pillows and hoping that the spectre of change is only a bad dream.

I have mentioned the grand national programmes of applied science now fashionable in almost all industrial countries. Happy as I am to see in my own country—at last—a strong political effort to finance more research and development, I must at the same time sound a warning signal. All will agree that scientific creativity and breakthroughs in basic science cannot be commanded by any type of bureaucracy. No one can plan the spontaneous creation of new knowledge. There is however much less understanding of the process of the application of knowledge in the development of new technology that will find a market in a highly competitive world. When I see large government agencies being set up to plan, finance and execute programmes in, for instance, microelectronics, robotics and bio-engineering, I get an uneasy feeling that we are breeding white elephants. All our experience in the academy, and indeed in the Convocation of Engineering Academies, tends to point to industry as a prime mover of technical commercial progress. Government and government agencies lack the necessary direct feedback from the markets. They have great difficulty in setting and maintaining their priorities, and they lack the flexibility that makes for success in new engineering. If these facts are not well understood, there is a great danger that our efforts to build a new technology will fail and that we shall feel disappointment and have new criticism directed both at research and development and also at the new policies of industrial renewal. The moods and fashions in the political world produce impatience. Time between elections is far too short to absorb and to learn from failures.

I have yet one more worry. Protectionism is rearing its ugly head in the wake of unemployment and shrinking markets. Voices are heard telling us that the free exchange of knowledge should also be curtailed, not only for strategic but also for commercial reasons. I am aware of the fact that Sweden can contribute only a small percentage of the new knowledge being created in the world and I am very much worried about any barrier to the free exchange of knowledge in basic as well as applied science.

There are other worries in our society, however. The most pronounced right now is the heavy and rising unemployment, especially among the young. This is not the only consequence of the present specific economic conditions. It will not be remedied by a rise—a normal rise at least—in our economic activities in the world. We have to understand that we have a new work pattern appearing where perhaps five per cent or less of the total population will be employed in agriculture, and the manufacture of all basic industrial goods will be taken care of by another 10 or at most 20 per cent. The rest of the population will have to find employment in services, in information and in other 'soft' trades. Certainly we would hope that a lot of this employment would go to keeping contact with and caring for our fellow citizens.

Possibly we shall have to move to other patterns of work. Work sharing is much talked about, but not very popular with management or the unions. There are many signs however of a loosening of the traditional eight-hour working day and the 40-hour working week. In many occupations, for instance on the oil rigs in the North Sea, the big pulp mills of Northern Sweden, the manufacture of electronic chips in the new microelectronics industry, and other places, we see much longer working shifts concentrated into one part of a week or a month, and between these shifts long periods of free time for the individual.

The coming of women on to the labour market has also placed emphasis on part-time and shared work, and this is spreading, in spite of many difficulties in the organizing and deployment of the human resources within the office or the workshop. There is in all our countries a great need for a much deeper understanding of what could and should be done to create new work patterns for larger parts of the population, and so meet the new economics of the market technology.

Another very little understood phase of technology in Western Europe is the rising vulnerability of our systems. We can see this perhaps most clearly when there are disturbances on the labour market, when we have strikes of, for instance, programmers or maintenance people, or workers in the water supply or in transportation systems. But the vulnerability goes much deeper than that. In the big information banks, in the food distribution chains, in the huge energy systems and in many other instances, we are highly sensitive to disturbances in the personnel sector and to failures of equipment. Such occurrences can play havoc with whole sectors of society.

Our modern technology has a high degree of resilience, and is yet so new that its rate of failure is still rather low. It is however apparent that many older technical systems, for instance our water distribution and sewage system in large parts of urbanized Europe, are now at the verge of their demise, and a huge programme of new construction will be needed within the next ten years. It is not uncommon for up to 50 per cent of the water produced at the wells to be lost on its way to the consumer. This holds true too for rail transport, for many older sectors of industry, for mining operations and for other areas of activity. Failures will happen again and again as systems become old and worn, and we shall have to give much more thought to a renewal of these systems over a long period.

I have other problems I could mention, but the last problem I shall touch on today is partly technological, partly psychological. I call it electronic loneliness, or electronic solitude. We now have a situation–which we try to deny–where our youngsters in Europe and the United States spend several hours a day in front of the TV screens and further substantial amounts of time on playing video games of various types. They do it alone with the machine, without contact with other human beings, and we are now in a new phase of adding to the electronic entertainment options in the home. We have the videocassette, and the videodisc is coming. Cable TV will soon be here in Europe, and satellite transmission of entertainment direct to the home is a real possibility within a few years. Certainly this is much to be acclaimed, especially for the old, the feeble and the sick, and for people in remote locations with little contact with their fellow citizens. On the other hand the great joy, the great necessity of life, is the co-operation and the togetherness between people. We must take steps, and great care, that we do not destroy the human network of contacts and impulses and exchange that for a sterile, technological, semi-conscious world.

It is extremely urgent for us, as scientists and engineers, to discuss all these issues with our fellow citizens, with each other and above all with the politicians. Most of our politicians still live in an old political world where so many other issues seem to be more important, not least the infighting between parties and the strife for power. We shall have to change that for a much deeper understanding of the possibilities and the threats of new knowledge, new science and new technology. I see the most important reason for our gathering at this Honda Symposium being exactly this possibility to discuss issues of this sort among ourselves, and then to bring them to the attention of, and initiate action by, our fellow politicians.

2.4 The Perspective of the Past: Indications from the History of the Industrial Revolution in Britain

Sir Peter Gadsden, President,
Ironbridge Gorge Museum Development Trust

There are moments, perhaps cynical, perhaps pessimistic, when one feels that what the modern British are best at is their past—a kind of reversal of the comment by Oscar Wilde on the Americans, that 'their youth was their oldest tradition'. A nation often priding itself on its modesty and gift for understatement has a talent for historical pageantry on its great state occasions—coronations, jubilees, royal weddings, Lord Mayors' shows, state visits—in which the deep traditions of centuries of history are reflected in the splendour of costumes, uniforms, coaches and ancient and beautiful ceremonial. Thousands come to these occasions, countless millions see them instantly on television. Year by year we ourselves and a host of visitors from overseas flock to see historical buildings associated with the Crown, with our parliamentary government and with our oldest centres of religion. Much is carefully safeguarded for us by the National Trust, by our aristocracy and landed families who, with that talent for living successfully in changing times, have made hundreds of stately homes and their surrounding gardens into more enjoyable and instructive history lessons than many of us had at school.

It has recently been estimated that over half the sites visited by tourists in Britain are such centres of historical pilgrimage. But it is not only because of associations with famous episodes of political or religious history or for their striking architectural qualities that places are visited. One place of historical interest frequently visited is the industrial one. From the late 1950s this new interest in industrial archaeology—the enclosed museum and the open-air site—has been quite phenomenal and has been parallelled by the foundation of scores of societies at local, regional and national level. This great interest has been remarkably spontaneous, and although it has had help and encouragement from museum staffs and academics, they did not initiate this movement. It has come about because of a deep feeling that a great age is passing into history, an age when industry had for the first time in world history been a way of life for many; an industry which had been dynamic, creative, pioneering, astonishingly inventive and a concentration of unprecedented skills. The first industrial nation had become the greatest among nations and had demonstrated the possibility of a notable rise in living standards, for others as well as for themselves. This success had not come easily, financial risks had been high, competition often fierce and rewards grossly unequal. The loyalty and dedication of the industrial worker was remarkable in a climate of harsh labour discipline, overcrowded housing, environmental pollution and ugliness. Nevertheless, there has suddenly been the realization among people of the most varied background and income that a shared historical experience has been passed through, an experience which the conventional history books hardly mention. There was also the realization that industrialization was taking on new forms, that workforces and equipment were changing out of recognition and that there would be a serious loss of heritage if all the most striking achievements of the Industrial Revolution were demolished and removed from the landscape. There was a feeling that a proper appreciation, even a serious study, of industrial history was inseparable from the evidence of its physical remains.

There is no doubt that interest in industrial history, its monuments and remains exists at various levels. There is nothing wrong with this. Perhaps the simplest level of interest is purely nostalgic. This can be found in a passion for the old, especially when it has some dramatic quality—a sense of power and movement, like old mill or mine steam engines. It may well result in more old locomotives being preserved than are really necessary for the historical record. Such interests for some may never advance beyond nostalgia and the basis for the hobby of a lifetime. But there are always those for whom they will lead to a more developed knowledge. They will start to make comparisons of efficiency and utility between machines and will want to know how their work contributed to the industry of which they are part. They will read modern and contemporary literature and in the end become quite serious historians on their subject. Of course collecting can be an enthusiasm of limited purpose, simply reflecting acquisitiveness, the love of possessions, a sense of rivalry with others. But what began as a casual collecting of a few old watches or pots can eventually turn individuals into international authorities on horology or ceramics. Academic historians are often heavily influenced by contemporary fashions and preoccupations, and sometimes neglect great areas of history. Time and again what they have forgotten has been preserved for posterity by the collector.

However, is there something to be learned from our industrial history which can be worth copying today, and which can justify the existence of industrial museums, beyond the creation of a superior kind of nostalgia—a sadness that world industrial leadership has passed from us and that our forebears were either better than we are or lived in an age of greater opportunity? Is it left to us only to experience that kind of post-imperial withdrawal symptom from which Britain is accused of suffering, not only loss of Empire but also loss of industry? Will we soon be grieving 'that even the shade of that, which once was great, is passed away'?

We rightly visit the monuments of the past which commemorate our military, our religious and our architectural history for inspiration as well as a factual history lesson, because imagination, innovation and a continually aspiring mind are necessary for our industrial achievements and we should find them in our industrial monuments and history. What, for instance, should we learn from Ironbridge, a leading industrial museum, which has expanded rapidly in recent years and which has received wide support and the most eminent patronage?

Firstly, we should be aware that the triumphs of the iron industry which are portrayed there were part of a long development that put Britain on a new path. There is no doubt that the last decades of the eighteenth century saw an acceleration of industrial growth, of the pace of technical change, of exports, of urbanization and the other developments which can be collectively regarded as the Industrial Revolution. But the beginning and progress of the kind of industrial development which distinguished Britain from other countries (which they had eventually to imitate) was much earlier.

The most important factor was the development of an industry based on coal. Whether it was the shortage of wood fuels that drove our ancestors to coal is debatable. It may have been the potential cheapness of the new fuel rather than a rise in cost of wood fuels which encouraged the exploitation of coal. This was done at a remarkable rate—a population of five million people in Britain may have produced almost three million tons of coal at the beginning of the eighteenth century. At the end of the century a population of eleven million were consuming coal at the rate of one ton per head per annum. It was necessary to discover ways of utilizing coal because it was usually impossible to use coal in place of wood without modifying the necessary equipment—hearths, boilers, furnaces, crucibles, etc.—without learning new methods of handling the fuel (including coking), without developing the use of fireclay for bricks and crucibles and without learning new skills of furnace management and developing a new range of equipment.

The iron industry was not the first to be converted to coal. Metal working, brewing, distilling, glass making, salt boiling, the smelting of non-ferrous metals and many other industries preceded it, because the technical problems of iron making with coal were the most difficult. That makes the achievements of Abraham Darby I in smelting iron with coke at Coalbrookdale in 1709 all the more remarkable, and the furnace he used (which still stands) one of the most important monuments in the history of technology. Of course the process did not stop at Ironbridge or elsewhere in Britain. At first Coalbrookdale became outstanding for the production of large iron castings and within a few years it was making cylinders for steam engines. By the 1760s it was producing the first iron rails and by the 1770s the world's first iron bridge—still there to be seen and used today. Just after the end of that century it was providing Trevithick with some of the first locomotive engineering and long before that (in about 1750) the first coke iron capable of being economically converted to wrought iron was being produced. Elsewhere coal continued to be applied to new processes—to making sulphuric acid, to making plate glass, to methods of making better wrought iron from coke-made pig iron, which culminated in the famous 'puddling and rolling' process of Henry Cort.

Almost simultaneously with Darby's discovery of coke iron came an invention as strictly tied to coal and equally as momentous a breakthrough in technology—the steam engine of Thomas Newcomen. From the 1760s Watt made great improvements, but the Newcomen engine was made in much greater numbers during the eighteenth century—perhaps 2,500. Rugged and reliable, it allowed the draining of deep mines which meant a vast expansion of the coal industry and of non-ferrous metal mining.

There was nothing of an accidental, random or fortuitous nature in British industrialization, for it occurred over a period of time before the late eighteenth century and the conventional dating of the Industrial Revolution. Textile innovation was developed in a country already advancing rapidly in mineral, metallurgical and engineering change and speedily took advantage of that situation. Other countries in the seventeenth century, especially on the continent of Europe, had seemed as far advanced technologically as Britain. They too had extensive domestic industries and some may have become more centralized and better organized than ours. But this did not give them modern industrialization. For this they had to absorb the methods of the new type of industry developed in Britain and to adopt the new technology, whilst major industrial regions tended to be near coalfields.

Some of the new technology was developed by intelligent workmen—the invention patented by Darby for making cast-iron pots which led him to coke-iron and Coalbrookdale had been devised by his apprentice. New techniques were not passed on in books—the British produced a technological revolution without technological literature; apprenticeship continued to be very important. By the nineteenth century, in some industries, much of the practical technology was with the superior workers rather than the management. Examining the Sheffield industry in the 1840s a Frenchman pointed out that 'the true metallurgists of Yorkshire are the workmen'. In many trades the critical processes remained based upon the physical strength and co-ordination of workmen guided by their observation and intelligence. Perhaps the best example was puddling iron, a trade which finally died out commercially in the 1970s, but is about to be re-created in a project now proceeding at Ironbridge. Whether this kind of skill ever received its fair share of the returns from industry is debatable. Eventually it led to the importance of craft unions—the origins and growth of the trade union movement which produced a mixed legacy: on the one hand of responsibility and on the other of conservativeness and inflexibility in the face of change. For both management and workers it has proved difficult to move to the science-based industry which began to be significant in the late nineteenth century and also to accept the critical role of a technical education. Paradoxically, the astonishing success which a predominantly craft technology had enjoyed for over a century made it all the more difficult for the changed situation to be accepted. On the credit side, the feeling of the skilled worker that his skill was his own and at the same time essential to the industry in which he worked was one of the main reasons why, in spite of the pressures of industrialization, the British worker rejected the path of revolution.

Our industrial history has been long and complex and of course greatly exceeds what can be seen and learnt at the Ironbridge Museum, where the most brilliant achievements preserved in its monuments are of the eighteenth century. But what can we learn from our industrial history? First of all we should derive not only nostalgia but real inspiration. It would be stupid to think that in the creation of the spirit of a modern navy the preservation of Nelson's *Victory* is irrelevant. The achievements of Britain in discovering the path to modern industrialization deserve preservation because they involved vision, risk, perseverance and the triumph of mind over matter. A mid-eighteenth-century Frenchman wrote of the Newcomen engine 'no contrivance does so much honour to the human spirit' and that is the attitude we should adopt towards our greatest industrial achievements.

We may also reflect that at the centre of our greatest period of growth was new technology aimed at improvement and the longest potential benefit using coal as a source of industrial fuel and mechanical energy. Choosing technologies with the best long-term potential is just as vital today. Visiting our industrial monuments must remind us that technology was at the centre of our first industrialization. The Industrial Revolution was not just a period of economic growth, it was a powerful new experience because it embodied new technology and more highly productive technology than any previous period of history.

Industrial monuments are not just physical objects, they are memorials to people. It is not possible to look at them intelligently without wondering—who invented this machine? who built this bridge? who conceived this system of production? who worked here and what did it feel like to work here? It was important to many workers in the past to possess a real and valued skill even if their reward in wages was not lavish, and this should remind us that if we create an industrial system without that kind of job satisfaction for employees the psychological and social consequences will not be favourable. At the other end of the spectrum we must appreciate that the great industrialists, the Darbys, Boulton, Wedgwood, Wilkinson, Arkwright and the Peels, were not like fortunate ships carried on a favourable tide. They had a real influence on history because their actions speeded up industrial growth and helped to determine its nature as well as its timing. We do not fully understand, and perhaps never will fully understand, the inspiration that motivated these men, but we must make sure that the measures of social control over industrial activity (however desirable in themselves) do not fail to allow room for personal satisfaction.

It has been possible to take only a few examples of the lessons which our industrial history and our industrial monuments have left for us. But in a period of international recession we must remember that the past always has something to teach the present by way of inspiration for the courageous pursuit of the new.

The Magna Carta was engrossed and sealed in 1215 'for the better extinguishing of discord which has arisen between us and the barons' and we now need a second Magna Carta–to extinguish discord in industry and bring about a spirit of co-operation and uniting of aim and endeavour to make Britain a proud and productive nation. This would benefit everyone. As that great Australian statesman Sir Robert Menzies once said: 'What is needed today is not some economists' theories but a great mood of unselfishness.' And let us avoid talking of 'two sides of industry'– we are all in this together and we can only survive if all involved in investment, production and marketing are inspired with a spirit of co-operation and an enthusiasm for their product. Every job is important–however monotonous and insignificant it may seem to the person doing it. One day Sir Christopher Wren went–disguised–to see how the work was progressing on the building of St Paul's Cathedral. He stopped by a stonemason who was chipping away and asked what he was doing. 'Chipping the stones to the same size, and it's very boring' was the reply. He asked another the same question, who answered: 'I'm chipping stones to the same size–and I don't get much for doing it.' Sir Christopher Wren felt rather downcast, but the third man he questioned said: 'I'm just chipping stones to the same size but I'm helping to build a magnificent cathedral.'

Now that's the kind of approach needed in industry today–and a return to the basic philosophy which made us a great nation.

Chapter Three

ADVANCED TECHNOLOGY IN NORTH AMERICA

Chairman: Sir Robert Clayton CBE FEng
Former Vice-President, The Fellowship of Engineering

Editor's Summary

The third session of the London MANTECH Symposium had the general title 'Advanced Technology in North America', although in fact it was entirely devoted to the scene in the United States. The keynote speakers from that country were anxious to deny any implication that advanced technology was unknown or unexploited in Canada.

The session began with a paper from Professor Herman Feshbach, Professor of Physics at the Massachusetts Institute of Technology and current President of the American Academy of Arts and Sciences, who had no difficulty in convincing his audience that advanced technology in his country was more widespread and more widely used even in 'trivial' applications (e.g. 'Star Wars' types of electronic games) than anywhere else on earth.[32] Several thousand 'home computers' were in use, plus some thousands more in schools, while in higher institutes of learning such as MIT first-year students were expected to be, and were, familiar with computing systems and programming methods.

Computerized automation in industry was becoming commonplace, and the pace and scope of its applications were increasing all the time. Throughout science new developments were constantly making obsolete yesterday's novelties, which had led to several major problems which Professor Feshbach proceeded to describe.

First, it was evident that no undertaking or organization could afford to update its systems every day, and the more complex the systems, the longer was needed to amortize sufficiently their costs. When in addition staff retraining was necessary, there was an inbuilt incentive to delay changes to at least some degree; yet the dangers of delaying too long were all too well illustrated by the plight of those who could be seen in retrospect to have done just that.

A second effect of the greatly increased use of advanced and especially computer-based automation (including robotics) was that in the production of goods in the USA, less than one-third of the available workforce could now meet all demands: in the rather special case of agriculture, permanent surpluses were already being produced by only three per cent of the labour force. On the other hand the phenomenal expansion of the 'information industry' had led to its employing 46 per cent of the total workforce.

In face of this it was not surprising that a substantial part of the population felt itself in the grip of permanent uncertainty, threatened by changes rarely understood and certainly out of the control of those principally affected. The resulting resentment both of 'the system' and of 'the experts' (the scientists and engineers who had brought the system into being) was apparent in the attitudes of labour unions and of the people themselves, and the social costs were high and rising. Nevertheless there was little concerted resistance to the new technologies: it was generally recognized that they had arrived and could not be turned away.

In the all-important field of employment there was very little remaining demand for 'unskilled' labour, and even some 'skilled' categories were uncertain of their future. On the other hand, computer programmers and related personnel were much sought after, and new uses for data storage and data-processing systems were continually being found. 'Information' had become a resource, to be collected, conserved, improved, then bought and sold (or stolen) like any other commodity. Laws now governed its trading, and much industrial information was subject to secrecy, leading sometimes to conflict over rights of protection, communication and diffusion.

One consequence of these developments, of which Professor Feshbach was somewhat critical, was the increased use of automatically collected and processed information to consolidate the control of enterprises by centralized leadership, often a leadership (by lawyers, financiers and other 'non-technicians') unable through ignorance to exploit fully or efficiently the system in their hands. For example, computer systems could be used for modelling and forecasting, and programs for these purposes could be bought, but their successful use often required understanding of statistical mathematics which the users did not possess. No computer system could give a 'good' answer unless it had been asked the right question, and Professor Feshbach ended with the well-known dictum (attributed originally to Picasso): 'Computers are useless—they only give answers.'[33]

The next speaker was Dr Robert A Frosch, Vice-President of General Motors Corporation and Director of the GM Research Laboratories. Although his paper[34] had been prepared (one may assume) without direct collaboration from Professor Feshbach, he was quick to take up and further emphasize the latter's final remarks about centralized direction, by legal and financial leadership, of incompletely understood technological operations by incompletely understood technological methods. While certainly not wishing to suggest that policy-makers and legislators were 'entirely poorly educated' ('that would be improper and unfair'), Dr Frosch believed it was generally easier to find 'an engineer with a reasonable basis for policy development' than to find 'a policy person who has any reasonable basis at all for dealing with a technological matter'.

The speaker was in fact in a gauntlet-throwing mood and his paper contained a number of challenges to a society which, though more and more technologically based, still prefers to keep the scientist or engineer 'on tap but not on top',[35] and he is thus not permitted to hold the reins of administration.

Yet few administrators had fully grasped the significance of developing communications and computer-based society, said Dr Frosch: even less was it appreciated that 'unskilled labour'—now comprising a major part of the unemployed—would probably never find new 'unskilled work' to do. For the new technological age, based on the computer and the microcomputer, had brought first automation and now robotics 'to the control and to the doing of work'. Furthermore these were no accidental developments; they had been sought and encouraged out of necessity to increase productivity and to reduce costs in an ever more competitive world. The resulting displacement of men by machines must be accepted as a permanent change, similar to but more emphatic than what had already happened in agriculture, and leading to greater availability of products at lower prices.[36]

The danger was that the overall economy, with many more unemployed deprived of income from which to buy even the cheaper products, could face collapse. At the very least an increasingly stratified society was in the making, and although the administrators and politicians of government were constantly being warned of this by their technological advisers, they showed little sign of awareness of the problem, hence no real interest in seeking a technically viable solution.

Turning to another subject, Dr Frosch considered the somewhat startling proposition—at least to some of his listeners—that robots could be conceived which could construct and operate machines for the construction of more robots. Already in Japan there was a factory where such a process was in use with only two human beings in charge: one in the control-room and one carrying out maintenance. If self-reproducing robots could be made, then they could be of great help in the exploration of planets beyond our earth, in sending back to us valuable minerals and other raw materials from those planets, and perhaps also preparing accommodation on them which could receive and support human life. The spectre this concept raises of an ultimate 'Sorcerer's Apprentice' scenario, even on our own planet, might perhaps be the subject of further discussion at a later DISCOVERIES symposium.

Discussion

The two foregoing addresses provoked a lively discussion, which however remained entirely earthbound, and was largely devoted to the problems of communication between technologists and those ignorant of the scientific method in either experiment or the transfer of information. There was general agreement that politicians presented greater difficulty in this respect than any others (although there were occasional exceptions), and it was left to Professor Hambraeus of Sweden to suggest that scientists and engineers could also, on occasion, be naïve in communicating with politicians. Overcoming this was part of the challenge facing the technologist, and it was particularly important today when the politician needed his advice more than ever in attacking many of society's problems, notably those related to unemployment. It was unfortunate that magical 'instant solutions' were sometimes expected and it was necessary to explain that miracles usually required a little time.

This led to several participants emphasizing again the difficulties of communication between two classes of highly intelligent people whose respective educations often lacked sufficient 'overlap' or common ground for statements (sometimes even individual words) to mean the same to each. Moreover it was generally agreed that the problem was unsymmetrical, for while the technologist could usually apply the disciplines of his profession to resolve administrative, social or other non-exact problems with a degree of success, it was extremely rare for anyone trained only in the liberal arts to be able to resolve scientific problems.

In case this conclusion might seem to encourage technologists towards arrogance and self-satisfaction, it was useful that these tendencies should be immediately exposed and questioned. The exposure came first from Professor Harold Linstone of Portland State University, who recalled a declaration, by a very senior engineer at MIT, that if the work of his institute had been able to help win World War II then it could certainly help solve the problems of modern society. However, the results of its work in this field (particularly concerned with urban development) were hardly awe-inspiring; a similar attempt by the aerospace industry to apply its own specialized techniques to solving social problems had produced equally modest results.[37]

Professor Feshbach took the matter further, pointing out that the apparent failure of politicians to heed technological advice did not necessarily signify technological ignorance. Sometimes, he said, the politicians understood the technologist very well but did not act on his advice, since for them his propositions had low priorities compared with their own.

But perhaps the final word on this subject (at least for the moment) came from Professor Kazuhiko Atsumi, Director of the Medical Electronics Institute of Tokyo University, who stated bluntly that 'Politicians cannot understand science and technology in Japan. During election campaigns they promise to build housing, roads and schools. If they were to talk about science and technology, that would not win them any elections!' Surprisingly no one was prepared to draw what, in view of Japanese technological prowess, might have seemed an obvious conclusion. However, the future may be expected to clarify the matter, for Professor Atsumi reported that some politicians were unhappy about the situation, and were hoping to change it. 'They want,' he said, 'to set up an informal committee to include both scholars and politicians, and the politicians want to run modern technology.' A most interesting and potentially instructive prospect!

Several participants wished to discuss a more general division than that between technologists and administrators (political, financial, legal or other).

They were concerned rather with the increasing stratification, referred to by Dr Frosch, separating society into technological haves and have-nots, the have-nots finding themselves increasingly unable to obtain any form of remunerative employment. Yet these have-nots were as much a part of the world as the haves and—as was pointed out by Training Consultant Mr George Walker—if only because of their massive numbers they would play a very important part in the evolution of world society.

This remark opened the way for Dr Surendra Patel (UNCTAD), the sole representative present of what he called 'the wretched in the Third World', to draw attention to the much more serious and physically much greater 'stratification' which already separated these people from even the most underprivileged in the advanced Western countries. Recalling the considerable alarm and despondency provoked in these countries by the Club of Rome's now historic report on limits to growth, Dr Patel suggested that the limits they were now experiencing were not in fact those of finite mineral, energy and food resources but rather those of 'social engineering', or the ability to manage an evolving social system in which, in fact, the operative limits were more those to consumption than to growth. These limits were of course completely absent from the Third World where, although Dr Patel did not expressly say so, the most restrictive limits were those imposed by lack of finance.[38] Dr Patel, self-declared 'unrepentant economist', should have known.

However, knowledge of the fundamental causes of growth restriction anywhere does not necessarily lead to remedies, and once more the discussion tended towards something of a three-cornered impasse (if such can describe a situation in which three possible escape routes are all blocked by their interdependence).

The most favoured way to expand growth appeared to be through an increase in employment in areas where there was evidently need for work to be done. This had been advocated earlier by Professor M W Thring, and certainly appeared a reasonable step provided it could be financed (back to Dr Patel's remarks!). True, social payments to the unemployed would be better applied in such constructive (or reconstructive) ways, but unless the payments for work were significantly higher than those for idleness, there would be little creation of new purchasing power. Yet the provision of additional finance must either involve creation of new 'paper money' (thus leading to renewed inflation) or it must be linked to real wealth which meant more efficient material production and hence, unless markets could be expanded, more unemployment.

There were several interventions implying that unemployment might be relieved by the sharing of work among more workpeople. But again it was pointed out (as it had been earlier by Viscount Caldecote, see page 15) that unless work-sharing were accompanied by increased productivity, the fruits of the work—particularly the payment for it—would also have to be shared. That too would in no way increase overall available purchasing power. Within existing financial systems in fact real growth in purchasing power—hence in demand and hence in employment—could result only from growth of real wealth. Since that could now be achieved perfectly well with a much reduced labour force, it was necessary to recognize that former links between growth in employment and growth in real wealth were disappearing, and the two matters becoming ever more independent.

Dr Harold Chestnut (US General Electric) believed it was beginning to be understood that 'the idea of putting machinery to do things that people have been doing in the past will upset this [labour] market'. Our sociologists should be warned to prepare for this coming and inevitable change. 'We may,' concluded Dr Chestnut, 'have to change some of our social structure.'

This clear and unequivocal declaration was certainly in line with the general thought of the meeting, namely that many of the 'new unemployed' could not expect to be re-employed, even when the current depression had ended, on the same types of work they had done in the past. Yet Dr Chestnut had some encouraging and invaluable words to add, which perhaps bridged the gap between the earlier remarks of HRH Prince Philip (that today's world was not one of unemployed makers of bows and arrows or farriers) and the conclusion that people could and did adapt themselves to changing circumstances. The essential element in this adaptation, said Dr Chestnut, was time—the pace of change largely determined whether it was acceptable. Professor Feshbach entirely agreed: 'The question,' he said, 'is whether the time scale in which change can be made in the skills of the unemployed is of the right order of magnitude.' There was evidence that that order of magnitude was similar to an average working life.

This led naturally to discussion of training (and retraining) in an increasingly technology-based society. Speakers were unsure that the more elderly industrialized countries, such as the UK, had yet persuaded their upcoming workforces how important such training was as preparation for the fullest possible (and most rewarding possible) future careers. Other countries were doing better; for example according to Mr Diarmuid Downs, 90 per cent of the Japanese population now received full-time education up to the age of 18. In Germany the percentage was 60, whereas in the UK it was only half this. The reason, said the speaker, was not that British youth was less educable than elsewhere, but reflected a combination of insufficient facilities and insufficient persuasion that further education was worthwhile. 'The idea,' concluded Mr Downs, 'that somebody can leave school at 16 in modern society and expect to find a job at an adult wage, to be able to marry and to bring up a family, is just ridiculous. There are no more van boys, office boys and what have you, and the sooner this is recognized the better.'

But more and better training required more and better teachers, and there had already been mention of the reluctance of teachers to adopt the comparatively rigorous disciplines of the natural sciences and engineering, when social science and the arts seemed less exacting and sufficiently if not excessively rewarding (i.e. offering a comfortable if not brilliant career). Implied in this was the criticism that a nation got the education it was prepared to pay for, and there was no doubt that in the UK very many promising young scientists and technologists were tempted to offer themselves as soon as possible for industrial employment rather than a teaching career. Nowhere was the old adage 'those who can, do; those who cannot, teach' better illustrated.

This prompted two observations from the Baroness Platt of Writtle, concerned with scientific and technological education through the Standing Committee of Schools, Science and Technology in the United Kingdom. The first was that the inadequacy of such teaching was recognized and important improvements were being introduced, albeit slowly. However, a particular problem was that 'the teachers themselves are not properly backed up in technology and therefore find it difficult to teach'; and although more help was being provided through in-service courses of further training, the Baroness was afraid 'we are probably not catching up with the teaching of technology as fast as technology itself is moving'.

Her second point concerned the dangerous phase in technological education at which sufficient knowledge had been acquired to appreciate possible risks and dangers but not the complex and(usually) highly effective precautions preventing these from materializing. The Baroness cited opposition to the use of asbestos or urea formaldehyde foam, land reclamation or nuclear power, as examples, though these were taken more from the books of 'middle administration' (e.g. local government officials) than from those of young students. Clearly the more elderly people would have benefited from a more rigorous technological education in their earlier days: presumably, as they were gradually replaced by succeeding generations, provided present educational improvements were continued this difficulty would decrease.

It would not however disappear, at least according to Professor Feshbach, who did not think it possible to make 'an entire population scientifically and technically literate'. (He did not add that a possible way round this problem would be for those who were not literate in these matters to regain their confidence in those who were.)

One further matter attracted attention in this particularly lively discussion: the alleged dangers of technologists being 'carried away' by their technologies, without pausing to consider the effects on society generally which these technologies might have.[39] A question on this was addressed to Dr Frosch by Mr A Silverleaf, a transport engineer, who cited such cases as the financially unsuccessful supersonic passenger aircraft, 'grandiose' schemes for large hovercraft-type ocean-going ships, and excessively expensive 'anecological' civil engineering works such as urban motorways. (In view of recent controversies, Mr Silverleaf might also have mentioned new airports and—although these were only remotely related to transport—hydroelectric dams.)

Dr Frosch did not deny that there were occasional happenings of this nature, but believed the risks were far less serious than those of 'people being carried away in social and economic issues by ideologies which they have not examined in any way which scientists or technologists would consider to be reasonable'. However, he did not wish to imply that dialectic had no uses, but rather that it was 'almost always useless' at the beginning of trying to solve a problem. 'It is no use whatever,' he said, 'to draw lines at the very beginning and then decide that one will not transcend those lines', and this was where he took issue with 'legal friends and social science friends' who habitually insisted on discussing scientifically meaningless questions.[40]

Dr Feshbach strongly agreed. He believed the problem was not so much one of education in scientific detail, as of education in *attitude* to innovation. His experience was that, despite the uncomplimentary remarks made about politicians, their attitudes in general were far more liberal and understanding than those of the legal profession. In fact if any profession could benefit more than any other from a basic training in science, it was that of the lawyer.[41]

A last word came from Professor Umberto Pellegrini (Milan University), an electrical, electronic and nuclear engineer with wide experience in many fields, who believed at least some blame attached to the professional scientific and technical associations, whose somewhat rigid statutes 'conceived in the last century' made the pursuit of interdisciplinary activities (e.g. involving lawyers and administrators) difficult or even impossible. Humanistic and political activities were particularly uncertain grounds for these associations, and Professor Pellegrini advocated changes which could open the way for non-scientists to join scientific and technical organizations, thereby helping to break down the barriers currently preventing scientists and engineers from playing their fullest parts in politics and legislation.

Three more main papers now followed, the first from Professor Ithiel de Sola Pool, Professor of Political Science at the Massachusetts Institute of Technology and Director of the Institute's Research Program on Communications Policy.

Unlike that of the two previous speakers from the United States, who had perhaps tended to view advanced technology as a continuing and necessary innovation to which society must and would adapt itself (to its ultimate substantial benefit), Professor Pool's approach was rather more critical.[42] In particular he was concerned with ways in which computer-based information technology could be expected to 'usurp' the role of human beings in what he termed 'intermediary' institutions—those between the originators of goods or services and their ultimate consumers. Such institutions were concerned with storage, transport, packaging and other intermediate operations and included banks, wholesalers, shippers and retailers. In the intellectual field they comprised libraries, publishers and broadcasters. In all these areas the arrival of computer-based 'global electronic communication', whereby the ultimate consumer, or customer, could acquire what he needed directly from the original producer simply by 'ordering' through his own electronic information link, would make the intermediary more or less redundant.

This might not be particularly serious in the case of 'non-intellectual' intermediaries such as shops, etc., but Professor Pool was concerned that the invaluable services of filtration, preliminary assessment, and elimination of clearly unwanted material, which are normally provided by libraries, bookshops and even publishers, should not suffer and perhaps disappear. He saw their traditional functions being replaced by direct information retrieval, videotex or other similar systems, these systems in fact becoming the new intermediaries.

All this could unfortunately lead to elimination of the already frail 'human links' between consumers of information and its providers (each operating only through machines and remote computer terminals), and Professor Pool speculated on the consequences of such isolation. 'How the computer will ultimately shape our thinking,' he concluded, 'I do not know. . .what was originally thought of as a mathematical machine to solve big sets of equations is now a very different thing: it is a word processor, a graphics display device, a game-player that answers back to the human.'

It was comforting that the professor did not consider it (at least as yet) to be a trans-Cartesian superbrain.

The next presentation was by Dr Roger Levien, a former Director of the International Institute for Applied Systems Analysis (IIASA) and currently directing the Corporate Strategy Office of the Xerox Corporation. As might be expected from a speaker so closely concerned with all forms of visual information presentation, his address[43] was lavishly illustrated with colour slides projected in an unbroken series in parallel with his spoken words. 'Since I am an information technologist,' he announced, 'I thought I would use some information technology.'[44]

Not wishing to duplicate the preceding remarks of Professor de Sola Pool, Dr Levien skilfully steered himself away from technology's social and cultural aspects, concentrating rather on the history of information technology—'one of the four grand technologies that mankind has developed'.[45] This history he traced from the earliest use of language, through communication by written signs and drawings, to the development of printing, the invention of electrical devices such as the telegraph, telephone (and gramophone), radio and television, and thence to today's electronic 'question-and-answer' system. These last, he said, gave everyone[46] a 'personal window on the world'. As a result he foresaw greater 'democratization', information specialization (or diversification) at the will of the 'consumer', and individual control by each consumer of his information supply. Although he also saw the risk of cutting human links and contacts (cf. the previous speaker, Professor Pool) he was convinced that in fact the human being, as long as he remained in charge of his destiny and his machines, would not permit this to happen.

The final speaker in this session was Professor Harold W Lawson, Head of the Computer Architecture Laboratory at Linköping University, Sweden. His paper, 'Some Consequences of Tomorrow's Electronics Computer Aided Design (CAD) Systems', was substantially more esoteric than any others in this session and its subject was certainly not confined to the North American scene. However, the professor was from the United States.

Broadly, the paper dealt with the automatic production of computer hardware (processors, memories, communication units or even entire systems) in what he termed silicon foundries, production facilities where complete digital computers (in miniscule form) could be only parts of a large capacity system produced, perhaps, even with 'inbuilt' algorithmic programs. Computer aided design systems for these purposes were currently being developed in several parts of the world, particularly the USA and Japan.

Professor Lawson's paper dealt in some detail with the principles behind CAD systems, which can provide ways of optimizing the series and parallel performance of system operations in the micro-hardware. It was unquestionable, he believed, that availability of the Tomorrow's CAD Systems of his title would be a dominating factor in the competitive race to provide tomorrow's electronic components and systems. He considered various concepts of 'design by analogy': personal analogy, direct analogy, symbolic analogy and fantasy analogy, all of which have fortunately been defined in the literature.[47] The professor then examined and explained abstraction philosophies and strategies for use with CAD systems, together with the forms of logic involved, some of which he illustrated by a 'home-made' type of ideographic diagram.

While this paper was undoubtedly fascinating for other electronic information specialists, for whom it certainly represented a cultural if not a social challenge, that challenge appeared to be presented more to the already initiated than to the scientist or engineer concerned with social and cultural repercussions of the rather speculative technologies described.

Discussion

Not surprisingly, after so much concentration on electronic computer-based information handling and communication, there were some participants who wondered whether any place remained in modern society for the 'old-fashioned' written word. The reflection was at least partly stimulated by concern that electronic information systems would be much more easily subjected to monitoring and control by 'authorities', opening the way for enforcement by those authorities of their own beliefs and ideologies to the exclusion of all others. One questioner stressed the immeasurable importance through the ages of books, recalling that although these had often been burnt in (unsuccessful) efforts to control information, virtually always some had survived and so preserved each age's thinking, in all its variety, for posterity.

Professor Pool was able to answer this point with an emphatic reassurance. He believed these traditional methods of communication were as valid today as ever, and pointed out that he was at that very moment 'making notes with a pen, not with a word processor.[48]

Professor Pool also had a reassuring answer to another question, posed *inter alia* by Professor Hambraeus of Sweden. This concerned the immense quantities of 'raw' information which the electronic systems could and would accept, from any source having appropriate 'inputting' equipment without any reference to the value or even accuracy of the information. The same systems would disgorge the same masses of unevaluated data to any user who followed the appropriate interrogation and retrieval routines. This would mean, said Professor Hambraeus, that we should need a machine (formerly it was an individual) to sift, to transcribe, to transform and to manipulate the information in a useful form for the actual use of the client.

Professor Pool agreed that this was indeed what would be required and what in fact was already being provided, 'in a very primitive and unsatisfactory form', by most existing information retrieval systems. Although he went no further, he might have added that the processes of data evaluation, essential to such intelligent information retrieval, were and were likely to remain principally a human function. Here at least was a field where unemployment was no threat!

To the admitted risks of 'over-centralized control' of information in ever-larger computer-based networks, the professor's antidote was the typically American one that the risks would be avoided by ensuring free competition between a number of rival 'information carriers', so making monopoly by any one impossible.

Much the same point had been made by Dr Levien of Xerox, who was convinced that whatever the risks of centralized information systems, the greater 'democratization' of society thus made possible was on balance an overwhelming advantage. However, Professor Linstone (Portland State University) was less sure: the same centralized system(s), once in existence, could easily and quickly be made to provide greater centralization and hence control ('cybernetic surveillance' and 'group-think') of society as a whole.[49]

Dr Levien could not deny the possibility, adding that the misuse of technology had always been a risk, whether in chemistry, biology, nuclear physics or now information handling and processing. It was up to society itself to protect itself, and the duty of those who understood both the benefits offered (by information technology) and the possible dangers to ensure that it remained our servant and did not become our master.

The discussion now turned to technicalities, albeit with important cultural implications. Professor Umberto Pellegrini (Milan University) had been impressed by the high levels of 'interactive intelligence exchange' between men and machines which Professor Harold Lawson had described in his paper. This, and the fact that the machines themselves were independently capable of 'information transformation', had convinced Professor Pellegrini that the machines possessed intelligence, so that their growing proliferation—especially in the form of microprocessors—was producing an intelligent environment.[50] The more intelligent that became, the more necessary it was to improve communication with it, i.e. with the machines which it comprised. Man-to-man communication alone was not enough.

Professor Pellegrini went on to examine existing and possible methods of communication between man and his machines (the 'interface'), pointing out that current computers were naturally (they were 'von Neumann structures') receptive of communications only in the alphanumeric languages of European origin. This must be unnecessarily restrictive and, in fact, 'the true universal language for man-machine communication should be visual language'. The requirement for such a symbolic (ideographic?) language was established, and would lead to 'a true new way of thinking about computers'.

Professor Lawson was in fullest agreement, drawing attention to the origins and development of the symbolic character languages of China and Japan. Work was under way in his and other computer laboratories which would almost certainly lead to 'very graphic oriented' communications.

Professor Fred Margulies, who besides representing the International Federation of Automatic Control (IFAC) is a leading Austrian trades unionist, was concerned with a different type of risk, namely that computer aided design systems and other sophisticated but soulless devices (at least in the normal connotation) besides being tools for creativity could also have the adverse effect of reducing that same creativity in the operating human being. 'CAD,' he said, 'means that the design process, which is essentially a creative process, can be transferred to the computer to such a degree that the designer himself has no room and no further possibility to be creative.' Dr Margulies went on to describe how a CAD system had been designed in Vienna by a large team of human designers, each determined that the final 'machine' should help them in their work without relieving them of it. However, subsequent comments by Professor Lawson seemed to suggest that later-generation CAD systems might not only resent but even forbid such interference. *Quis igitur designat ipsos designatores?*

In view of this it was reassuring to hear from the session chairman, Sir Robert Clayton, in a brief summing-up, that '. . .even with the coming of expert systems there has been a certain optimism here that people and [human] intelligence will still be needed. Mankind had not yet lost its *raison d'être.*

EDITOR'S NOTES

32 For the full text of Professor Feshbach's address see page 91.

33 The point has often been made, in DISCOVERIES meetings and elsewhere, in the somewhat more positive sense frequently emphasized by Professor Eduardo Caianiello (Salerno University), that asking the right questions can be a substantial step towards obtaining the right answers. The corollary concerning the wrong questions is often ignored: see concluding paragraphs of next paper, page 97.

34 For the full text of Dr Frosch's address see page 101.

35 The title of Dr Frosch's paper.

36 Artificial distortion, as in the European agricultural scene, excepted?

37 This is certainly no new experience, and certainly gives cause for reflection. Since the quality of both the scientists and their science may be assumed as impeccable, the fault must have been an incorrect and/or incomplete understanding or representation of the problem(s). Presumably, in fact, 'the right questions' were not asked.

38 Several symposium participants, in private conversation with the writer, readily agreed that the importance of money as an end in itself, rather than as a means towards the desirable end of enabling all people to share in the munificence of a munificent earth, was generally and grossly overrated. At least for the present, as had been well demonstrated by a series of oil crises, the limits to growth were dictated by conflicts over how flexible this artificial yardstick (money) should and could be made.

39 Workers in the nuclear power industry have frequently been accused of this, as more recently have biochemists, genetic 'engineers' and others who, for some unexplained reason, are invariably supposed to have no thought or concern either for their own well-being or for that of their families, descendants, friends and neighbours, or for humanity as a whole.

40 See the professor's remarks (page 104) on the attempt by lawyers to define the value of π as 3.

41 Some enlightened lawyers have certainly appreciated this, and cases could be cited where scientific endeavours have been particularly successful under the direction of such people. Moreover some scientists and engineers, perhaps frustrated by their legal colleagues, have taken the trouble to become lawyers themselves.

42 For the full text of the professor's address see page 108.

43 For the full text of Dr Levien's address see page 114.

44 This method of combined audio-visual presentation, extremely popular in recent years in North America, can be more or less effective according to the division of information conveyed via the two channels. Where the projected visual information is no more than an emphasis of the spoken word, it can be of great help; however, where the projection includes more or different information, the effect on the listener/viewer, trying simultaneously to absorb two distinct data streams, can be near schizophrenic. Dr Levien's presentation was substantially in the first (acceptable) category; nevertheless the need to verify this continually, as slide after slide flashed up, produced evident fatigue symptoms in quite a few among the attentive audience.

45 The other three, as listed by the speaker, were those concerned with materials and structures; with energy and motion; and with genetics and organisms—the last category being previously developed through farming, agriculture and medicine, but now entering a new stage of development through genetic engineering.

46 Who possessed the necessary apparatus.

47 E.g. Gordon, W J J, *Synectics*, Harper & Row, 1961.

48 See also footnote 8, page 8. Participants who had attended the Paris DISCOVERIES Symposium in 1978 may have recalled remarks then made about books by Professor Murray Eden (US National Institutes of Health): 'People can read books slowly or fast, sitting erect or lying down, at a desk, in a bus or in a bathtub, in bright sunlight or candlelight. People can read from first page to last, browse, skip, pay attention, doze, put the book aside or pick it up, switch from one book to another, write comments in the margins, tear out the pages when sufficiently aroused or, having finished with the book, use it to light a fire, or

worse! Neither the clay tablets in prehistory nor microfilm today offers such a marvellous range of autonomous acts.'

Although it must be admitted that the 'electronic book' of the future, together with its associated reading, reference and recall equipment, will probably also offer most but certainly not all of these facilities (especially the last!), current trends in 'real life' suggest that the old-fashioned book still has a very long life before it.

49 Precisely the same dilemma of contrariety arose in the 1978 (Paris) DISCOVERIES Symposium, when it was recognized that the physical decentralization of society made possible by increasing unification of communications systems could well be accompanied by greater administrative centralization than previously—which, at least initially, could prove more efficient. See *Proceedings* of Paris Symposium, page 322 (Honda Foundation, Tokyo, 1979), or *The Humane Use of Human Ideas: the DISCOVERIES Project and Eco-Technology*, page 62 (Pergamon Press, 1983).

50 The exact definition of this expression—and of others in the paragraph—may cause the reader some difficulty, as it did the writer. In a general sense, the meaning seems clear and even unambiguous, but seeking greater precision leads immediately to the esotericism of jargon, invalid unless shared by and standardized among users and prospective users. The 'problem' is well illustrated by Professor Lawson's paper itself.

3.1 Reflections on the Microprocessor Revolution: A Physicist's Viewpoint

Herman Feshbach, President,
American Academy of Arts and Sciences

As I have tried to emphasize in my title, my principal experience has been as a theoretical physicist, although I have had some exposure to technology and management. As a physicist I should remind you, if that is necessary, that the technical advances whose impact we are considering are based on the discoveries and innovations of the physical sciences, and I should add the biological sciences as well, although these are more for the future.

The twentieth century has witnessed the development of a profound understanding of the material universe, ranging from the properties of nuclei, atoms and molecules, separately and in the aggregate, to the constitution, evolution and energy production of stars, and has even given us an insight into the birth of our universe. The study of the atom and molecule yields an understanding of the chemical processes involved in ordinary energy production; the study of the nuclei of the energy and element production in stars; while the study of nucleons provides an insight into the phenomena occurring just after the 'big bang'. Investigations now in progress may yield laboratory phenomena which mimic the 'big bang' itself. This is an extraordinary set of accomplishments, made more so because it has been possible to obtain their explanation from a remarkably small set of general statements.

In view of the symbiotic relationship between science and technology, one is not surprised to find a corresponding set of technological advances. One need only compare the capability of today's industrial society with that available at the beginning of this century. That revolution continues today, and I would first like to make some general comments on its nature.

One characteristic of great importance is pace. As Stout* has written: 'The pace of advance in potentially applicable technology has been bewilderingly rapid in the past 30 years and appears still to be accelerating.' Most recently we can discern the advent of another quantum jump through the applications of

* David K Stout, 'The Impact of Technology on Economic Growth in the 1980s,' *Daedalus 109*, 159, 1980. S R Graubard, ed.

discoveries in molecular biology. These technical advances are economically of immense importance, for today innovation is the major source of economic growth in industrial societies.*

As a second comment, note that the unpredictability of the impact of scientific and technical discovery mirrors the unpredictability of scientific discovery itself. One can ask for the development of a technical solution to a social or economic need. But very often that solution comes from an unexpected quarter as science itself develops in unexpected ways. Who would have imagined that study of the crystal structure of proteins, begun well before World War II, would lead to a practical method for the production of insulin? Or that the study of the properties of materials would lead to the chip and its myriad circuits? And it is quite common to find technical solutions to hitherto unperceived problems. As Boorstin** has put it: 'The technological revolution is characterized by unexpected answers to unimagined questions.'

One finds a similar history with respect to the impact of discovery. Boorstin continues by asking who would have predicted that the internal combustion engine and the automobile would alter the meaning of cities; or that the study of the nucleus would revolutionize warfare or, adding to his question, that scaling circuits, the precursor of the circuits of the modern computer, would change the whole structure of information and communication?

This uncertainty regarding the impact of technical innovation, together with the rapid pace, have immediate effects on the nature of industrial society, as well as the associated social costs. These put a premium on research and development and on flexibility of management and of the workforce. For the latter this translates into a greater need for skilled as opposed to unskilled labour. For the former it is reflected in the need for managers who take the long-range point of view and whose vision is not bounded by the immediate bottom line. Obsolescence and insufficiently flexible management or workforce lead to falling productivity and unemployment. Retraining (and often relocation) of the unemployed is a formidable task. But it is probably equally difficult to change managerial policies and educate the stockholder. And of course it can be enormously expensive to replace ageing industrial facilities.

The impact on the 'man in the street' should not be forgotten. He is presented by technology with a world in a continual state of flux. It is a world he never requested, a world developed without his consent, without any prior consultation with him, and one over whose rapid changes he has no control. The quality of his life, the environment, the nature of his personal relations, are all affected substantially, non-trivially. There is on the one hand an appreciation and on the other hand a resentment of the expert, the engineer and the scientist.

* Harvey Brooks, 'Technology, Evolution and Purpose', *Daedalus, 109*,65, 1980.

** Daniel J Boorstin, *The Republic of Technology,* Harper & Row, New York, 1978.

Underlying these feelings is the realization that these advances in the standard of living are accompanied by a whole set of social costs and transformations. And in many cases the unpredictability with respect to invention clearly applies as well to social costs, whether environmental—toxic wastes, acid rain, etc.—or institutional, as in the impact on the nuclear family or on labour unions, or political, on the whole nature of international relations and the international economy.

In his prescient 1971 book *The Coming of the Post-Industrial Society*, Daniel Bell* predicted the transformation of industrial society into a 'knowledge' society. Just as the number of agricultural workers would have diminished by 1980 so that three per cent of the workforce was producing surpluses, Bell predicted that the goods-producing faction would also begin to shrink from 44 per cent in 1947 to 31 per cent in 1980, while the service sector would grow from 43 per cent to 66 per cent. Drucker** tells us, in agreement with this forecast, that 'the blue-collar workers are being made redundant by the shift to knowledge-intensive work'. And Porat*** estimated that in 1977 about 46 per cent of the workforce was employed in the information industry alone. Predictions have been made that this decline in manpower employed in industrial production will continue, being a result of the increased productivity obtained primarily through the introduction of computerized automation, replacing the unskilled and eventually the semi-skilled labourer. Accompanying the shrinking of the industrial proletariat is the growth of the managerial and technical-scientific classes. According to Bell* the result will be a society whose strength is dependent upon technical and scientific capability. But he makes the critical point that the managers will determine policy and particularly capital investment.

The tool which underlies most of the developments is the modern electronic digital computer, and more generally the microprocessor. Invented at first in response to scientific needs, it is rapidly becoming essential to management as well as to increased productivity, and to quality control in the industrial sector. The nature of industrial processes has changed, requiring a different kind of worker whose task is not to be a part of a mass production line but rather to provide the skills forming the interface between the robotized machine and the

* Daniel Bell, *The Coming of Post-Industrial Society*, Basic Books, New York, 1973.

** Peter F Drucker, 'Doing Well to Do Good,' in forthcoming volume *Public and Private Partnership: New Opportunities for Meeting Social Needs* (tentative title)(ed H Brooks, L Liebman, C Schelling). To be published for the American Academy of Arts and Sciences, Cambridge, Massachusetts.

*** Marc Uri Porat, 'The Information Economy,' Department of Commerce, Office of Telecommunications, Special Publication 77-12, Washington, DC 1977.

user. Moreover,'. . . the work requires high level skills precisely because problems cannot be anticipated' as 'techniques change rapidly and in directions that cannot be foreseen'.*

Again we see the impact of pace and unpredictability. Can we adjust? Or, as Stout suggests, shall we find that 'the increased obsolescence of existing human and physical capital will tend to outrun the natural pace of labor movement and reequipment by way of training, retraining and capital replacement'? The impact on labour is already visible as unemployment affects mostly the unskilled and semi-skilled worker, with direct consequences for the strength of labour unions. There is concern that the US is developing a permanent underclass without job skills or the hope of gaining meaningful work. At the same time, the modernization of much of American industry is delayed by the large capital investment needed.

The requirement of flexibility applies as well to the managerial system. American industry has witnessed the growth of ever more elaborate systems of management control. The ratio of management positions to production workers has been steadily increasing. Such systems have a large inertia and viscosity typical of bureaucratization and cannot move with the speed required to match the present pace of advance. Nor will they be able to react to unexpected directions which this advance might take. And they will not be competitive with managerial systems which do have the required flexibility.

The impact of computerization extends far beyond the automation of industrial processes. The microprocessor, combined with more effective and faithful methods of communication, made possible with the aid of satellites, and coaxial cable or optical fibre transmission lines, has generated a revolution—a term not used lightly in this context—in the generation, transmission, storage and retrieval of information.** The dimensions of this revolution are just beginning to become apparent.

As symptomatic evidence, note that last year alone in the US about 2,800,000 computers were sold for home use, while about 1,200,000 were purchased for small businesses. As of September 1982 there were a minimum of '18,474 central processing units operating within the Federal bureaucracy'.***The impact on education generally, beyond that for computer scientists, will grow rapidly. A survey by the National Center for Educational Statistics**** of the country's 82,000 schools shows that 31,000 microcomputers were in use in 1980 and there are many more in classrooms today (1983). In the same three-year period

* Robert B Reich, 'The Next American Frontier,' *Atlantic Monthly, 251,* 43, 1983.

** W K Scheuten in *Emerging Technologies: Consequences for Economic Growth, Structural Change and Employment* (ed H Giersch). J C B Mohr, Tübingen, 1982.

*** David Burnham, 'The Week in Review,' *New York Times,* p 20E, 17 April 1983.

**** Muriel Cohen, *Boston Globe,* 9 January 1983.

the number of schools equipped with small computers or terminals rose from 29,000 to 36,000. Most of the first-year students at my own institution, MIT, arrive quite conversant with computers, with programming and the computing jargon. The coming decade will see an adjustment of our educational process to this capability and interest. And of course it will not be confined to science-based institutions like MIT. The message here is that the educated American public is developing a sophistication with respect to computers which surely will have a significant impact on our social and political system.

A primary technique is digitization. It is relatively easy to digitize alphabets (and even ideograms, although this is more difficult) and therefore words, and from there any kind of written message customarily available in the form of letters, articles or books. It is possible to digitize symbols as well as images which ordinarily are recorded by photographs. The result is more accuracy, higher quality and greater flexibility. That process is now being introduced into television with a consequent big improvement in quality. The vast improvement over the ordinary X-ray photograph provided by the X-ray CAT scanner is achieved in part through digitization. Digitization of musical performances will replace the present-day methods of recording and the phonograph disc-needle method of replay, and the quality will be incomparably better.

It is to be emphasized, as the above examples demonstrate, that the chip brings more than just convenience. Its use makes it possible to manage routine tasks more effectively, more accurately, more rapidly, be they inventory control, banking and financial transactions, electronic mail or word processing. But the chip permits a sensitivity which yields a qualitative change in capability. In my own field the computer has been not a convenience but a necessity in many research areas—without computers it would not be possible to carry out the desired investigations. This application has taken at least two forms. In one, on-line data analysis, an event or set of events is immediately analysed so that an on-line decision can be made as to the next set of experimental parameters to be employed. In another, the computer is used to select, out of a large number of events, those events pertinent to the research. It is particularly useful when one looks at rare, improbable events. The discovery of the J particle by S C C Ting and his colleagues required the identification of a very rare occurrence equivalent to the identification of the one coloured raindrop present in an all-day-long rainstorm. The elimination of the unwanted events is obtained not simply by spatial separation and discard, a procedure which became rapidly impractical as the number of these events increased. Rather, in addition, through the use of signals, one can pick out and record only the particle with the desired characteristics. The elimination thus occurs essentially through the use of software which programs the discard of the unwanted and the retention of the wanted.

The ability to select, by programming, the rare event (or to focus on a particular feature) is of course the essential ingredient in quality control and it is here that the microprocessor is so useful.

This improvement in digitization and in digital processing has a most important application to communication, as with appropriate software a substantial improvement in the signal to noise ratio is obtained. Together with the development of improved methods of transmission it has become possible for conversations to be held between almost any two principal cities. This point is made dramatically by the transmission of data from satellites as far away as Saturn or Jupiter or the extraction of important data from the universe's babble by radio astronomers. Here the computer plays a vital role in accentuating the signal and eliminating the noise.

As Bell emphasizes, not only is communication limited by cost alone, distance playing a secondary role, but also the number of individuals interacting with one individual and the number of arenas in which he or she can be active has increased substantially. The same remark applies to the corporation, so that multinational corporations can be more easily managed while geographical constraints are relaxed and propinquity becomes less essential. The dissemination of information becomes more rapid and universal. Nearly simultaneous worldwide publication of a newspaper is possible. The concept of one world loses its abstract quality.

The information-communication revolution will have its social costs, and I would like to mention a few that I see. Information* is 'valued as a critical resource in the same sense as labour or capital. Information is different in that it is often enhanced rather than depleted through use'. Information is treated as a commodity—to be bought and sold and to be stolen or kept as a secret. The US Export Control Act requires licences for export of sensitive types of goods, particularly those of military value. Included is information—that is, one may be required to obtain a licence to export information, whether in written or oral form. The need for secrecy with respect to industrial data is particularly apparent in view of the rapid pace of technology development. But when does information collected on behalf of the needs of science become industrial data? Complete freedom of communication is central to the scientific method and to the progress of science. Secrecy, export controls, etc. are totally inimical to the spirit of science, which is truly international in character, as any examination of the history of a scientific advance will confirm. Clearly the line must be carefully drawn as the success of science is necessary for the advances of technology. The imposition of secrecy on science will in the long run kill 'the goose which lays the golden eggs'.

Another example: the computer has come to be regarded by its users as another individual who can bear responsibility. Too often we are told by the service industries that the computer was responsible for one mistake or another: 'Sorry, sir, it was a computer error.' But of course this attitude forgets that people designed the computer and that people devised the programs it processes.

* Donald J Hillman in 'Science, Technology and the Issues of the Eighties' in *Policy Outlook* (ed Albert H Teich and Ray Thornton). Westview Press, Boulder, Colorado, 1982.

Too often one is carried away by the apparent accuracy of the numbers generated by the computer, forgetting that the programs used involve assumptions and schemes whose nature is generally incompletely realized by the user of the computer. Computers give answers, but to what questions? The limitations of computers limit the nature of the questions it can answer. As Weizenbaum* points out, these are questions 'whose very forms severely diminish the number of degrees of freedom in our range of decision-making. Whoever dictates the questions in large part determines the answers'. Models often used to ape (for example) economic behaviour can provide very precise answers which are, however, no better than the assumptions upon which the model is based. There are many examples in which unhappily this truth is forgotten.

For well-documented cases, it is possible to determine these assumptions and thus obtain a realistic evaluation of the meaning of the results. But unfortunately well-documented programs are not always available. 'But what about the many programs on which management, most particularly the government and the military, rely, programs which can in no sense be said to rest on explicable theories but are indeed enormous patchworks of programming techniques strung together to make them work?** They are put together by teams of programmers often working over many years, and no one individual can understand their inner workings at the time they are finally put into use. It may very well be, as Wiener*** points out, that this understanding may be developed long after the task for which the machine has been designed has been completed. Of course these remarks are relevant for large and complex calculations; but these may well be the ones used for decision-making and for modelling.

Another and not unrelated issue is that some attributes are not quantifiable. Quality cannot be quantified. Can one quantify the performance of an orchestra, the impact of poetry, the concepts of an Einstein? Not-quantifiable effects are often simply not considered by the computer-oriented manager. In my own field, the value of elaborate calculation often in agreement with experiment is questioned unless it provides a new understanding of qualitative importance. The value of a new concept is not quantifiable. The prediction of long-range effects will also fail when non-quantifiable qualitative effects are not taken into account. Such predictions in any event have a widening range of uncertainty as the time from the present increases. But unfortunately they are sometimes presented

* Joseph Weizenbaum, 'On the Impact of the Computer on Society,' *Science, 176,* 609, 1972

** Joseph Weizenbaum, op.cit.

*** N Wiener, *Science, 131,* 1335, 1960.

without qualification—for, after all, were they not the detailed output of a computer good to umpteen significant figures? We are dealing once again with the primary fact that the output of a quantification is no more valid than the assumptions which underlie the process. Of course such a lack of sophistication or critical evaluation need not be the norm, but to the extent that it occurs there is a cost which flows from such misuse—a cost in that it may affect decisions, whether governmental, industrial or educational.

The danger of over- and mis-interpretation is present in much poll-taking, the basis of many a political and marketing decision. Marketing analysis attempts to obtain an estimate of consumer demand for a given product or range of products. As far as it goes it is accurate. But it fails to take into account that the availability of a product can change the demand in ways which the consumer cannot predict, as confirmed by the unpredictability of the effects of inventions commented on above. As Abernathy and Rosenbloom point out,* 'the needs expressed in the market tend to reinforce the status quo because standard market surveys measure what the customer knows he or she wants now. The initial market estimates for computers, xerographic copiers, the Land camera and other major innovations, for example, fell short by factors of thousands'. 'The point is not that product development strategies should always be geared toward latent rather than expressed consumer needs, but that management attitudes and practices geared to the quantifiable and provable, the here and now, risk the loss of such opportunities to use technology to gain competitive advantage.'**

The devotion of much of management to the 'quantifiable and provable' is not only apparent in the use of market surveys but seems to be part and parcel of the approach to the formulation of decisions. This may in part be a consequence of the large representation in top management of individuals with backgrounds in law and finance, according to Abernathy and Rosenbloom.*** In agreement Reich comments 'approximately 40 per cent of the chief executive officers of America's largest firms have backgrounds in law or finance and rose to their present positions from company legal or financial staffs'. This is in contrast to the situation in 1950 when the fraction was only 13 per cent. Correspondingly fewer of these leadership positions are filled by the technically and scientifically trained individuals who were in many cases the original entrepreneurs. As a consequence, many of the problems that arise in business 'are apt to be viewed as problems of law and finance, to be dodged through clever manipulation of rules or numbers',**** rather than resolved through

* William J Abernathy and Richard S Rosenbloom in *Science, Technology and the Issues of the Eighties.*

** William J Abernathy and Richard S Rosenbloom, op.cit.

*** William J Abernathy and Richard S Rosenbloom, op.cit.

**** Robert B Reich, 'The Next American Frontier,' *Atlantic Monthly, 251*,43,1983.

technical solutions. Emphasis on cutting costs rather than increased emphases on research and development is a characteristic. 'Contemporary managers display a preference for short-term cost reduction rather than long-term technological investment . . . they rely heavily upon market research and its ability to reveal consumer preferences, rather than depend upon the introduction of a new product to tap latent preferences and upon an educational programme for altering those preferences.'*

These conclusions are based on Abernathy and Rosenbloom's study of the consumer electronics industry. They are given additional support by Mechlin and Berg,** who argue that 'return on investment' analytic techniques for evaluating the value of research to a corporation fail in providing a correct measure and in fact impede research progress. Of course one must be careful to realize that description is not universally applicable.

The important phrase in these quotations is 'analytic techniques', which simply refers to the use of quantification to analyse, model and predict. The computer makes such analysis relatively accessible. The statistical error is small but the systematic error may be large. Micromanagement, the enemy of research, becomes the rule rather than the exception and innovation is stifled at birth.

These attitudes are reflected in educational practice.*** 'Increasingly, professional education in America stresses the manipulation of symbols to the exclusion of other sorts of skills that are more relevant to the newly competitive world economy. And more and more the career ambitions of America's best students have turned to professions that allow them to continue attending to symbols from quiet offices equipped with a telephone, a Telex and a good secretary.' I would add a word processor and an office computer.

On the other hand, information technology may open up new educational modes 'optimizing educational resources and offering new flexibility in individualized course work'.**** And of course the ability to make use of information technology needs to be part of the skills and background a student should acquire as it becomes a most pervasive aspect of the logistics of US society.

We have called attention earlier to the widespread presence of computers in the American classroom. Just how effective these are in improving instruction

* William J Abernathy and Richard S Rosenbloom in *Science, Technology and the Issues of the Eighties.*

** G F Mechlin and D Berg, *Harvard Business Review, 58,* 93, 1980.

*** Robert B Reich, 'The Next American Frontier,' *Atlantic Monthly, 251,* 43, 1983.

**** Donald J Hillman in 'Science, Technology and the Issues of the Eighties' in *Policy outlook* (ed Albert H Teich and Ray Thornton). Westview Press, Boulder, Colorado, 1982.

is not known. We recall the enthusiasm for audio-visual aids and most recently for television in the same context, an enthusiasm which so far has turned out to be overly optimistic. Certainly computers are popular with the students. But undeniably some of that interest reflects a faddish absorption in computer games, many of which have a pseudo-military background. One must view with alarm the picture of many thousands of young people enjoying the thrill of a successful computer war game!

It is not possible in the little time available to do justice to this important topic, the information 'revolution'. And none is left for other examples of important technology. There was no time to discuss the new inventions and capabilities on the horizon and thus document the 'rapid pace'. One could not delineate in detail the extent to which information technology now pervades our society and the rapid growth foreseen for that penetration. Nor was it possible except in broad terms to allude to the multi-dimensional impact on society and the economy of both a positive and negative character. I have chosen primarily to emphasize some of the challenges posed by the new computer-based technology. Flexibility of the workforce at all levels, flexibility in management, in research and development, may require significant changes in institutional structure as well as in attitude. I have chosen to discuss some of the dangers accompanying the new technology. The one which gives me the greatest concern is its misuse because of the simplistic understanding of the significance of information provided, in part because of the usual incompleteness and lack of documentation of the input assumptions. Picasso is rumoured to have responded when asked about the value of computers: 'Computers are useless. They only give answers.' An exaggeration of course, but it does make an important point.

3.2 On Tap But Not On Top

Robert A Frosch, Vice-President (Research),
General Motors Corporation

My title refers to the position of scientists and engineers in North American society, or at least to that position as seen by non-scientists and non-engineers.

To put this in context I propose to talk about three current aspects of technology in the United States. First, what I think is happening; then the 'on tap but not on top' problem; and finally, a comment on limits to growth.

I can in no sense speak for North America as a whole, and I am sure my Canadian colleagues would be offended if I tried to do so. However, it is reasonable to try to describe the pattern that I see developing. One dominant aspect of that pattern is clearly the emergence of the computer and the microcomputer and, most significantly, their application to the control and to the doing of work. This is more likely to be important in flexible automation, and the development of means for doing things, than just in the applications to computation or communications, although those applications are important as well.

The robotics area is where the next major wave of change will come. It will come because we are creating it purposely. It will come less by accident than by intent; it arises from the competitive need to increase productivity and to reduce costs. Systematically, the work that was done by hands, and to some extent the simpler kinds of work that have been done by human brains, is being replaced by work done by machines behind which are people who have exercised their hands and brains. But it appears, and it must be so from the economics of it, that while the hands and brains are driven 'upstream' into higher skills to provide the machines and the software to do the former human work, the replacement of people is far less than one for one, even though the increase of skills in each involved individual may have to be very great.

We have seen this before in the transition to machine operation in agriculture, where we went from many hands and brains and few machines to many machines and few hands and brains. In that transition the people left the farms and went, in the US at any rate, in large measure to the automobile factories, and as they now leave the automobile factories there is some question as to where they will go next.

The curious thing is that at the same time this major displacement of people by machines is happening, is being made to happen, there is an important quality-of-worklife movement developing in a number of industries. Thus the displacement of people is coupled with a strong attempt to improve the conditions of work of those people who remain in factories. This is an uneasy kind of operation so far. It would be wrong to say that all of management or all of labour are enthusiastic about it, but there are beginning to be pockets of enthusiasm and there is a transition coming.

Given this displacement of people, we find ourselves facing the problem of the stratified society, which has been mentioned before in this meeting, and the problem of unemployment.

There is a lovely anecdote, which may even be true, of an interchange between Walter Reuther, then President of the United Auto Workers, and one of the senior managers of Ford, although it could have been any of the automobile companies. Some years ago they were touring a factory which was in the process of automation, and the manager was waxing enthusiastic about the number of machines replacing the terrible work on the line, and worrying a little bit with the labour leader about what would happen to the displaced people. Walter Reuther finally enquired as to how many automobiles the manager thought the machines were likely to buy in the coming model year.

This anecdote introduces the economic and social problem which is central to the issue. With the increase in productivity we are beginning to face the possibility of what I will call a Midas economy: a situation in which it is possible that the price of production of goods, even given the large investments necessary, may really be made to tumble rather markedly, so that the availability of goods will go up and the price of goods will go down, as happened with the availability of agricultural products and is happening now with computers. The traditional economic and social mechanisms for giving people an economic base from which they purchase those goods may collapse while this happens, because of the replacement of people by machines on a massive scale.

I find it interesting that the meetings which discuss this subject, like the present meeting, are almost entirely stimulated, called and populated by engineers and scientists. I have been trying for some time, along with other colleagues, to get the lawyers, the economists and the political scientists at least marginally interested in this long-term question, but they seem entirely occupied in facing the past. In most of my discussions with economists they have simply taken the attitude that it has not happened lately and therefore they do not think it will happen. When I say that they do not understand, that there are lots of us who are in the business of making the change happen, there is a kind of shoulder shrug and an approach that I can only describe as rampant Micawberism: something will turn up, we really do not need to take any action.

In contrast, the concern among engineers, perhaps because of the difficulties of attracting the attention of the economists, is coupled with an attitude very strong in the institutional parts of engineering in the United States. I have been fascinated, in the past couple of days, to find the same thing here in the UK. For the Americans I shall describe it as the Rodney Dangerfield complex of engineers. For others who do not know this name, he is an American comedian now frequently seen in TV commercials. His general line of approach is to be maladroit and then humiliated, after which he says: 'I don't get no respect'.

The other aspect of this shift towards the automated economy which is of interest in US discussion today is the great discussion about whether we should build our society on 'high tech' or on smoke-stack industry. It seems to me that high tech is likely to make a significant impact–not just in its own right but through its application to the smoke stacks; that is, it will be like the application of high tech to agriculture, which was important for the uses of machines rather than for the machines themselves. I can see a great deal coming in the manipulation of symbols and the use of the computer, but man does not (and cannot) live by communications alone. He communicates about something, and frequently what he is communicating about is the production and distribution of goods, as well as art and literature and other important human concerns.

In the economic realm, the manipulation of higher and higher orders of symbology has not turned out to be very productive. As His Royal Highness pointed out, we have indeed gotten to the point where people sell each other their debts. In fact, we have gotten to a point where we are manipulating money markets at a higher and higher level of abstraction in a way which is frequently, in the United States, mistaken for productive business. It later turns out that, nothing having been produced, the 'business' can collapse at a whim, nothing being there but a manipulation of symbols. If we are driven by this computer revolution completely in that direction, then we shall find ourselves in considerable trouble.

That is only to say that the old economist's story about the Irish town that lived by everybody taking in each other's washing is not a very good model of an economy, whether it is washing or the transmission of money.

Let me now talk about the relationship of scientists and engineers to policy-making in society, which is what I mean by 'on tap, but not on top'. This is a comment attributed to an official (whose name I have not been able to track down) some time in the Eisenhower Administration to the effect that 'scientists should be on tap but not on top'.*

We scientists and engineers are much in that situation. It is symbolic that we are having a meeting on the effect of technology on society. I am not aware of any meetings to discuss the effect of accounting rules on culture and society, whereas they have an extremely important, and usually deleterious, impact. There is no meeting on the effects of economic theory on social and cultural behaviour. It has effects but there does not seem to be that much introspection about what is going on.

* Note added in proof: Professor Ithiel de Sola Pool informs me that the phrase antedates my reference, being found in a US Government Administration Manual of the 1930s.

I have spent a large part of my career being a senior scientist or engineer attached to, around or involved in governmental policy processes, both legislative and executive, and I have to say I have gotten very tired of teaching kindergarten. I put it as bluntly and flatly as that. We are called in to sit at the end of the table and explain the technical issues, at which point if we are too junior we are politely asked to leave while the adults will discuss the subject. I eventually got senior enough to stay sitting there while the adults discussed the subject, which they allegedly understood, and a pitiful performance it normally was. I would have to explain that no, no, no, you could not, no matter what you liked, decide that a risk was equal to zero. There are laws of physics and laws of information that have to do with that, and merely legislating the fact, as they did in the State of Kentucky once, that the value of π was to be 3 would not affect what the land surveyors did one little bit. You cannot decide to be a completely cautious engineer; you have to balance your caution against its contradictory effects, and there are always engineering 'trade-offs' which must be made.

Now, perhaps I am exaggerating somewhat, and I do not mean to suggest that the legislators and executive policy-makers with whom I have dealt are less than intelligent—that would be improper and unfair—or that they are entirely poorly educated. They are frequently brilliant and often well educated in some areas. But on the whole we are more likely to find an engineer who has a reasonable basis for a policy education than to find a policy person who has any reasonable basis at all for dealing with a technological matter.

I would not suggest that the legislature or policy levels of executive departments should be populated with engineers and scientists. We have our own form of defect in that kind of policy operation. But it is really difficult to deal with policy issues where there is no understanding of what underlies them. For example, in many issues of risk the best that can be said from a scientific or technological point of view is that the issue has become trans-scientific—a term that Alvin Weinberg of Oak Ridge invented to mean that the effects are so small and so long-term that one could not in a reasonable amount of time collect data that enabled one to tell what was really happening. We are faced with this situation frequently, and yet there is a continual cry that the issue be solved for the policy-makers by the production of an instant scientific result. Hence the cry in the US Congressional Committee for a one-handed scientist, because of annoyance at the number of people who come up and say: 'Well on the one hand this, but on the other hand that'. The technical truth may be simply that there are certain issues which cannot be provided with a scientific base, and that is the fact that must be understood. We get legislation allegedly with a scientific basis, but because the technological difficulty is not understood, things go badly awry, whereas they could have been handled fairly sensibly.

In a number of forms of legislation and regulation, what is being undertaken is a social experiment. But since the people who are undertaking the action do not know what an experiment is, they proceed ideologically and assert that they are solving a problem. The result is that there is no experimental design, and as a consequence we never can figure out what it was we did. Increasingly we have vast experiments, not only in technical but in non-technical areas, with no way to tell whether they worked at all. There is not even a simple perception that taking a series of actions is an experiment, and that one needs to design such a thing, otherwise no conclusion can result.

The foregoing comments are a set of statements about education as much as anything else. As I said earlier, they are not a set of statements that mean everyone should be educated as a technologist or a scientist. But it becomes increasingly acute that we break the tradition that a proper education, a liberal education, is something which may quite sensibly contain no mathematics, no science and no engineering. It is believed by most that an education is perfectly all right as long as it contains some history, a touch of economics, some law and a few other things. That has now become an entirely obsolete concept of education, and while there is a great deal of discussion of this subject there is remarkably little action. Some of this may solve itself by a certain kind of omnipresence of the computer, but that worries me if it is not accompanied by some more basic form of education.

Science and technology are not systems of sleight of hand, or systems of magic where one need only know the incantations in order to produce sense. Fortunately or unfortunately it is not enough to know the spells. One has to take on the 'philosophy' and understand the innards of the subject. In order to be able to make sensible decisions about science and technology, it is more important to understand some of the philosophical innards than to know all the spells.

This implies more than the construction of some courses in science and technology for poets and political scientists. That has been tried, but since the courses have normally been so heavily involved in teaching the spells, they never did get around to teaching the philosophy. I think it is more important to understand the underpinnings than the details, but nobody has yet found a very good way to teach that.

Finally, I come to the question of limits to growth, and shall throw out a perhaps unfamiliar set of ideas, but the subject has been referred to several times and I feel constrained to make the point. It has been correctly said that we are living on the only planet that we know can support life, that it is finite, and that the numbers of us are increasing exponentially, although we are fiddling somewhat with the coefficient in the exponent. That certainly implies that we have a number-of-people problem to be considered.

There is a line of thought directly connected with the robotic and computer revolution that suggests that there is another class of possibilities besides industrial growth limitation. I shall not try to describe this in detail but will only sketch the idea. The idea begins when we ask whether we live on the earth or in the solar system. With the use of the kind of computer and robotics technology we are now beginning to learn about, it will be possible, and it is not so very far off, to construct what I call a pseudo-biology. That is, taking a leaf from some theorems of von Neumann (although the architecture will probably not be a von Neumann architecture), we can construct machines that are quite capable of assembling the parts that make themselves. We are quite capable of designing machines that will mine material, and beneficiate it, and make the parts that are necessary to make the machines. So we can construct a self-replicating, self-producing, machine system.

The process is well on its way. There is at least one automatic factory, owned by Fujitsu-Fanne in Japan, which makes robots. Robots assemble robots. It takes one person in the computer control room and one maintenance person to run an otherwise untended full shift. We are very close to the edge of what I have just described.

If we put that set of self-reproducing machine ideas together with either the moon or the nearest convenient asteroid, and the large availability of solar energy, we have the perfectly good possibility of a self-reproducing industrial system, which is an industrial system building itself, and giving access to the total resources of the solar system.

What is usually said at this point is that what I have said is economically ridiculous. I want to make the clear point that it does not violate either of the laws of thermodynamics. We are using a very high-temperature heat source called the sun. It is dilute energy, but there is a lot of it. We are using materials, and the economics are very straightforward. If we build a reasonably reliable small set of these machines, so that they continue working, and there is not too much mutation of the software, then we do have the possibility of taking a finite investment, albeit likely to be of the order of $\$10^{11}$ (but that is only a piece of the US federal deficit), spread out over a long period of time, and getting an eventually indefinitely large repay on that investment. Thus there may be a technologically driven system that can really release us from the complete constraint of our planet.*

I come back, however, to the caution. This is the only planet we know of on which we can live conveniently. While I have perhaps produced an economical idea for industrial escape, I have not produced a new way for people to live conveniently until we use that industrial capability to build a livable home in space. So we had better take reasonable care of where we are living now, and not relax on the assumption that we can live in lots of other places.

The central point of all this is that indeed the technological revolutions that we are creating (and I dislike the talk that they are somehow happening to us without our control—we are creating them) raise the problem of whether

* These ideas were worked out with Barney Oliver of Hewlett Packard, Ricardo Giacconi, then of MIT (now Director of the Space Telescope Institute at Johns Hopkins University), George Field of the Smithsonian Observatory at Harvard and myself at a NASA summer study. They were also described (earlier) by Freeman Dyson and are discussed in his book *Disturbing the Universe.*

technology can be coped with. It seems to me that the problem is much more whether the non-technological issues thus raised are having applied to them the same class and kind of thought that we apply to technological issues. The traditional modes of thought that are applied in policy areas simply are not up to this kind of operation.

They are not up to it for a simple reason: they are basically not problem-solving modes of thought. They are conflict-resolution modes of thought. When we get into policy discussions in a government, when we get into legislative discussions, we are normally in a form of legal discussion in which people are arguing about whether the answer to a given question is A or B. Technologists tend to come at that problem by enquiring whether the question is a reasonable and correct question, and regard the problem itself as malleable and redefinable before the issue of solution needs to be approached. That is not a legislative habit, nor is it a policy habit; we have another form of educational shift that will have to take place.

I am, it is clear, more confident of our ability to handle the technology than I am of our ability to handle our social and economic affairs. I am somewhat bothered by the fact that we have not been able to apply to them any of the modes of thought or any of the kinds of operations that we do use in technological affairs. I think that is a major challenge for society, but since I get invited to talk about it to groups of engineers, and never to business schools or lawyers, it is not clear to me that I have much effect.

3.3 Changing Technology - Its Social Impact

Ithiel de Sola Pool, Director, Research Program on Communications Policy, Massachusetts Institute of Technology

In advanced industrialized countries, such as the United States, technology today is indeed affecting physical production as Robert Frosch noted, but it is affecting intellectual and organizational activities even more.

For most of human history, the main use of technology has been to transform resources drawn or grown from the earth into usable physical commodities. The uses were many: food, toys, weapons, pots and pans. But whatever the use the end product was a physical object. Technological progress in such commodity production continues today. It continues in biotechnology, robotics, fibre optics and new materials. What is new is a change in the balance between technology aimed at improving such production of physical goods and technology aimed at improving thinking, communicating and organizing.

During the nineteenth and first half of the twentieth century progress in the technology of physical production increased wealth vastly and did so without increasing the manpower in agriculture and industry required to produce it. It increased wealth by increasing the productivity of the labour force. The manpower required for agriculture declined to the point where (as Herman Feshbach has noted) it takes only three per cent of the American labour force to produce all the food Americans eat and also much that we export. In the early days of industrialization that permitted manpower to move into the factories but automation eventually permitted industrial production also to grow with a reduced labour force.

The growth in wealth that the agricultural and industrial revolution brought about required a parallel growth in government, marketing, finance, research and education. But these grew without much technological improvement in their productivity. So the growth of these intellectual and organizational activities entailed a vast growth in the number of people engaged in them. That kind of growth, of course, has its inherent limits.

The burden of the ever-growing costs of organizational activities has now created an incentive for development of the technology or technologies of information. The computer is the most important of these.

The computer has its impact on such institutions as banks, governments, libraries, publishers and education. These are what may be called 'intermediary' institutions. They mediate between the originators of some good or service that people want and the ultimate consumer. These intermediaries serve to store, transport, package, customize and explain the product to its user. For example, banks are financial intermediaries. There are people who have money that they do not need at the moment and which they would like to make available to others for a fee. There are other people who need money or need it delivered to their creditors. Banks bring these parties together, for the convenience of all. Other intermediary institutions are wholesalers, shippers and retailers. In the intellectual field, on which I shall now concentrate, intermediary institutions include libraries, publishers and broadcasters.

One observation common in the USA about the impact of computers on people in the middle of the production flow is that they tend to squeeze out middle management. This is often asserted, and with much plausibility, but how far it has happened is not well documented. None the less some casual experience lends credence to the hypothesis. Management information systems allow top management to gain direct access to any data in their company's records. When there are global on-line information systems, field managers need no longer be given decision autonomy; they can be under constant instantaneous review. Similarly, the role of the ambassador in diplomacy is much reduced once long-distance communications puts the ministry in the capital in direct minute-by-minute contact with every crisis in the field. The decline of diplomats and the tendency of cabinet-level teams to run crisis management out of the White House is very conspicuous in the United States.

This observation about middle management, to the extent that it proves true, is, I would argue, a special case of one of the most important and most common effects of computers and global electronic communication. The general pattern is that the ultimate user of information is put in the position to have direct access to the basic or even raw information that he wishes without the need for intermediary organizations to process and transport the information to him. Electronic information is not place-bound; it is usable from anywhere without delay. That is very different from the situation for printed information.

Let me overstate the case to make my point clear. The intermediary organizations in the intellectual field do not in general create information. For the most part they handle physical packets of paper on which information happens to be stored. The people who create information are researchers, writers, composers, artists. Typically they work on their own or in institutions devoted to knowledge rather than to the dissemination of knowledge. When they finish a study or a novel or a score, they shop around for a journal or a publisher who will take it off their hands and distribute it. The publisher is expert in promotion, editing, printing, or at least in how to contract for each of these functions. His stock in trade is an inventory of physical documents which he knows how to market. The same is true of a bookseller.

Similarly, a library does not create knowledge. It stores paper, and if it relies on the Library of Congress cards to describe the books, it can operate with little knowledge of the contents. There are special consultants called reference librarians who help unskilled users find what they want, but that is not a line function of a library.

I know that I am overstating the case. Any economist would tell us that delivering a product to where it is wanted, packaging it conveniently and informing the public about it is as productive an activity as what happens on the assembly line. I agree. I do not for a moment wish to minimize the importance of what publishers or librarians do. Indeed my concern is precisely that the effect of some technological changes may be to weaken these vital institutions. None the less, I have stated the distinction sharply so as to highlight the contrast between the functions which I called the creation of knowledge and the functions that arise from the need to distribute that knowledge in the form of pieces of paper, and which will be drastically changed when that knowledge is distributed in some other way.

My point is that the intellectual processes involved in seeking out knowledge and expressing it well will remain challenging and difficult forty years hence, as they are now, even if computer-aided. News services, universities, laboratories will be as much a part of that society, if not more so, as they are today. However, when computers have become universal in homes and offices, when they are all on efficient and cheap data networks, the functions of publishers, bookstores and libraries will be markedly changed and very likely reduced.

In the kind of information system represented by computerized information retrieval, videotex or other such systems, there are, of course, intermediary organizations of new and different kinds. We might note four of them: carriers, promoters, directories and billers.

Some sort of telecommunications carrier has to transmit the information from its source to its user. That could be the post office transporting disks or tapes, but it is far more likely to be economical to download this material electronically. The carrier is in a strategic situation, though the carrier's strategic hold is likely to be reduced by the evolution of a number of competing alternative means of delivery. If the same material can be sent by direct satellite transmission, by phone lines, by FM subcarrier, by cellular radio or by mailing disks, then possible monopolistic control of content by the carrier is less of a threat than if there were only one network. None the less, the different carriers are not equally efficient for all functions, so carriers may acquire substantial market power.

By coincidence, on the very day that this paper is being delivered at the Honda DISCOVERIES Symposium, the British Home Office is issuing its White Paper on the role in the future market to be allowed to cable TV carriers.

In the United States we can begin to see a major political battle shaping up over the market power of cable television systems. Now that 35 per cent of the public is getting its TV by cable, and it is clear that soon it will be most of the public, and now that there are systems with more than 100 channels, it is evident that access by publishers of all sorts to those cables is extremely important for the survival of free communication.

Just how the new patterns of information distribution will work out in contrast to the old ones no one can forecast with certainty. None the less we can begin to see some respects in which the system may change. The reason that the heart of the present information distribution system is the publisher-bookstore-library complex is that getting paper documents to the reader is a big job. The heart of a future information distribution system however is on the one hand the electronic carrier and on the other hand one specialized information activity, namely telling the reader where he can find the information that he wants. The creator of information can keep his information on his own computer, and give access to it to anyone, so long as there is a carrier that will serve him without discrimination and a publicist and directory service that will tell the world what he has. That emerging system puts the creator of information in much more direct contact with the reader than is the case today.

Undoubtedly the more aggressive and fleet-footed of the present publishers will find ways to get themselves into the new directory and publicity functions, but one cannot minimize the problems that publishing and libraries will have in adapting to this new world.

Some commentators on new computerized information systems suggest that their effects will mainly be felt by the disadvantaged, the uneducated, the computer illiterate. They will of course be affected, but the greatest effects are likely to be on some highly educated professionals whose present privileges arise from their specialized skills in information technologies that will become either obsolete or easy.

In the end the result is likely to be a much more pluralistic world than that in which we now live. One of the earliest observations on the effects of the Industrial Revolution concerned its propensity to create larger and larger social units. The steam engine promoted factories with thousands of workers. With that came urbanism; until the last century, the great majority of mankind in all societies had lived in the countryside and in villages. That balance has now been reversed. Along with industrialization and urbanization has also come the powerful nation state, exercising detailed regulation of life.

But human history is not a monotonic trend. It is a churning process of contradictions. The centralizing phenomena that for the last couple of hundred years have been so conspicuous have simultaneously been infiltrated and eroded by forces of pluralism. Industrial growth was achieved, for example, by private enterprise which restricted the power of the state. World transportation and trade created a global arena for cultural interaction and thus gave us options of learning and choosing from all societies. (These DISCOVERIES symposia are a star example.) And some technologies of production and communication promote dispersion of activities.

Electricity is one example. As early as 1894 Frederick A C Perrine, in the new journal of the new profession, *Electrical Engineering,* noted that electricity would favour smaller plants than did steam power, and would also allow dispersal of settlements. Perrine's successors such as Amory Lovins, and less controversially the proponents of co-generation, suggest that we are only beginning to see the possibilities of decentralization in the electric power area.

The trend toward distributed activities in what Daniel Bell has called the post-industrial society is even more conspicuous in the technologies of communication and information. In modern telecommunications networks we see a fairly rapid migration of functions from the central equipment to the customer premises equipment. In the United States this is happening more rapidly than elsewhere because deregulation removes legal barriers to this process, but it is happening all over the world, too.

Many of the things that have made universities or newspapers large bureaucratic structures will change when what is needed for access to information is to know how to use one's terminal. The need for university lecture halls, central libraries or newspaper delivery systems is likely to be much reduced.

I am not saying that, in education, human contact with the teacher is going to be replaced by computer interaction. On the contrary, I am saying that these things may increase as convenient, cheap electronic delivery reduces dependence on cumbersome expensive distribution requirements for handling much tonnage of preprinted paper. Dialogue with the teacher becomes much more possible in a computer-aided environment than in one without that facilitating device. That requires however not just the invention of the computer but the innovation of its widespread distribution in an easy-to-use form.

The first experiments in computer-aided instruction (CAI) in the 1960s and 1970s were largely failures, though not because students did not learn from what was on the terminal. On the contrary, most experiments showed that CAI worked; the students did learn. But the systems based on large computers were far too rigid. They got in the way of the teacher's management of the course. They intruded in the social structure of the teacher-student interaction. Now as we move to the age of abundant and cheap micros, things that did not work in the past may well begin to work. With the student and teacher interacting both face to face and through their computers, and with the programs being changeable by the teacher to meet needs he or she defines, the computer becomes a more flexible textbook, not a substitute for the teacher. The boom in use of the computer in education is already quite visible. It has been estimated that over four million students are already using computers in the USA.

Technology is itself one aspect of the world that we experience and which changes our thinking. There is a famous experiment done by Gordon Allport with an African tribe that lived deep in the interior in round beehive-like houses. These people had never seen a right angle. Right angles do not exist in nature. They are products of our technology; they were not parts of their technology. As a result those tribesmen were not taken in by various optical illusions that confuse us because we assume that windows or walls are shaped in rectangles.

How the computer will ultimately shape our thinking I do not know. The computer in its early form has already done so. Let me illustrate the point by reference to the history of the earliest electronic computers. It is widely assumed that computers came to be invented because certain of the basic theoretical ideas such as Boolean logic, automata theory and cybernetics were around to be expressed in physical form. However, each of the earliest computers such as Colossus, ENIAC or Whirlwind were engineering triumphs, not theoretical ones. They were doing simple operations repetitively and fast, and the triumph was to make them work given the unreliability of the vacuum tubes and other components that then existed.

But once the computer had been built, theoretical formulations, some of them new and some old but not widely known, came to the fore. Such theoretical ideas as the changeable stored program, 'or/if' statements, or higher-order languages, each expressed in clear form a concept that was already there in the machines' rudimentary form as a practical engineering solution to operating problems. The theory came to be recognized as important because it rationalized what the engineer was already doing.

Now we are entering a new age of computer usage. What was originally thought of as a mathematical machine to solve big sets of equations—hence the name computer—is now a very different thing. It is a word processor, a graphics display device, a game player that answers back to the human. Not only will there be drastic changes in some of our most important intellectual institutions, but also new theoretical concepts will come out of that technology that may be very different from the theories that grew up with the computers of the 1950s and 1960s.

3.4 Interactive Information in Office and Home - Technological Evolution, Societal Revolution

Roger E Levien, Principal, Corporate Strategy Office,
The Xerox Corporation

The organizers of this conference, being aware of my proclivity to speak about the social and cultural aspects of technology, and being aware that Professor Pool was sharing the platform with me, asked me to balance my talk more to the technological side rather than the social and cultural in the hope that we would therefore minimize the prospect of pre-emption. In fact it has been minimized, although a little bit is there, and I shall try to avoid duplicating what Professor Pool has said.

Since I am an information technologist, I thought to use some information technology. The points that I should like to stress in my discussions are not so much the fine points of technology, not so much the details of bits and bytes, but rather the broader sweep of technology and the evolution that it has undergone over the centuries, which has indeed had revolutionary consequences, not only for our own time but for times past as well.

To locate us in the spectrum of technologies let me give my feeling about the role of information technology as one of the four grand technologies that mankind has developed, the other three being those concerned with materials and structures, with energy and motion and with genetics and organisms; the last category being previously developed through farming, agriculture and medicine, but now entering a new stage of development through the new genetic engineering.

Each of these technologies has been concerned with the extraction, the processing, the transportation, the storage and the utilization of some object or some aspect of nature, whether materials, energy, information or organisms. I shall be concentrating, naturally enough, on this grand technology—which I have called the information technology—concerning itself with language, with printing and nowadays with computing. This is a subject which has so much jargon that it is useful to start with a definition of terms. I shall be using three terms or categories and I make the distinction here to avoid confusion as I talk.

I shall be talking about information, but rather than defining it precisely I shall say that that is the sort of thing we mean when we talk about data, propositions, facts, sentences. These are information.

Then there is what I shall call intelligence, crudely speaking the processing of information, generally characterized by what we now call a computer, or the human mind for that matter, operating under the control of an algorithm or a program. That is what I shall call—in a very loose use of the term, but I find it a useful one—intelligence.

The third term I shall use occasionally is expertise, which is what we generally mean when we talk about heuristics, inference, skill, judgment: those aspects of information processing which are not guided by algorithms or programs to a specified end. In this broad perspective information technology has been with us for generations. Indeed, I shall characterize it as having evolved in three stages. The first stage, pre-history to 1800, was begun with the invention of language (which is a man-made although perhaps God-given technology) and drawing, so far back in pre-history that it is hard to characterize by a date. But in this very broad sense of technology, the use by man of artefacts for his purposes, the first information technology which we can date is writing, in the period around the middle of the fourth millennium BC; the alphabet around 1700 BC; the development of paper and books in China and then, moving through the Middle East, to Europe, and the period from 100 BC to AD 700; culminating in the development of the movable type printing press in the middle of the fifteenth century. This span of technology resulted in three major characteristics or tools for mankind. First, it enabled written information to be stored and transmitted. The result of that was that information could be cumulated and conveyed over space and time. That was the major social consequence of the first phase of the information evolution, because it not only enabled our society to learn from the immediate environs but also culture to evolve, and information, knowledge and understanding to be conveyed, over time and space—a fundamental evolutionary and revolutionary consequence. But of course it was characterized too by the information being available only to the literate, in those days a relatively small portion of our society.

The second phase of information technology's evolution covers a much shorter period, 150 years, from the beginning of the nineteenth century to the middle of this century. I have listed a number of the prototype or paradigm inventions which mankind cumulated during that period that gave him new capabilities:

—photography
—the telegraph
—the typewriter
—the gramophone or phonograph
—motion pictures
—magnetic recording
—radio and television.

The consequence of this stream of invention was that now sound, as well as words in written form, text and pictures, could be stored and transmitted. Events, and not only sentences, could be captured and conveyed over space and time through television recording, through motion pictures and so on.

But the most important characteristic of this phase of the information evolution was that now information could be broadcast at electronic speeds. Now it was no longer a matter of just the transmission of paper at human speeds from point to point, but information could be broadcast at electronic speeds. The consequence of this was, of course, the shrinking of the distances among mankind, making a truly single earth, and truly a series of highly interdependent societies and economies. Furthermore, since literacy was no longer important for the capture and conveyance of information, it made information in a true sense available to everyone. Again truly revolutionary social and cultural consequences of information technology; so revolutionary that we tend to forget about them, not to think about them as consequences of technology. But if we take this view of technology we have to recognize that they are.

The third stage in the information evolution has occurred very rapidly, roughly since 1945. It began with the invention of the stored program computer and the transistor, which both occurred in the 1940s. I come from the Xerox Corporation so I find it quite natural to include the invention of the copier in this list. Indeed, it did democratize the printing process in a way that we still have not really characterized as a cultural consequence of technology, but I think it is. Magnetic storage, the integrated circuit and programming languages were added in the fifties.

There is a cumulative sense in which technology evolves our capabilities to handle information, and various ways grow. In the sixties we had the interactive computer and the computer networks. In the seventies, the truly revolutionary stage in this evolution was the invention of the microprocessor, the integrated circuit memory which serves it, and their sum in the personal computer. What happened during this period was that we now added the ability to store and transport algorithms: not just information but procedures, ways of doing things, could now be stored and transported, which made possible—and I shall come back to this point in more detail—the capturing and conveyance of expertise over space and time. Those who are engineers can imagine now the expertise embodied in a simulation program, or an analysis program, or a CAD program; it captures not only routines of computation but also styles of analysis and design, and these are now embodied in a physical object which can be conveyed over space and time as opposed to being embodied in a human being. The next important consequence of this evolutionary revolution is that information is accessed interactively at electronic speeds. But it is no longer simply the broadcast mode of transmission.

Finally intelligence—in the sense that I mean intelligence, namely information processing capability—is accessible to everyone.

I shall spend the remainder of the talk elaborating on these points, but before doing so let me characterize very quickly the trends in technology we are in the midst of now and which will be working themselves out over the coming decade.

In the sense of computers there is an obvious and clear trend from the large macro-computers towards the micro-computers. I do not mean that macro-computers will disappear. I simply mean that if we count up the computational cycles around the world the larger proportion of them will be contributed by the micro-computer relative to those contributed by the macro-computer, now become an expensive and isolated device. (When I first entered the field in 1957 I learnt to program on a Univac 1 at the computation lab at Harvard University, which was in a very well-designed glassed-in room, very carefully nurtured and very carefully controlled. It cost about $1 million and had about 1,000 memory locations, and its computing rate was in the thousands of operations per second. Now we can each carry in our own breast pockets machines which have much more capability than that Univac 1!)

We are in fact moving from centralized to decentralized computers, from specialized languages which are arcane and usable only by specialists who study them to more natural languages; from programs which serve us as tools to programs which convey expertise and knowledge in ways that are useful to us beyond that of a tool; from separate programs to those which are interconnected to work together for functions that go beyond any single program; from narrow band communications to broad; from expensive to cheap; from communication in a single level to a hierarchy of communications; from storage that is small relative to that characterized by paper storage to very large quantities of electronic storage which are no longer centrally located but rather locally distributed, and which are not fixed in a single object but are exchangeable and transportable.

Finally, we are having displays and printers which present their images not only in black and white but in colour; not only in low resolution but in high resolution; not only characters but pictures.

It sounds like an unalloyed technologist's dream, and in some sense it is. It is one of the amazing characteristics of this phase of our technological revolution.

But these very broad trends are hardly important in themselves. They are important because they provide new opportunities to mankind; not only new quantitative opportunities but new qualitative opportunities. That is what I should like to concentrate on for the rest of my time.

Three qualitatively different abilities are now made available by the new inventions in information technology:

1 Intelligence can be distributed in such a way that it can be located at the point of use.

2 Interactive communication enables us to have a personal window on the world in a way that a broadcast communication does not.

3 Expertise can be transmitted in space and time in the way that books have enabled us to transmit information in space and time.

I use the floppy disc as a typical example. It is the most common, but it is not the only way in which we can transport expertise.

Let me come back to what I mean by each of these points.

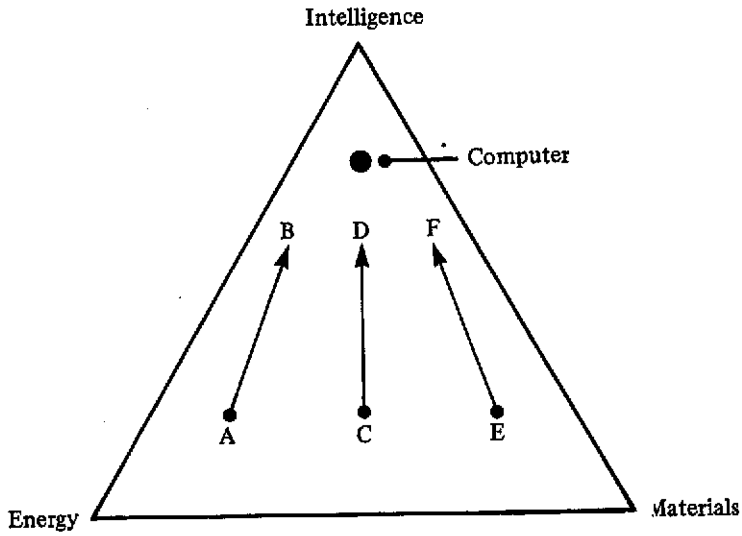
By distributed intelligence I am referring to the availability of the microprocessor, which is an inexpensive, indeed a cheap, machine for information processing–what I have called intelligence. It is exactly analogous, to my mind, to the role that the fractional-horsepower motor has played in the energy technologies, making energy available at the point of use in machines, and opening a whole range and panoply of technologies that had not been available when motors were large, bulky and non-transportable. We now have the microprocessor which is available to provide intelligence at the point of use.

Why is that important? All, or virtually all, products of man's technology combine in some way these three objects: the materials that I referred to earlier, energy and intelligence–some combination! We make the choice and there is a trade-off among the uses of these three according to the relative price of each. What has happened in recent decades is that the relative costs of intelligence have been declining compared with those of materials and energy, and that alters the balance of materials, energy and intelligence incorporated in man's products. This results in inexpensive intelligence being used in machines. To illustrate that let me use a conceptual diagram (Figure 1) in which I have placed intelligence, energy and materials, the three constituents of any product. We can then locate in conceptual terms a particular product within the triangular space, depending on whether it is energy-intensive, intelligence-intensive, materials-intensive or some combination thereof.

What has happened is that as the relative price of the intelligence component has decreased we have been incorporating more of that in our products and less of materials or energy. For example, I have included at Point A the automobile engine, which is obviously an energy-intensive device employing materials and until recently relatively little intelligence. But now the microprocessor has added intelligence to engine control, which has improved engine efficiency in the use of energy, thus reducing the relative component of energy, and somewhat more efficient in the use of materials.

An example I am more familiar with is the copier. The conventional copier employs energy and materials, and a slight amount of intelligence. New copiers however have intelligence embodied in them to a very large extent, so that fewer materials, and sometimes less energy, are used. Most copiers have a single motor force, an electric motor, linked by gears and bands of various sorts to the various sites in the copying engine where power should be applied. The Japanese have done away with all the materials embodied in the gears, and very many of them in the motor, by replacing that single motor by a series of five motors located where power is needed and linked and co-ordinated by a microprocessor. The latest Xerox copier, the 1075, has five microprocessors in it, all communicating via a local network. That replaces a very large wiring harness, a particularly large one because this machine has many options and modules that can be connected.

Figure 1



AUTOMOBILE ENGINE
A Conventional
B With Microprocessor

COPIER
C Conventional
D With Microprocessor

MACHINE TOOL
E Conventional
F With Microprocessor,
'Robotics'

Had it to be done by normal technology there would have to be a great many wires. Instead the wires have been replaced by a single local area network and five microprocessors.

With machine tools we see a similar phenomenon in which the conventional machine tool is now being replaced by a machine tool with microprocessing capability—we tend to call these robots, but they need not all be so—using less material and less energy to achieve the same productive end.

So the first different consequence the new trend of information technology has offered us is the availability of intelligence in a distributed way.

The second major qualitative difference that I want to refer to concerns interactive communications capabilities. The personal computer can be looked at simply as a device, a tool, an artefact; or, as a friend of mine, Ted Nelson, has urged for the last decade and a half, it can be seen as a new medium, because the display screen, which will be—in many cases already is—a full-colour television display, is now able to show a large variety of images under control of the perceiver of those images. It combines communications and a colour display to form a window on the world.

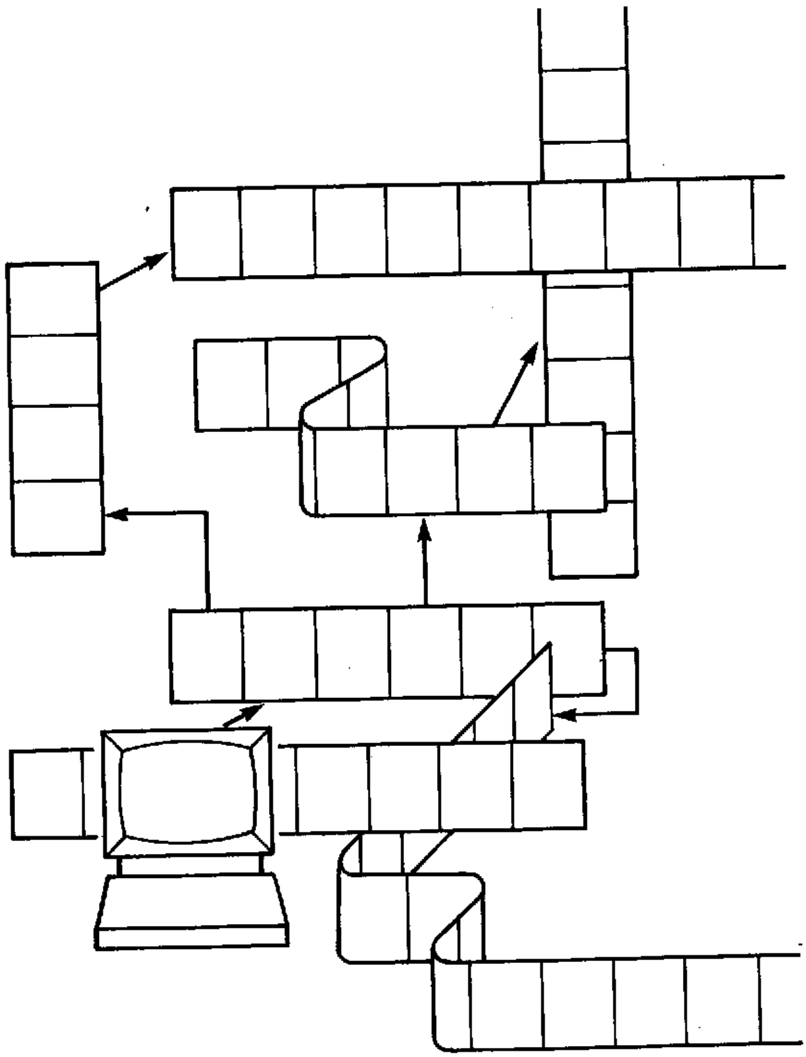
It is not easy to conceive how such a device might be helpful, in the same way that it was perhaps not easy for our predecessors to imagine how the motion picture might be helpful. Indeed, the first attempt to use motion pictures was the filming of stage plays. It took D W Griffith and his compatriots of that era to develop a new 'grammar' of film which understood that this was a new medium that had to be used in different ways, and in that sense we have not yet come to grips with the fact that the computer-mediated television display opens the possibility of a new medium of entertainment and information.

In the past our media have been overwhelmingly one-way, broadcast, whether television and radio or the newspaper. Now we are beginning to see two-way media. The computer game is a good example. Here the user is in complete control of the entertainment he receives. He interacts with it and guides his own particular path through that medium in a way that would have been impossible before the invention of the computer. But we are at the very first stage in the development of this medium. Soon the images on the screen will be much more realistic. The complexity of the phenomena that we can participate in will be much greater. We can see it already in some of the training simulations that are used by the military: to teach pilots to fly, for example. We have, through teletext and videotext, new means of access to databases under our control, as opposed to the control of the person who has put together the data we are to see.

The more general form of this is a word coined by Ted Nelson, *hypertext* (Figure 2). To characterize it briefly, imagine the normal forms of communication as being linear, in that information follows frame by frame in a way the author of that information wants it to present itself. Hypertext imagines that the computer-mediated visual screen will be able to pass through the linear text and then at a particular point, where for example more information is desired in a deeper way, or some examples are required, or animation is sought, or a film needs to be displayed, under the control of the keyboard of the user, of the viewer, the text can be moved to a new form or a new place. This is a potential that the combination of computer, high quality visual screen and information networks offers us, but it is not a potential that has yet been realized to any true extent, because it requires the development of new technologies of construction and materials, new authorship techniques, new editing techniques, new storage and retrieval techniques. It is still a potential that lies ahead of us and not one that has been well realized in any form, except to some extent in computer games.

The final characteristic of this stage of information evolution is the portability of expertise. The floppy disc, however specific its technology, has the virtue of being an exchangeable medium for the transport and sale of programs. In that sense, in the very broad scope of information technology that I have been describing, it has an equivalence to the book, or the record, or the film, except that instead of embodying information or events it embodies a program which can capture either a tool or expertise. By expertise in this sense

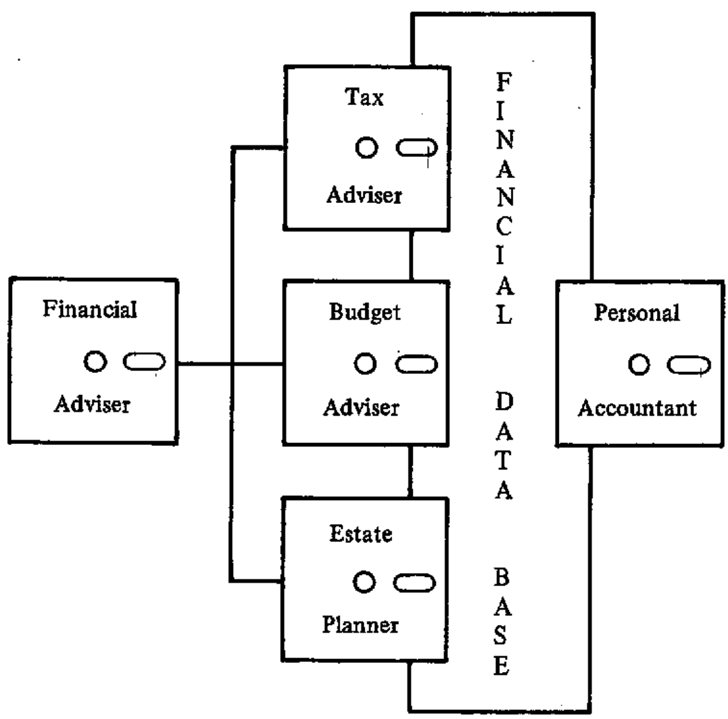
Figure 2: Hypertext: Typical Conceptual Outline



I mean a personal talent which embodies experience, knowledge, judgment and inference ability which has ordinarily been tied to the individual. But if a program is written to be used by an individual such as a tax accountant or tax adviser who has a personal financial database to scan that database and make judgments about tax liability, that program embodies expertise. We frequently hear about expert programs which embody the expertise of a chemist, a geologist, a computer designer in programs which will carry out a proportion of their functions. This is just the cutting edge of a phenomenon which we shall see increasingly as the decade passes. Portable expertise, then, comprises programs embodying expertise, programs that can now be replicated for thousands of millions of uses and transferred in space and time, that can be refined and extended. Suppose I am another tax accountant who sees the program produced by my competitor or colleague, and having examined it I realize that it can be improved and refined: I can quickly put out a new competing program, which in the market place will either capture more or fewer users depending on its efficiency. The point is that it is now possible to express expertise in a concrete way: it is no longer embodied simply in the mind but in a portable and saleable form that can be refined, extended and, most importantly, embodied in other programs. Expertise therefore can be cumulated. Just as the book made possible the cumulation of information, the floppy disc offers the possibility for cumulation of and building upon expertise.

Figure 3 shows schematically a personal financial database with a floppy disc built by a tax adviser, a second one built by a budget adviser and a third by an estate planner, each being used to examine the data entered by an individual concerning his financial situation. These could then be combined with the expertise of an overall financial adviser in a larger program embodying a series of separate steps. I have particularly chosen a mundane example because it is

Figure 3: Cumulative Expertise



something familiar to all of us, but what is possible here, the cumulation of expertise in the form of transportable programs, applies as well to our own fields of engineering or to any of the specialized technologies. This is not to say that each of us will be replaced by floppy discs, but rather that we shall be able to build our technology, build our competence, on the basis of embodied knowledge from colleagues—both current and past.

Finally, let me refer to the major social and cultural effects that these technologies may open to us. In general I have taken a rather positive view of the potential of information technology for society. It can lead to a greater democratization in the sense that it will further broaden our access to information, but also to intelligence and expertise. It will increase, as it can increase, individualization in the sense that it can enhance an individual's control of his access to information, intelligence and expertise. At the same time there will be a tendency to increase specialization, since by enabling expertise to be captured it enables the further refinement of that expertise to occur more rapidly. This can be both a positive and a negative consequence. There will be a greater diversity in that the new communications technologies offer an opportunity for the increased formation of special interest groups. For example, the internal network of the Xerox Corporation has not only business special interest groups but people around the world who communicate with each other on books, films, wine, food, sports and other subjects. They would never have been able to communicate and form these special interest groups so readily before this technology. The negative side of course is that the development of special interest groups enhances the tendency in our societies toward more refined social divisions. The final fear we all have is that technology will substitute for that aspect of our culture which all of us value most highly, the opportunity for human contacts in meetings such as this. I do not look forward to the years when we shall have to meet via electronic communication and our electronic windows on the world. There are still humane and human aspects of society which none of us hopes will be replaced by these new technologies.

3.5 Some Consequences of Tomorrow's Electronics CAD Systems

Harold W Lawson Jr, Head, Computer Architecture Laboratory, Linköping University, Sweden

Introduction

The availability of highly integrated circuit technology producing circuits flexibly via mask patterns has opened new dimensions, new problems and new possibilities for the future. Silicon foundries are in operation that produce electronics and computer systems hardware on order based upon circuit mask descriptions. Thus we can expect a softening of the hardware, i.e. the possibility of translating higher level hardware descriptions into circuits and systems in a manner similar to the translation 'compilation' of higher level programming languages.

One can speculate that companies (foundries) well equipped with automated circuit production facilities may in the next 5-10 years accept descriptions of processors, memories, communication facilities (even entire systems) and automatically produce the hardware to order. Consider that today Fujitsu, via highly automated electronic production facilities, produce their own series FACOM, plus Amdahl, Siemens and ICL medium and large scale systems on order. One can further speculate that for systems in which digital computer systems are embedded the description may well include the application algorithmic or 'programs', and that the embedded computer architecture is optimized in some manner by the translation process.

The key to realizing these possibilities lies in the availability of a new generation of computer aided design tools. New methodologies and techniques are being developed that simplify design and development, including the verification of the correctness of system behaviour. It is clear that in order to realize tomorrow's advanced systems we must first make an all-out attack on the complexity of current computer system structures. These advances must then be incorporated into the design of tomorrow's CAD systems.

In this paper we shall consider several aspects of current research and development activities related to providing such systems and some of the probable consequences of their availability. Some of these activities are being pursued at the LSI Design Centre of Linköpings University in co-operation with the Institute of Information Science and the Department of Electrical Engineering at Keio University in Yokohama, Japan,* but one can find counterparts to several of the activities as well as complementary efforts at several research and development establishments around the world. Future CAD systems are the object of intensive research and development.

Eco-Technology in Digital Electronic System Design

Aida** points out that in much of modern scientific and technological development, nature ('the natural order of things') has been regarded as an opponent to be conquered rather than an asset to be utilized. This tendency is highly visible in digital electronic system design and is one of the primary sources of complexity.

Time is of course an essential and ever-present aspect of our natural surroundings. The battle to conquer time introduces complexity into many digital electronic systems. Time is divided into clock periods of nanosecond or even picosecond resolution. Designers of the digital system then try to accommodate as many parallel activities inside each clock period as possible. The set of parallel activities to be accomplished in a single clock period are selected by the designer and placed as timing requirements upon the digital logic implementers of the system. If the members of the set of parallel activities are highly heterogeneous, the implementation may then require twisting and bending, moaning and groaning, sleepless nights, trial and error, etc. to get all parallel logic paths to meet the stringent timing requirements. We shall refer to this form of parallelism as unnatural parallelism, i.e. man-made parallelism. This author has experienced several digital electronic systems in which after the tedious efforts put into achieving this man-made parallelism, the users (normally microprogrammers) had so much difficulty understanding the heterogeneous activities of the system that much of the potential parallelism was never exploited.

In digital electronics jargon we refer to the above design strategy as synchronous control, where the set of activities is started and terminated solely in relationship to the clock pulses. Synchronous control can however be utilized as a natural parallelism realization when the system being designed is composed of homogeneous activities or naturally partitioned sets of homogeneous activities that require approximately the same amount of time per activity or per set.

* Lawson Jr, H W, 'Tools for Tomorrow's Integrated Hardware/Software Development', *Proceedings of NordDATA 83,* Oslo, Norway, 1983.

** *The Humane Uses of Human Ideas: Discoveries Project and Eco-Technology,* Pergamon Press, 1983.

The biggest mistake is then for the designer to take a problem heterogeneous by nature and map it unnaturally into a synchronous control structure.

It is possible to design highly efficient digital electronic systems that contain many heterogeneous activities without resorting to man-made parallelism design manipulations. The set of activities can be independently organized to determine their own starting and terminating points in relationship to the other members of the set, without the stress of completing their activities in strict relationship to clock pulses. The activities, once started, take as much time as they need and signal their own termination. The activities interact in a natural manner, much as molecules interact in nature. This design strategy is called asynchronous control and is also based upon natural parallelism in which those activities that can naturally be executed in parallel are executed in parallel. During their execution they are entirely independent of one another.

Many current problems in computer architecture are related to these fundamental and important timing issues. This author believes that the natural parallelism alternative, which is very interestingly related to the eco-technology principles laid down by Aida is to be preferred. The nature of the problem should determine if synchronous or asynchronous natural parallelism is attainable. Complex man-made mappings are to be avoided. The possibilities of using natural parallelism in digital computer system design are further discussed by Lawson.* With the flexibility now afforded by integrated circuit fabrication, our future CAD systems should provide the vehicle for experimenting with and developing digital electronic systems that work in closer harmony using, for example, the principles of eco-technology.

CAD as a Tool for Realizing Creativity

It is unquestionable, from this author's point of view, that the availability of tomorrow's CAD system will be a dominating factor in the competitive race to provide tomorrow's electronic components and systems. A large part of the 'know-how' and creative ideas of individuals and groups will be collected into and realized via these high-level design tools. It is therefore evident that the availability of the tools will be of strategic corporate, national and international importance.

In order to achieve the maximal benefits of tomorrow's CAD systems, we must be willing to question the intra- and inter-level man-made partitioning in the hierarchy of digital computer system hardwares and softwares. The CAD system should permit experimentation and the evaluation of different architectural partitionings. Further expert systems, an integral part of the CAD system, should provide advice on selecting design alternatives. Knowledge about natural solutions as opposed to unnatural man-made solutions should

* Lawson Jr, H W, 'New Directions for Micro- and System Architectures in the 1980s', *Proceedings of National Computer Conference,* Chicago, Illinois, 1981.

about natural solutions as opposed to unnatural man-made solutions should become integrated into the CAD expert system. To achieve this goal we must have design philosophies and strategies as well as suitable means of concretely representing design details and parameters. These issues will be addressed in subsequent sections of this paper.

Using Eco-Technological Principles to Stimulate Creativity

What type of digital electronic systems shall we build using tomorrow's CAD systems? Where shall we get our ideas? These are quite important issues whose solution will be highly dependent upon our creative thinking and problem-solving methods. In order to achieve systems that use nature as an asset, we can appropriately apply the concept of design by analogy: we design the algorithms 'programs' and hardware of the computer system by analogy with natural systems. A thought in this direction is proposed by Carver Mead and Lynn Conway who have been instrumental in spreading VLSI technology.* 'Human organizations, like computer organizations, suffer if communication costs are high or if concurrent processing cannot be exploited. In fact, a human brings to an organization what VLSI brings to a circuit: both combine processing and memory effortlessly. Analogies with human structure may help to suggest the kinds of behaviour we might achieve in computational structures.'

The notion of using analogies as stimuli to creative activities is of course not new. Gordon** describes the application of analogies to creative processes which he has termed synectics. Gordon presents the following basic analogy forms:

Personal Analogy

Personal identification with the elements of a problem releases the individual from viewing the problem in terms of its previously analysed elements.

The creative technical person can think himself a dancing molecule, discarding the detachment of the expert and throwing himself into the activity of the elements involved. He becomes one of the molecules. He permits himself to be pushed and pulled by the molecule forces. He remains a human being but acts as though he were a molecule. For the moment the rigid formulas do not govern, and he feels what happens to a molecule. This analogy can readily be applied to the structure of an electronic circuit or the architecture of a computer.

* Mead, C and Conway, L, *Introduction to VLSI Systems.* Addison-Wesley Publishing Company, Reading, Mass, 1980.

** Gordon, W J J, *Synectics.* Harper & Row, New York, 1961.

Direct Analogy

This mechanism describes the actual comparison of parallel facts, knowledge or technology. The strained comparison of a scientific observation in one field with that in another field tends to force an expression of a problem in a new way.

The practitioners of synectics have observed after many years of experience that the richest source of direct analogy is biology. This is because biology lacks mystical terminology and the organic aspect of biology brings out analogies which breathe life into problems that are stiff and rigidly quantitative.

Symbolic Analogy

This mechanism uses objective and impersonal images to describe the problem. The individual summons up an image which, though technically inaccurate, is aesthetically satisfying. It is a compressed description of the function or elements of the problem as the person views it. Symbolic analogy tends to impart to familiar objects and concepts more useful strangeness than either personal or direct analogy.

Fantasy Analogy

When a problem is presented to the mind it is useful to imagine the best of all possible worlds, a helpful universe permitting the most satisfying possible viewpoint leading to the most elegant of all possible solutions. This mechanism has operated in the subconscious because the rational character of man denies himself and the world the vision of that part of himself which is other than proudly coherent.

Play with analogies, an integral part of the synectics methodology, covers a scale with an endless variety of levels, ranging from what is apparent to the popular mind to that which is known only to the expert. Unfortunately the trained expert frequently tends to be super-rational and feels threatened by any thinking which attacks his logical universe. This attitude makes breakthrough impossible.

The use of these analogies, particularly personal analogy and direct analogy, is in close alignment with eco-technological principles and they can be utilized as guiding methods for technological developments in the digital electronics area as well as in virtually all scientific and engineering endeavours.

It is asking quite a bit of tomorrow's CAD systems to assist directly in providing analogies of the personal, direct, symbolic and fantasy types other than possibly in database catalogue form. Creativity, which remains in the human domain, should be accomplished prior to committing the digital electronic system design to the CAD system. On a more concrete plan, however, it is quite conceivable, even probable, that expert systems will be used to compare ongoing design with previous designs stored in the database and enlighten the CAD users of analogous solutions.

In order to approach the design of electronic systems we need to begin with an appropriate abstraction philosophy and strategies for realizing our designs. We now consider a feasible approach to these matters.

Base Logic and Programmed Logic Philosophy

A necessary condition for achieving tomorrow's unified CAD system is the development of a common view of the architectural ingredients of a system. We should not think of classical design levels of hardware, microprograms, machine language, assembly language and programming languages as separate domains. We need an 'integrated' point of view. Consequently, base logic is defined as nonrefinable digital (atomic) activities not internally controlled by programmed logic. Base logic normally corresponds to a combinational circuit in classical digital logic terms. Everything above this level falls into the category of programmed logic, i.e. logic that activates the atomic base logic at appropriate points in time in order to achieve the desired computational results. While a hierarchy of programmed logic may well be necessary for defining a structured computation engine, the development methodology, language structure, etc. must provide, at their highest level of abstraction, the essence of architecture and algorithm structure instead of machine details.

Processes and Processors as a Partitioning Strategy

In order to provide a common logic partitioning strategy, both within an architectural level and between architectural levels in a hierarchy, we introduce processes as a useful abstraction. The process can have one or more inputs and produce one or more outputs. The transformation(s) performed by the process are either base logic or programmed logic algorithms recognized in their concrete form by a processor. In the case of base logic the processor is obviously the underlying atomic electronic circuitry. For programmed logic the processor is some process or set of co-operating processes in base logic at the lowest level or lower level programmed logic which interprets the concrete representation of the algorithms (program instructions) of the higher level.

These abstractions, useful in explaining today's computer systems even to the neophyte, are illustrated by the analogies provided in Figures 4 to 7. Figure 4 illustrates a relationship between a physical process, an abstraction description of the process and the processor where the human places him or herself in the role of a processor; namely, as the interpreter of the process algorithm (washing dishes in this case). This same concept, that it is the combination of the process-

Figure 4:

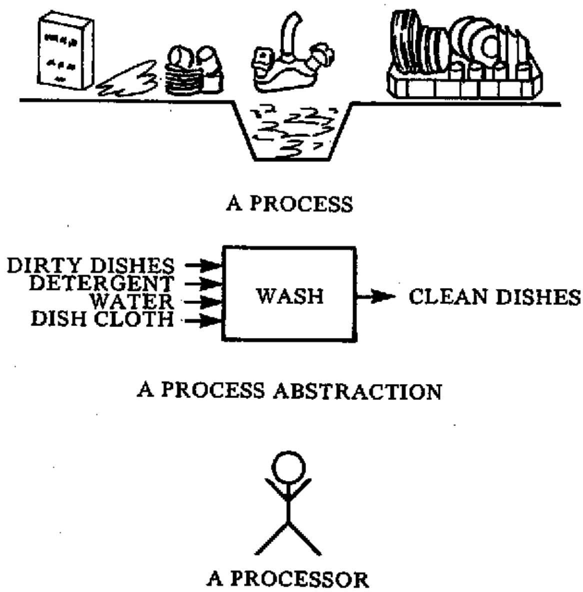
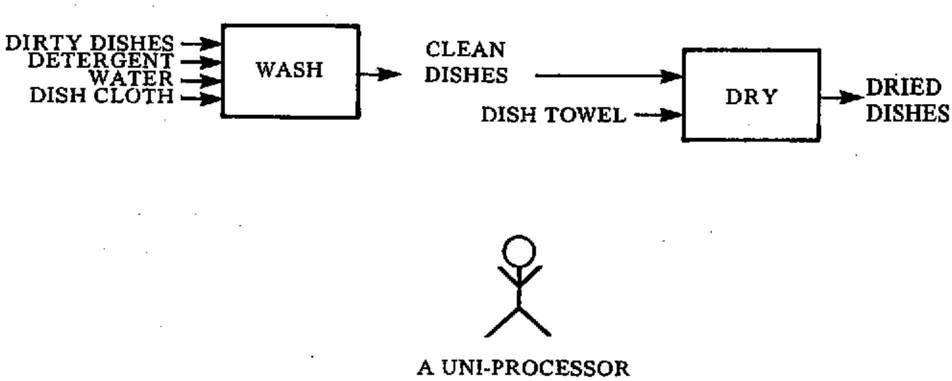


Figure 5:



processor that permits the execution of a process, is central to the concepts of computer architecture. Note the synectics personal analogy approach. In Figures 5 and 6 we see the coupling of a system of co-operating processes served by either a single (uni-) processor or by a processor-per-process (multi-processor). The implications have their direct counterparts in computer system design. In Figure 7 the idea of nesting collections of co-operating processes (realized by processor-memory pairs) to build a central processing unit is captured in terms of some existing classical computer system levels. The processes realized via each processor-memory pair define a new higher level processor architecture. The target system level corresponds to what is normally termed 'machine language'. In the future one should challenge these partitionings and the level of 'languages' supported (interpreted) at each level of the system, thus finding appropriate natural boundaries relevant for the system being constructed. In this case, synectics direct analogies may well be useful. The CAD system must assist in proving ideas in this structuring via multi-level simulation with understandable presentations of simulated results.

Languages and Concrete Representations of Abstractions

While it is desirable for design purposes to deal in terms of abstractions, we need to have concrete representations in order to realize products. Thus we utilize concrete languages for describing our abstractions. Textual representations (for programmed logic and in some cases base logic encodings) in linear textual format are given to translators which synthesize the language into another concrete form recognizable by a processor.

Logic expressed in linear text, while quite processable by translators (compilers), is not very 'processable' by us humans. We need to find common forms that are processable both by humans and by computerized translator processes where the semantics can easily be extracted by both, thus minimizing the misunderstandings that result in costly errors. These common language forms will undoubtedly be graphic oriented.

For base logic many CAD systems currently utilize graphic methods in developing circuit cell descriptions destined for cataloguing in cell libraries. Graphic based circuit layout programs are available for connecting primitive cells into larger super cells for creating appropriate base logic level processors. The activities at Linköpings LSI Design Centre in this area are described by Pääbo and Siemienski.*

For algorithm descriptions of programmed logic, a potential common graphic representation form based upon dimensional flowchart ideas first introduced

* Pääbo, M and Siemienski, P, 'A VLSI Toolbox', *Proceedings of NordDATA 83,* Oslo, Norway, June 1983.

by Witty* may be possible. We have found that these methods can be applied by procedural algorithm development at any level of programmed logic. This is true since dimensional flowcharts are based upon a canonical graphic form for algorithm conditional predicate logic structure and unconditional processing logic. These primitives are common denominators for the realization of control structures at all programmed logic levels. The activities at Linköpings LSI Design Centre in this area are described by Jönsson and Patel.**

The concrete representation of processes and systems of co-operating processes can also be realized graphically. The graphic 'icons' represent the elements of an architectural language interconnected by wires, channels, busses, cables, satellites, etc. depending upon the contextual level of the architecture described. Further, synthesis from the graphic representations to an executable simulator model is also possible. Very little new algorithm 'program' development may be necessary if available model symbols are stored in a database and extracted to compose the simulator. This form of design tool will require less detail-oriented competence on the part of the users. The activities at Linköpings LSI Design Centre and at Keio University in Yokohama are described by Yamamoto and Lenngren.***

Some interesting highly related work, although not yet graphically oriented, is the MacPitts Design Language described by Siskind *et al***** in a paper entitled 'Generating Custom High Performance VLSI Designs from Succinct Algorithmic Descriptions'. It is worthwhile noting that this language is named after McCulloch and Pitts, the originators of the study of neurological systems from a mathematical and logical standpoint.

The Availability of New Media and Tools

It seems clear that suitable new tools for graphics will be available in 5-10 years' time. High resolution graphics are available today for use in graphic animation in the movie-making and TV industries. This equipment is of course quite expensive. However, we expect that by 1985 reasonably priced graphics

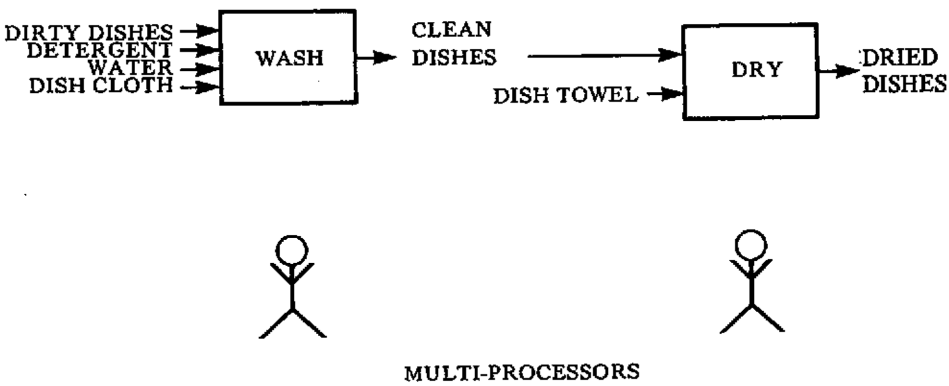
* Witty, R W , 'Dimensional Flowcharting', *Software Practice and Experience,* Vol 7, 1977.

** Jönsson, A and Patel, M, 'Graphic Algorithm Description and Program Development', *Proceedings of NordDATA 83,* Oslo, Norway, June 1983.

*** Yamamoto, Y and Lenngren, M, 'GMBS Graphic Model Building System', *Proceedings of NordDATA 83,* Oslo, Norway, June 1983.

****Siskind, J M, Southard, J R, and Crouch, K W, 'Generating Custom High Performance VLSI Designs from Succinct Algorithmic Descriptions', *Conference on Advanced Research in VLSI,* Massachusetts Institute of Technology, 1982.

Figure 6:



equipment will be available that provides at least 2048 x 2048 colour pixel resolution with vector drawing speeds of 200K vectors per second. This would be quite sufficient for high quality interactive graphics and animation. This animation of architectural structures and algorithmic programmed logic in their concrete graphic form should be achievable.

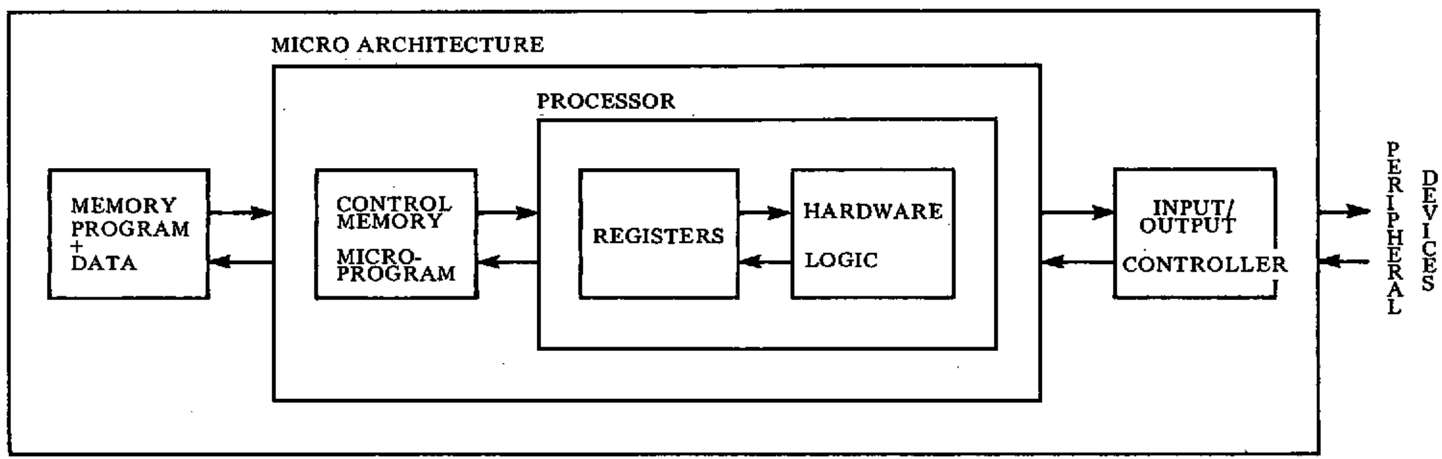
We can also expect that video wall size projection from the graphic systems will be commonly available by late 1985, thus providing the possibility of improving human-to-human communications about design and implementation of computer and electronic systems. Our fantasy is the only limiting factor in appropriately exploiting these new possibilities. Later in the 1980s one can even expect that reasonably priced directly addressable flat panel displays of meter sized formats will be available. The availability of pixel memory to support such displays is already assured by very high density integrated circuit memories.

In addition to the graphic facilities we can expect support for video disk technology, providing large capacity storage for data, program representations and pictures required for making practical use of our new CAD tools. Large format colour graphic hardcopy units are available today and their prices should be reduced during the next few years. We can also expect improved voice input and output equipment to become available.

Many of these new technologies have already been used in experimentation in the form of a media room at the Massachusetts Institute of Technology School of Architecture.* Thus we can expect that a media room will be an essential

* '"Put-That-There": Voice and Gesture of the Graphics Interface', *ACM SIGGRAPH Proceedings*, July 1980.

Figure 7: Architecture of the Target System



resource for tomorrow's CAD system. The preliminary activities at Linköpings University, primarily concentrated around graphic facilities, are described by Peterson.*

Group-Machine Communication

In contrast to the MIT media room concept, intended primarily for single users, we can speculate that media room will be available for small groups of 2 to 6 active users. Thus we have defined a new type of communication which we shall call group-machine communication.

This type of communication is directly aimed at improving one of the most difficult and costly problems in the computer and electronics field: human-to-human communication about system design and implementation. Group-machine communication is aimed at improving design and development by providing interactive tools for working together on a project where observation and constructive criticism are the main catalysts for improvement and are also important ingredients in system verification. That a superior form of education and training becomes available should be quite obvious.

Our preliminary utilization of graphic methods for architectural and algorithmic structures has led us to an interesting observation in respect of the fact that we have been working in a mixed natural language environment (English, Swedish and Japanese). These graphic-based methods provide a vehicle by which people who speak a variety of native natural languages can communicate their ideas to one another more effectively. Large detailed specification and operational manuals written in quasi-standard natural languages such as English are subject to misinterpretation; whereas individuals can make their own interpretations (normally consistent with one another) from graphic representations. Thus group-machine communication using advanced media takes on an international flavour.

Educational Consequences

New media, new philosophies and strategies, while helping in attacking the complexities of design and implementation, will also provide improved communication in education and training. However, we must develop consistent educational and training strategies. Our educational activities, particularly in the computer area, have suffered from being too detailed and have prohibited students from obtaining holistic views.

* Peterson, T, 'Graphics for VAX', *Proceedings of NordDATA 83,* Oslo, Norway, June 1983.

Experimentation with the analogy approach and the use of process and processor partitioning strategy have led to an introductory text* which provides a holistic view right from the beginning of computer-related education. In this text the beginner is exposed to concepts and terminology related to all levels of relevant hardware and software and is thus freed from details. Figures 4 to 7, described earlier, are taken from this book. Notice that this is in direct contrast to many highly popular course introductions to computer systems which at an early stage introduce the details of a programming language and let the student swim in a sea of seemingly unrelated details. Students should learn details, for example the syntax and semantics of a programming language, only after principles and appropriate contextual frameworks have been established. It is important that this change of educational direction receives worldwide attention; thus this book is now available in Swedish as *Att Förstå Datorsystem* and in a Spanish version entitled *Hacia la Comprension de la Informatica.* During 1983 it will also be available in Finnish, German, Dutch, French and Japanese. However, this is only the beginning. In this author's opinion a new strategy for education in the computer area is required.** This new strategy is required to gain maximum effect from the utilization of the new CAD tools for realizing creative design.

* Lawson Jr, H W, *Understanding Computer Systems.* Computer Science Press, Rockville, Maryland, 1979.

** Lawson Jr, H W, 'An Architecture Based Strategy for Improving Computer Education', *MICROSYSTEMS: Architecture, Integration and Use, North-Holland Publishing Company, 1982.*

Chapter Four

TECHNOLOGY AND CULTURES IN DEVELOPING COUNTRIES

Chairman: The Rt Hon The Lord Nelson of Stafford FEng

Editor's Summary

The title of the fourth session of MANTECH was 'Technology and Cultures in Developing Countries'.

It can of course be argued that all countries fall into this category, the only differences being in the stage of their development. However, this session of the Symposium was principally concerned with countries where development was still enjoying comparative infancy, being therefore usually accompanied by a higher rate of growth than in the Advanced Industrial Countries (AICs).

The session began with an address by HE Sheikh Yamani,[51] Minister of Petroleum and Mineral Resources in Saudi Arabia, who gave an account of the rapid rise of his country to 'semi-industrial' status, and of the great investments in both money and effort which had brought this about. This was certainly a salutary exercise after the previous sessions devoted to technologies that were not simply modern but ultra-modern—or even, as in the last paper of the previous session, still to come.

Sheikh Yamani described in detail how Saudi Arabia, since the end of World War II, had installed a great amount of new industrial plant—much of course connected with the country's oil-producing industry—and had at the same time pursued a programme of labour training in farmland creation and improvement by irrigation, fertilization and the use of plant-protecting agents. Combined with high-fertility seeds, this had produced a significant improvement in land productivity for a comparatively modest financial investment.

Other developing countries, said the Sheikh, were pursuing similar programmes, though not always with the same success, but the important message for MANTECH was that these countries' needs, while elementary in terms of today's technologies, were often desperate, involving such fundamentals as water and sanitation, elementary housing and heating, and at least some mechanized transport. Often the countries had great mineral or agricultural wealth, but could not exploit it for lack of capital investment. He recognized that Saudi Arabia had achieved her great advances because in fact she had been able to exploit her oil—the cheapest still-abundant source in the world. 'Under a free trade system,' he said, 'this should be utilized for furthering world trade efficiencies, based on the principle of efficient allocation.' 'Our oil policy in Saudi Arabia,' he continued, 'is geared to furthering this principle and the principle that the best means of securing a steady flow of imports is through a steady rise in exports on a competitive basis.' This Saudi Arabia had certainly achieved, in many cases despite artificial tax barriers applied to reduce customer demand for oil. If Sheikh Yamani was somewhat critical of these barriers, it might not have been inappropriate to examine their origins.

The next speaker was Dr Surendra J Patel, Director of the Technology Division of the United Nations Conference on Trade and Development (UNCTAD) and, in his own earlier words (see page 81), representative of 'the wretched in the Third World'. His concern was not for the successful, indigenously rich countries such as that of Sheikh Yamani, nor for the prosperous newly industrialized countries (NICs) such as South Korea, Hong Kong, Taiwan or Singapore, but rather for the struggling part of the southern sector in what has come to be known as the North-South division, after the 1980 report of the Brandt Commission on International Development Issues.[52] Dr Patel pointed out that many of these underprivileged countries had in the past contributed massively—particularly through the supply of raw materials—to the present wealth of 'the North', and it was entirely reasonable that they should now look to those past beneficiaries for investment and other help. All Third World countries were of course making unprecedented efforts to help themselves, and some were beginning to succeed; thus the Third World was gradually achieving its rightful place alongside its hitherto dominant 'northern' neighbours.[53]

But none of this progress had been, or was, easy. Most was dependent on the acquisition of modern technology, often at very great cost, by purchase or through 'leasing under feudal conditions... some so archaic that when they are made public it causes embarrassment for those who impose such conditions'.

'In the world of my dreams,' said Dr Patel, 'I like to think of technology as a common heritage of mankind... available for the service of all people everywhere.' Although this remark prompted a rejoinder from the floor asking whether the speaker would like to see, for example, the world's oil resources similarly treated, there was no doubt that he had put before his audience a statement and a plea of the utmost importance. This was not the first time that a representative of the Third World had brought a DISCOVERIES meeting back from technological fantasies to the realities of millions suffering from malnutrition or worse in countries where 'those who could, went: those who could not, starved at home'—and that applied particularly to scientists and engineers.

Discussion

The discussion which now followed was opened with a comment from a representative of the Rome-based 'February '74 Research and Documentation

Centre', one of the several Italian institutions concerned with practical impacts of technological development on society and culture. Dr Annalisa Cicerchia, a social scientist, had in fact prepared a paper entitled 'Remarks on the Socio-Cultural Effects of Western Technology in Non-Western Cultures', and her spoken remarks were in the nature of an introductory summary.[54] These remarks concerned three examples of cultural stress engendered by the penetration of 'Western' technological ideas into 'traditional' communities, albeit communities already aware of–and to some extent already benefiting from–the new technologies in action.

The examples presented by Dr Cicerchia were the displacement of Nubian communities from parts of the Nile Valley which were flooded, following construction of the Aswan High Dam, to form Lake Nasser; the profound effects of 'Western ideas' introduced, through modern mass communications (radio, television, film and video players), into the previously 'closed culture' of the Ibadite community in the M'Zab region of the Algerian Sahara; and the substantial benefits but also severe problems which modern technological developments had brought to the Navajo Indians–original natives of what are now the south-western states of the USA.

Since the details of these examples are in Dr Cicerchia's paper, they will not be repeated here. Suffice it to cite her president's affirmation that 'the social and cultural challenge of modern technology is not only a challenge to our operative creativity, but above all a challenge to know seriously who (or what) is man'. No educated person could disagree: few could suggest how this desirable goal might be achieved.

Returning to discussion more directly related to the two preceding 'keynote addresses', Professor John F Coales (Cambridge University) wished to follow up some remarks of Dr Patel concerning the needs of developing countries for qualified engineers to enable them to benefit fully from the advanced technology now becoming available to them. Professor Coales had calculated some years previously that growth in these countries was less likely to be limited by lack of energy supplies than by lack of engineers and technicians.

The professor reported on the work of the Commonwealth Board for Engineering Education and Training (CBEET) which had been studying this question over the past five years. One of the conclusions reached was that if the LDCs were to achieve, in the twenty-first century, standards of living even one-third as high as those of the developed countries, eight per cent of their populations would have to be employed in productive industries by the start of that century. Furthermore, of this eight per cent one-thirtieth, or approximately three per thousand of the total population, would need to be qualified engineers and technologists, and at least 12 per thousand would need to be technicians.

To attain these figures enormously increased facilities for the education and training of engineers in the LDCs would be required. Only India already had, and Nigeria had plans for, the necessary training facilities to produce these sorts of numbers of engineering and science graduates. India was currently producing about half the numbers required to meet her needs in the year 2000, and no other LDC in the Commonwealth was producing even a quarter of the numbers required. The shortfall in training technicians was in most LDCs even more serious.

An expansion of the education and training facilities to their required magnitudes, continued Professor Coales, was far beyond the capabilities of most LDCs in relation to both the capital investment and to the qualified teaching staff needed, unless more efficient and cost-effective methods of teaching and training could be developed. 'With this in mind,' he said, 'we have proposed to the Commonwealth Foundation a plan for the use of programmed learning and case studies in engineering courses in the universities, polytechnics and technical colleges of the Commonwealth LDCs; and we have prepared, at the request of the foundation, a comprehensive plan for introducing programmed learning courses and case studies in those institutions which wish to avail themselves of the material.[55]

The professor gave the estimated cost of bringing the plan to fruition as approximately five million pounds. 'But,' he concluded, 'even if only about one-tenth of the educational institutions in Commonwealth LDCs participate, the net savings over ten years will exceed £500 million. Not a bad return on capital invested!'

Commenting on this, Sheikh Yamani said the problems of technological training in his country were very much as described by Professor Coales, but he was sure they would be resolved. Saudi Arabia was now equipped with several universities one of which—the University of Petroleum and Minerals—included a number of schools of engineering science and applied engineering. In addition every industrial plant in the country had its own training centre, and was also sending students for studies abroad.

Replying to a question posed by Mr M Ruhemann, who had wondered how Saudi Arabia would continue to finance her industrial and other development programmes 'when the oil ran out', Sheikh Yamani declared himself unconcerned about this. His worries, he said, were more related to world industry as a whole and its future needs for oil, both for power generation and for chemical feedstocks. Saudi Arabia would be the last producer of oil on earth: new reserves were still being discovered in both existing and new fields, and 'huge quantities' were as yet untapped.

These reserves were being safeguarded for the benefit of the world, and there was no doubt that they would be adequate to finance all Saudi-Arabian industrial programmes well beyond the time when other countries (producers and consumers) would have exhausted their own or any alternative supplies.

Finally, referring to Dr Patel's dream of technology as a common heritage of mankind, Sheikh Yamani insisted that, for and in his country, technology was bought and sold—not leased whether under feudal conditions or otherwise. 'We are talking about a sale of technology and not a lease of technology,' he said, 'just as we are talking about a sale of oil and not a lease of oil.'

Very few if any of those present could have been unaware of this.

The next contribution was from Mr Barry M Grime, Director of English Clays Lovering Pochin & Company, whose paper 'The Potential for National Resources with Reference to International Trade' comprised a masterly guide to using resources of energy, minerals, certain other products and—a resource not always regarded as such—people.[56] However, the people mainly referred to were not the large potential workforces but rather, at least in the developing countries, those exceptional few with higher educational qualifications.

Mr Grime's paper was largely a record of personal experience in world trading and development, and as such it was particularly interesting that he could not envisage success for popularly advocated 'zero-growth' policies so long as world population was still rising (still exponentially) or even so long as some three-quarters of the existing population remained severely undernourished. Greater efficiencies in the use of raw materials and all natural resources were certainly to be pursued, and Mr Grime offered various suggestions. He also cited some of the immediate disadvantages—for example for developing countries wishing to increase exploitation of their mineral reserves as encashable resources—which could easily lead to the 'bandwagon effect' of world surpluses.

Yet 'doing more with less' was clearly an essential element in long-term survival for the global village: it was specially encouraging for those to whom DISCOVERIES means concrete efforts towards a better, more united world community to hear Mr Grime describe that village as 'Spaceship World'.

The last paper in this session was from Professor Brian May, Dean of the Faculty of Agricultural Engineering, Food Production and Rural Land Use at the Cranfield Institute of Technology. Entitled 'Effective Use of Agricultural Technology in the Developing Countries', his paper[57] was perhaps the most practically oriented of the entire Symposium towards helping people in the field to improve crop yields and animal production, and helping research and development institutions towards greater support for such field activities. Like Mr Grime before him, he began from the premise of a world population greater than six billion (10^9) in the year 2000, the nourishment of which would require at least 'an agricultural output some 50-60 per cent greater than in 1980'. (Zero-growth theorists again please note!) Professor May listed four main ways in which the additional output could be realized:

—increasing the arable area
—raising the proportion of that area harvested each year
—increasing the yields from each unit harvested by intensive production
—raising the proportion of harvested crops actually reaching the consumer (notably by improved methods of preservation during storage).

The professor stressed the great importance of good land management, including well-planned tenure arrangements to avoid over-division into parcels too small for efficient production. Optimum yields also required correct 'inputs', from water and fertilizers to improved seeds, crop protection and mechanization (the most important input being fresh water). He pointed out that fertilizers were estimated to have been responsible for 'more than half the increase in yields in developing countries between 1965 and 1976', and he had some highly significant practical comments on the use of pesticides.[58] Turning to relationships between livestock and crop production, Professor May believed that, especially in developing countries, both could benefit from closer integration than commonly existed.

Lastly, concerning energy, the professor remarked that 'Agriculture is comparatively a very modest user of commercial energy', but that 'if it should come to allocating scarce energy supplies, then agriculture must have one of the highest priorities'. There were many who would have maintained that it should have the highest priority of all.

Discussion

The discussion of these last two papers of the session, with not infrequent references to earlier contributions, began with some thought-provoking remarks from Mr Glyn England, former Chairman of the Central Electricity Generating Board (UK). In view of the difficulties which that and other electricity authorities seemed recently to have experienced with their forward planning, it was perhaps not surprising that Mr England should call for such activities to be treated as 'technology in its own right'.[59]

His particular current concern was that readily available 'computer packages' (complex programs and the machines to run them) were encouraging those who did not—and perhaps could not—give enough attention to 'the conceptual work that ought to be associated with the planning process' to engage in that process in the belief that, provided correct 'historic data' were fed to their 'black boxes', helpful planning information would automatically come out. There was ample practical evidence that this was not so.[60]

Drawing from his own experience with electricity supply planning, Mr England said that it was easy to produce computer predictions as to amounts of new plant needed, related investment profiles, fuel requirements and use, and the consequential costs and cash flows. Moreover, by varying particular input data over a range of values, a computer system could be made to show how sensitive its outputs were to such variations, and with appropriate peripheral equipment these variations could be presented in either tabular or graphical forms (or both)—'beautiful' material for inclusion in impressive planning documents. But if all this suggested that the planner's tasks had been greatly eased, the counter-evidence was that plans frequently proved to be as inaccurate today as in the pre-computer era.

This was of course a most serious matter in electricity supply, but evidently far more serious when developing wider-based 'scenarios' for technology penetration and economic growth at international levels. The penalties for error could be enormous.

'So my concern,' concluded Mr England, 'is that having made tremendous strides in developing the tools–the mechanics of planning–we should exercise very great care to see that those mechanics do not dominate . . . that we do have this fairly broadly based rigorous thought process going alongside, an integral part of the process, not something that is quite separate. I believe that if we could manage this it would help to ensure, in both the more developed and the less developed countries, that our further development process would–in the words of our Senior Fellow–meet the perceived, practical human needs.'

What were those needs, particularly in the developing countries? Dr J C Chapman (Chapman & Dowling) reminded the meeting that it was discussing the challenge of modern technology, with the objective of deriving maximum benefit from that technology while avoiding social and cultural 'disbenefits'. Dr Chapman wondered what positive action MANTECH, with the blessing and help of the Fellowship of Engineering and perhaps other concerned organizations, might take to further that objective.

First, he believed, support should be recorded for the Brandt Reports[61] and then–recognizing the difficulties and inertias involved in bringing about official governmental actions–professional organizations and their members should examine what they themselves might initiate and/or undertake. A particularly important area was evidently that of education, not only of students in and from the LDCs (as discussed earlier by Professor Coales) but of students from the industrialized countries themselves who often had no detailed knowledge of Third World problems or of how those problems might be eased by appropriate applications of technology.

Dr Chapman thought these matters should find a specific place in advanced countries' university courses; even that some knowledge of the Third World should be made a condition of entrance to these courses. Greater efforts might also be made to encourage participation in the same courses of LDC students who ' . . . would after all be our future collaborators and customers'.

Institutions such as the Fellowship should promote and strengthen links with appropriate bodies in the LDCs, organizing joint research programmes where such seemed desirable. In this way North-South communications could be greatly improved, an essential step towards closer co-operation ' . . . at all levels, not just the top professional level'. 'We must,' he said, 'begin to think of ourselves as part of a world community in which most of our fellows are impoverished, and in poor health, because they are undernourished and lack such basic amenities as a clean and adequate water supply. We could devote the next two centuries to spreading wealth around the world.'

The challenge and the opportunity were there: the willingness to grasp both seemed general and uncontested, at least within the meeting, and the only part of Dr Chapman's declaration which might have been questioned was why 'spreading wealth around the world' should be limited to the next two centuries.

But another and clearly most important point called for discussion. It was introduced by Professor M W Thring (Queen Mary College, London University) who had seen for himself, while with a UNESCO mission in Bangladesh, the difficulties LDCs could experience in 'absorbing' the technologies of the advanced industrial countries. Large-scale central generation of electricity, for example, was unusable in a country where tens of thousands of small villages were spread over a vast area for which a gigantic 'national grid' would not only be uneconomic but technically inefficient. Such villages, said Professor Thring, needed only a 'few kilowatts from solar energy' each. (He mentioned the possibility of deriving such powers from a solar steam engine currently under development, which would also be usable for cooking rice.) The professor referred to several other developments which, he said, would be 'more appropriate than the very high energy-usage things that we have in countries like Britain'.

This remark opened the way for several interventions concerning 'intermediate technology', 'appropriate technology' and similar concepts which now attract substantial interest from groups aware of the difficulties, even disasters, which can result from over-rapid introduction of advanced technologies. As Mr G McRobie of the Intermediate Technology Group pointed out, it was frequently more satisfactory to adapt technology to 'the culture and the real conditions of the poor', rather than expecting that culture and those conditions to adapt themselves to an overspill of advanced technology from the tables of the rich.

Mr McRobie's call, in fact, was to turn from labour-saving to capital-saving, thereby simultaneously avoiding technology-created unemployment and the all too often accompanying financial collapse. The logic seemed impeccable, like that of Professor Thring, and at least one listener was beginning to think that perhaps electricity generation in huge multi-person treadmills was to be favoured after all. Fortunately Dr Patel was able to restore the correct perspective by insisting that 'intermediate' should always mean just that and never be considered as 'final'. As to appropriateness, intermediate solutions were appropriate for intermediate problems, just as preliminary solutions were appropriate for preliminary problems, advanced solutions for advanced problems and final solutions for final problems. Provided this were not forgotten, then each solution—each technology—had its place. But Dr Patel had experienced cases where an alleged need for labour-intensive technology had provided a market for selling old-type machines; when this was realized by the hoped-for customers (LDCs) the same machines were marketed under the label of intermediate technology, then as appropriate technology. 'And,' said Dr Patel, 'when it is all unmasked, then each one has been concerned with the same things—mostly improving village toilets or improving bullock carts.' He admitted that all this was necessary and invaluable, but it should not be thought that the developing countries wished to be excluded for ever from the very sophisticated technologies of their more advanced world partners.[62]

Professor Ungku Aziz (University of Malaya) had personal experience of both 'intermediate' and 'appropriate' technology, and of indigenous research and development work in his own country. He was not able to report unqualified success, and gave as an example the fact that although Malaya, as a major rubber producer, had a long-established research programme on rubber technology (currently absorbing over £10 million per year), production of a high-quality motor tyre, equivalent to those made routinely in the advanced countries, had still to be achieved. Clearly, whatever technology transfer had been effected had not been effective.[63] On the other hand Professor Aziz had examples where such transfer, completely successful from the technological viewpoint, had nevertheless failed because its financial cost had proved too great. This was especially true in the case of small farmers who had exchanged their traditional buffaloes for tractors: highly successful until an unexpected crop failure deprived them of money to buy tractor fuel. In the past their children would have taken the buffaloes regularly to graze before using them for new ploughing, an operation costing much sweat but no money. But tractor fuel had to be paid for, and that was in fact a restriction on the small farmers' liberty. The same was true of Malaysian fishermen, who had exchanged their former sailing boats for motor-driven craft, bought directly or more often hired through a government leasing system. Again, a poor haul of fish left them short of money and hence of fuel.

In fact, said the professor, they were demonstrating the basic dependence of the 'technological revolution' on energy—whether for straightforward uses as in tractors or fishing boats, or in the more complex chains of advanced fertilizer production and application, irrigation by pumped water, or product conservation and marketing after production.

'In the developing countries,' concluded Professor Aziz, '... the technologists and the engineers bring the message that using this chemical or that process will solve our problems. But they take no cognisance of landlords, moneylenders and monopolistic marketing systems.'

This prompted Professor May to remark that problems of finance and energy, though clearly no less important in agriculture than in other sectors, were not basically due to the introduction of new (and extremely valuable) technologies, but resulted from structural anomalies and difficulties in society as a whole, largely due to political and economic policies. Such difficulties should not be allowed to conceal or detract from the very real benefits that the new technologies, *per se*, undoubtedly offered.

The discussion ended with a return to what many—perhaps most—of those present regarded as the fundamental problem of the LDCs in responding to the challenges of new technologies, namely the production of more scientists, engineers and technicians. Evidently this was a task in which the developed countries must continue to play a leading part, and since the Symposium was taking place in Britain there was particular reference to the role of British universities and professional institutions.

Several speakers added emphasis to earlier remarks calling for greater involvement with and exchange of LDC experience in British technological education, and for the latter's more direct association with the solution of 'real problems of the day' in those countries. The clear message was that technological training should never be considered an end in itself but as a powerful and essential means towards prosperity and hence stability in countries so long denied those advantages.

In this connection there was considerable concern over the cost of British education to students from the LDCs (indeed from all overseas countries). Professors Gordon Wray and J Swithenbank were only two of those who, while recognizing that the university education they and their colleagues provided was a very saleable commodity, were in favour of official subsidies to facilitate its export. Both were perturbed over recent decisions to charge overseas students in Britain 'so-called full-cost fees'.

Dr Patel was in full agreement. Noting that he spoke from personal experience, for his own son was studying in Britain, he provided a fitting epithet not only for the conclusion of this session but perhaps for the MANTECH Symposium as a whole.

'There is no better way,' he said, 'not only of closing the technological gap [between advanced and developing countries] but of bringing people together to break the mythology of how different we are. This is the way people are brought together, the myths are broken, and we create a band of brothers. I hope that with the powerful support of the Fellowship some further steps can be taken in this matter of tuition.'

EDITOR'S NOTES

51 For the full text see page 150.

52 *North-South: a Programme for Survival.* Report of the Independent Commission on International Development Issues, under the chairmanship of Willy Brandt. Published for the Commission by Pan Books, London, 1980. A follow-up report, *Common Crisis,* was published by the Commission early in 1983.

The origin of the expression North-South is the preponderance of advanced industrial countries (AICs) in the northern hemisphere and of late developing countries (LDCs) in the southern.

53 For the full text of Dr Patel's address see page 156.

54 See page 162. Dr Cicerchia also introduced a second paper, by the president of her centre Dr Giancarlo Quaranta, the text of which follows her own (page 169).

55 Professor Coales said the CBEET would be pleased to send copies of the plan to MANTECH participants.

56 For the full text see page 174.

57 For the full text see page 187.

58 Briefly, he advocated avoiding excessive use of pesticides, combining their use with 'natural' (and age-old) practices such as crop rotation and ploughing in stubble, encouraging the natural enemies of the pests and developing pest-resistant strains of seeds and crops. (See the full text of the paper, page 187.)

59 Though not, of course, for its own sake!

60 Some other participants, notably Professors Feshbach and Frosch, had already (Session 3) drawn attention to the dangers of 'blind confidence' in incompletely understood technology, making it clear that difficulties could arise from two separate types of failure: failure to realize that a computing system's output was completely dependent on its man-given instructions—even when these comprised so-called self-organizing programs; and failure to realize that 'answers produced' could never be more valid than the input data from which they were derived (i.e. if input ignored recent changes in historic trends, so would output).

61 See footnote 52 (page 148).

62 Some of Dr Patel's remarks were perhaps a little unfair, or so it seemed to one who has frequently been impressed by the very advanced technologies embodied in systems (such as the solar panels and associated equipment of Professor Thring) which are simple to use and could correctly be termed 'appropriate' in cases where even diesel-electric generation, although less 'advanced', would prove too expensive in fuel. Much recent agricultural technology (fertilizers, selective herbicides, pesticides, improved seeds) is very advanced indeed, but none the less appropriate at (almost) any price. Dr Patel might well have paraphrased the famous dictum of his countryman Dr Homi Bhabha, 'father' of India's nuclear power programme, who more than a quarter of a century ago said 'no energy is more expensive than no energy'. No agricultural progress can be more expensive than no agricultural progress.

63 Unfortunately for the tyre manufacturers, modern technologies have so improved their products that demand has slumped. The drop has been encouraged by high fuel prices restricting expansion of motor transport. In the circumstances it is not surprising that successful manufacturers, having perfected a product better than average, are extremely jealous of their production secrets.

4.1 The Potential for Industrial Technology in Developing Countries

HE Sheikh Yamani, Minister of Petroleum and Mineral Resources, Saudi Arabia

Industry in the modern sense was virtually non-existent in developing countries at the close of World War II. However, in the span of the 30 years that followed, the economic change which took place within them was so dramatic that they were brought much closer to the stage of industrialization at various levels and intensities. Manufacturing in developing countries over the period 1950-80 grew at a rate of seven per cent per annum, outpacing the five per cent rate of the industrialized countries. Their exports of manufactured goods during the same period had even exceeded their industrial growth and reached 15 per cent per annum, whereas that of the industrialized countries amounted to only 10 per cent.

These developments underscored a breakthrough for the countries concerned in their struggle towards industrialization. They came about as a result of the determination of their economic planners to utilize capital and technology made available by industrialized countries in diversifying their economies towards more efficient means of production. They took account of the fact that, unlike the industrialized countries, capital is a scarce resource in their countries, and when invested in the right channels its marginal productivity exceeds that of the industrialized countries. Industry is generally more capital intensive than agriculture or other productive sectors. Less labour is employed per unit of output and therefore it is much more efficient. This efficiency element is a decisive factor in achieving growth and development, since it further leads to capital and technological accumulation that provides the means of reinvestment, and hence additional employment and growth.

In contrast to industry, agriculture is labour intensive and less efficient even if mechanization is being applied. Agricultural efficiencies as well as productivity increases are not necessarily brought about by the intensive use of capital. They may in fact be achieved simply with the same amount of employment per unit of land by other means such as training of labour in modern means of irrigation, fertilization, plant protecting agents and use of high fertility seeds. Using such advanced technology can improve land productivity without intensive use of capital.

After centuries of stagnation developing countries are now making big strides in development and growth because of their move towards industrialization. A survey of the degree of industrialization in developing countries revealed that the share of industrial output in total output of physical goods (comprising agriculture, fishing, mining, forestry, power, other utilities and construction) ranges for most of them between 20 per cent and 40 per cent. The most advanced of those countries have even attained a higher degree of industrialization in which the share of manufacturing is between 40 per cent and 60 per cent of total output of commodities. They are classified as semi-industrialized since full industrialization is a trait reserved only for the developed countries where the share of manufacturing exceeds 60 per cent. This leaves only around 30 developing countries out of 100 which are still classified as non-industrialized. In them the contribution of manufacturing to total goods produced is less than 20 per cent.*

The experience of the industrialized countries provided the developing countries with the best example of the path to be followed in their development process. It demonstrated unequivocally how industrialization, and not agriculture or mining, is the crucial factor that really counts in achieving growth. Until the middle of the nineteenth century, just prior to the advent of full industrialization, per capita income in the industrialized countries had only marginally exceeded that of developing countries. However in 1960 per capita income in industrialized countries had increased eightfold whereas that of the developing countries increased only by 20 per cent.** Clearly the reason for this dramatic growth in the industrialized countries was therefore industrialization and nothing else.

As can be expected, it may still be argued by some economists that developing countries endowed with wide resource bases in agriculture and mining do not need to industrialize in order to achieve growth. The basis of that argument is that such countries can intensify their efforts towards raising their agricultural output and extractive industries beyond subsistence level, and export the surplus as a means of obtaining the necessary amounts of manufactured goods they need in exchange. The experience of the last 30 years has demonstrated beyond doubt that the value of such raw exports is unstable. Most of the time it is subject to sharp deterioration, as the markets of industrialized countries are limited or artificially restrained. Further expansion in the production of raw materials will lead only to wasteful surpluses and lower earnings rather than accumulation of the means of production, which is the basis of growth.

* Cody John, Hughes Helen and Wall David, *Policies for Industrial Progress in Developing Countries.*

** Cukor, Gyorgy, *Strategies of Industrialization in the Developing Countries.*

Acceptance of this argument can only aggravate the plight of developing countries, particularly in view of the fact that their populations are sharply rising. Although petroleum was less exposed to falling demand and declining price trends than agricultural products and other raw materials owing to its scarcity, none the less the experience of the last two years provides evidence that it is not an exception. Being advantageously concentrated in large amounts in few countries does not alter the fact that it is a wasting and short-lived non-renewable asset subject to full depletion. Further analysis reveals that most of the developing countries, even those with a large agricultural base like India, are endowed with a kind of a soil generally less fertile than soil in industrialized countries. There are many problems with animal breeding and husbandry owing to inadequate weather conditions. Certainly good prospects for agricultural development exist in developing countries, but the problems that face such development are tremendous, though not insuperable. A good example of the lower productivity of agriculture in developing countries is rice production. In the USA land can produce four times as much as India by the use of the same amount of fertilizers. Working out the proper technology for agriculture in developing countries will take a very long time, and development can lag further behind. Industry on the other hand can be immediately erected, bearing fruit much sooner, and development is brought forward much earlier as a result.

It follows from these introductory remarks about the importance of industry that developing countries are more in need of industrialization than industrialized countries themselves. Bearing all these facts in mind, it is perhaps now useful to focus some attention on the experience of Saudi Arabia in industrialization and development. Arable land in Saudi Arabia is not limited in size as might have been imagined. Some experts estimate its extent at about seven per cent of the total area, which is considerable by any standard. The major drawback in the development of agriculture is the severe shortage of water coupled with a dry, warm climate. Another drawback is the wide dispersion of such land in all corners of the country, a situation that calls for an extensive and costly infrastructure, particularly roads, schools, health services, electricity and telecommunications. With these formidable impediments blocking agricultural development, Saudi Arabia, unlike many other countries, does not have the luxury of choosing between alternative means of development. The only opportunity for development that remained was industry. That did not mean that agriculture was neglected. On the contrary it received as much support as necessary to bring about a viable and steady source of food products; wheat production in the seven years ending 1982 for instance increased from 15,000 tons to 300,000 tons.

It was obvious that in order to industrialize we should opt for the type of industries that are large-scale, capital-intensive, technology-intensive and above all energy-intensive. Since the first development plan was laid down in 1970 the government decided that as the country was deprived of the infrastructure without which no industry could grow, two locations, Jubail on the Arabian

Gulf and Yanbu on the Red Sea, were to be chosen as the sites of the new industries. All the necessary infrastructure was laid down over the next 12 years, and construction of the plants commenced about three years ago. By 1985 all the basic industries will be put on stream. Apart from the huge investment for infrastructure projects such as power, water desalination, transportation, ports, communications and housing, the investment envisaged for the plants themselves is about 40 billion Saudi rials.

These industries comprise ten major plants, three of which will produce ethylene and its derivatives at the rate of 1.5 million tons a year. Two will produce methanol at the rate of 1.3 million tons a year. Four will produce polyethylene at the rate of 800,000 tons. Two more will produce steel at the initial combined rate of 970,000 tons, with plans to raise their capacity to about four million tons. In building these plants Saudi Arabia moved to the stage of heavy industry without going through the stage of small-scale industry like machine tools, textiles, workshops or processing agricultural products, which evolved in the economies of the industrialized countries during the nineteenth century. The petrochemical industry as such is relatively modern. It has not evolved from traditional small-scale industries but was big from the outset. In selecting the type of technology used for production six criteria were used: simplicity of operation, compatibility with the local environment, efficient maintenance, capital cost, size of the workforce and type of product. The Saudi Arabian Basic Industries Corporation bought the licences for running the production systems from internationally reputable firms in the field of petrochemicals.

As is already well known, the raw material used is natural gas, which is abundant in Saudi Arabia. After flaring it for decades for lack of economic outlets, it has been gathered, treated and fractionated into its major components. Methane being the most abundant is earmarked mostly for energy use, but also partially as a raw material for fertilizers and manufacture of methanol. Ethane will be used for both energy and raw material purposes for manufacturing ethylene, polyethylene, glycol, styrene and caustic soda. The remaining gas was designated for exports, as LPG and natural gasoline, and other local outlets, mainly water desalination and electricity generation. Steel plants will also use methane as a source of energy and for reduction purposes. In comparison to the high capital intensity of these projects, the labour force has not been planned to exceed 7,000, the majority of which are Saudis. With this small number of employees, the efficiency and productivity of these plants will be very high. The value added of the output of all these plants combined is expected to reach $3 billion in 1985.

Small industry has also grown substantially over the last 20 years. But it was recognized from the outset that, no matter how extensive and efficient it may be, it can only contribute moderately towards growth and the use of technology. An examination of our GNP components by sector revealed that the share of small industry, including refining, in total production of goods and commodities in Saudi Arabia in 1982 amounted to 27 per cent only. But when the value of petrochemical and steel output is added, total manufacturing gets a share of 55 per cent after allowing for continued growth of agriculture and other production sectors. This percentage is high enough to shift the position of Saudi Arabia in 1985 to the category of the semi-industrialized, which comprises South Korea, Brazil, Argentina, Taiwan, Hong Kong and Singapore. When these plants are running full scale, the advantages will not stop at the value added earned. They will spill over to other small industries that will either act as tributaries for supplying the large industries with materials, spare parts and maintenance, or to newly formed plants that will use some of the raw materials produced for processing into consumer goods designed for the home market and neighbouring countries. Steps have already been taken by the private sector to erect small plants on both sides of these large-scale industries.

Two main difficulties might still confront our industrial progress. The first is the non-indigenousness of our technology. The second is the marketing of products. Regarding the first, active measures have already been taken to train Saudis in running the factories at the highest technical levels. Research and development centres were also founded in each major plant for conducting studies to improve the technologies used. Technologies in such industries are constantly changing and must always be updated if our industries are to compete at the international level. As regards marketing, our products are cheaper when compared to similar products in the international market, despite the fact that the capital cost involved is 1.3 to 1.6 times higher. The offsetting factor here is the cheap raw material used as a feedstock and as energy.

From the standpoint of international division of labour, Saudi Arabia is endowed with the cheapest source of energy in the world, which under a free trade system should be utilized for furthering world trade efficiency, based on the principle of efficient allocation of resources. Our oil policy in Saudi Arabia is geared to furthering this principle and the principle that the best means of securing a steady flow of imports is through a steady rise in exports on a competitive basis. This matter is of pressing importance if the world is to continue its march towards growth and development, particularly under prevailing world conditions. Our policy has succeeded at home and abroad, despite impediments, over the last 30 years. The huge taxes levied on oil consumption at the consumer level in the importing countries are one such impediment.

We achieved greater success when eight years ago our government bought the entire assets of the erstwhile foreign concessionaires. Capital investment which was provided by the foreign investor is now provided by the State. Decision-making at technical and business levels is also run by Saudis. None the less certain technologies are still provided under a commercial arrangement by the international companies that had previously owned the production facilities. Imports of capital goods have also continued to flow in support of expanding production, recovery programmes and refining. Our oil industry thus is a good example of an industry which is capital–and technology–intensive, run for some time by a foreign partner, but finally turned over to local management. That was the first step. Our second step is industrialization, both large-scale and small-scale. Both will constitute a solid basis for continued imports of capital goods and technology and exports of raw materials, semi-finished and finished products. The trend towards industrialization in developing countries has begun. A long time will pass before full industrialization is reached. But in the life of nations no period of time is too long.

4.2 Technological Distance Between the North and the South

**Surendra J Patel, Director, Technology Division,
United Nations Conference on Trade and Development**

I intend to take a broad view of technological development and the manner in which the countries of the South are struggling to grapple with it. In my title I say 'North and South', but people have talked of East and West, developed and developing, centre and periphery. I prefer the terms centre and periphery because there is no geographical precision about Kipling's East and West, about the modern writer's North or South, or even developing and developed, because there are several facets and phases in which these distinctions are made.

By centre I mean the centre of industrialization. The periphery is the rest of mankind which has not yet formed part of the centre. If we look at it that way it is important to define the technological distance.

The discussions we have heard in this meeting centred upon particular segments of frontier technologies, so one can define technological distance according to frontier technologies in one or another industry. One can define technological distance according to the resources devoted to technology, whether as monetary inputs or research and development manpower. One can even be statistical and talk about the patents registered, because after all invention and innovation, when they become a marketable product, may find expression in the form of a patent.

All these definitions concern individual sectors but none of them is capable of reflecting the totality of relationships. This is one reason why there is a great advantage when talking about technological relations among nations in taking an indicator which sums them all up. This is where I intend to use productivity as the totality of the transition from scientific breakthroughs, discoveries, inventions, innovations and their final translation into investment, to their spread in such a fashion that they affect the productivity of all segments of society, whether agriculture, industry or several branches and plants in industry.

In talking of North-South relations, or centre-periphery relations, I shall use productivity, per-occupied-person-productivity, as a measure. That is where technology is embodied in productive assets and generates a stream of goods and services.

If we look at it that way two conclusions immediately emerge. One, the current fashion of talking of West and East or developed and developing immediately appears relatively myopic in terms of mankind's history. If one takes domestication of animals, irrigation, smelting of metals, the invention of scripts, not to mention religions, and many other inventions including paper, the early part of printing, the putting together of books, and gunpowder—in all of that the basic technological flow was from the rest of the world to what is now geographically described as the North. The flow has never necessarily been for any long part of history from the North to the South. It is only in the last 100 or 150 years that this has become Northcentric flow. Before that it was always the other way around. The North was a small segment of the world's humanity and it is only in the last hundred years or so that special circumstances have given it a special place. This is one observation.

Second, looking at the broad current of mankind's development we see that, from the birth of civilization until the end of the eighteenth century, there was no more than a marginal rise in per-man productivity (productivity divided by population as opposed to productivity-per-occupied-person). Whenever productivity rose it was absorbed in the expansion of the population stock, and therefore by and large per capita levels or per-person levels fluctuated marginally. Nations went up and nations went down. Powers rose and powers fell, but if we look at economic history or technological history, man's capacity to produce goods and services per person by and large saw only marginal increases up to the arrival of the Industrial Revolution. Again there is a striking feature, of probably no particular significance, but the big bunching of those innovations that propelled industrialization and its spread all over the world has always centred somewhere around the threshold of the fourth quarter of a century. Take 1775 and the ten years preceding and the ten years following. Take 1875 and the ten years preceding and the ten years following. Take the seventies and eighties now. It is simply a curious fact of technological history which has intrigued me, but for which I have no explanation.[64] But it is in this period that in the industrial countries per-man-productivity saw a rise of nearly tenfold. This then I call the technological distance between the industrialized and the developing countries. It is in these 200 years that this tenfold rise in output has taken place.

But even that is an exaggeration. After all, what was happening in 1775? Adam Smith was walking the streets with his head tilted writing or composing the draft for *The Wealth of Nations*, and Watt and Bolton were completing the possible design of a steam engine which occupied almost a third of this room to produce ten horsepower. England had no more than ten thousand steam engines, stationary steam engines, even at the crest of the first post-Napoleonic boom, which brings us to 1840. It was all limited to railway engines, textiles and coal—up to about 1875.

Let us ride a time machine and move not forward but backward into history, and land in the City of London in 1875. The good old bicycle was there, but without pneumatic tyres and without ball bearings. The typewriter was a huge contraption and made an immense noise. The motors for generating electricity were not there. The converter was not there. The diesel motor was still at the experimental stage of the two-stroke engine. The car was still being tried out and 1878 saw its first run, as a three-wheeled contraption capable of the immense speed of eight miles an hour. They had to find a name, and since Benz's daughter was called Mercedes, what better name to give to this contraption than Mercedes? That was the origin of Mercedes-Benz–in 1878. By a curious turn of history, at that very time England was enacting the Red Flag Act, in 1876, through a fear of these vehicles travelling at immense speeds and creating traffic hazards. By the Red Flag Act–nothing to do with the Red Flag as it became known later–Parliament enacted that any vehicle travelling at more than five miles an hour must be preceded by somebody carrying a red flag so that all the citizens could move away and not be crushed by the oncoming monster. The red flag stays still. The speed limits are higher, and today's version of the flag is installed in both the front and the back of vehicles.

Also 100 years ago there was no organic chemistry, no electricity products. Even in social technology, Gladstone and Disraeli were still to fight the famous battles over the spread of education in England. The Mother of Parliaments was still elected by less than ten per cent of the popular vote–and that was then the most democratic institution in the world.

What I am trying to underline is that the technological landscape only 100 years ago was bereft of all the actors that we now see on the stage. What is the meaning? The meaning is that this is not even a two-hundred-year-old transition. It is a two-hundred-year-old transition if we take the scientific breakthroughs, discoveries, inventions and innovations, but the transition is not yet completed. However, if we take the changes that are now fully incorporated into our systems of production most of the foundations are only about 100 years old.

A tenfold rise in productivity in 100 years is (if historians or economists are allowed to talk of kinetics) approximately a two per cent rate of growth per year. The technological transformation of mankind in the developed countries in the past 100 years has proceeded at an annual pace of approximately two per cent per productively employed person per year.

The notions of East and West, North and South, developing and developed, are again not too helpful in considering the spread of productivity. In 1775 incorporating technological innovations into the productive system affected not even a million persons in the tiny triangle surrounding Manchester. Not even a million persons, less than one per cent of the entire population of mankind in 1775, were in what might be called a technologically enlightened or advanced occupation. From one per cent in 1775, by 1875 it was a little below ten per cent, and by 1980 it had grown to approximately 25 per cent of mankind. So not only is it a case of two per cent per person per year, but there is the spread. From one million people it spread to approximately 50 million people and then to about one billion people. The absorption from the technologically advanced centre to the rest of mankind has proceeded at a rate such that only 50 million were added in the 100 years between 1775 and 1875, but almost 900 million people have been absorbed into it since 1875. This is my second observation. My first was on distance and space, and my second is on the spread.

There is one more very interesting factor about the spread. Up to 1875, Britain was the workshop of the world, producing 40 per cent of the world's industrial output, almost 70 per cent of the steel, 30 per cent of the textiles, 80-90 per cent of the shipping. But between 1873 and 1896 came what the economic historians call the Long Depression. The Americans had just finished the Civil War and the Germans had been unified under Bismarck, known appropriately as the Iron Chancellor. In fact he unified Germany in several ways. It was precisely in that period of depression in what was then the centre—the United Kingdom—that the United States, Germany and the countries surrounding Germany, the small European countries, started their industrialization. Moreover the UK's population at that time was about 25 million, but the new entrants had a population two to three times as large: 50-70 million instead of 25 million.

In the 1920s the world experienced what was called the Great Depression. (Historians did not want to use the term Long Depression again, and so this was called the Great because it was quite intense.) But again the depression was of the centre, that is what was at that time the industrial centre, which had shifted from less than one million people to a little over 50 million people. It was precisely in this period of depression that industrialization began in Japan, one of the two industrial countries (one in the West and one in the North—that too is an interesting reflection on the course of economic history) that have joined together to host this gathering.

It was also during the Great Depression that the industrialization of another country, the USSR, took place, bringing two big new entrants on to the world stage, with populations again moving up in scale from the smaller countries. These were not countries of 20 million people, but of 50-100 million people or more. So in the pace and spread of technological absorption or diffusion two factors come together. One is that it is precisely in a depression, or a crisis of the centre, that the periphery becomes active. My grandmother in her wisdom used to say—although the economic historians did not believe it—that when the cat was away the mice had their way. It is precisely when the most powerful economic and technological actors are not that confident about the way they are managing the stage that the actors from the periphery can enter what otherwise might have been called the theatre of the absurd and start acting on a small scale as its rightful protagonists.

This has a significance for the world's situation now. As His Excellency Sheikh Yamani has very rightly pointed out, the Third World, the developing countries, has entered the world arena. These countries are no longer replicas of what our university professors used in the fifties to label as nations short of capital and short of skills. If there are two countries which embody the invalidity of this generalization, one is His Excellency's country and the other is my own: Saudi Arabia and India. Capital shortage surely cannot be a major feature of the Saudi economy, nor is a shortage of skills a characteristic of the Indian economy. In 30 years the Third World's classic image as portrayed in the Oxfam poster and in the descriptions put out by other charities has vastly altered.

I have no wish to go into lengthy details, but let me at least point out four or five significant ones. First, throughout the last 25 years the rate of growth of the Third World as a whole has been higher than the rate of growth of the developed countries for which this was certainly a golden age of growth, because they themselves have never experienced anything like this before. Secondly, industrial output in the Third World is now seven times what it was in 1950. His Excellency quoted seven per cent and I am tiying to translate it into quantitative measures. In sum total the Third World now produces more industrial output—and that is what technological transformation is about—than the entire world produced at the beginning of the century.

Third, from capital formation in the Third World being only 10 per cent of GDP in 1950, or even less (hence the strong case for external aid), it has now risen to 26 per cent of the total. The average for the Western countries, or what we call the developed market economies, is 22.7 per cent. Nowhere, at no time in history, in any comparable period has capital formation increased as rapidly as in the Third World in the last 25 years.

Fourth, technology is the creation of man's mind, translated by his deft fingers into equipment and tools. Today one out of every four students who enrols in institutes of higher learning comes from the Third World. The total was not even one-sixteenth of that at the end of the forties. There has been a sixteenfold expansion, the fastest and most rapid expansion ever of trained manpower. It has not yet been put fully to use.

To summarize. The Third World is an entirely novel phenomenon on the stage of history as it has emerged in the last 25 to 30 years: in terms of growth in GDP, in terms of growth in industrial output, in terms of growth in capital formation, in terms of skilled manpower. It is fumbling; it is having problems. But one nice feature—I consider it a comforting feature of the present world—is that there is no country anywhere, East, North or South, which could arrogantly say that the world's problems are centred on itself and no other. In fact the entire world economy, world society, the world's technological leadership—all of them are, I would submit, in a profoundly critical situation; a situation in which neither the politicians nor the industrial leaders nor the labour leaders have any clear, convincing ideas about where they want their own societies to go in the next 25 years.

It is good that there is a bit of modesty. The Third World is not the only problem child of the world. The whole world is a problem child, and every one of us seeks the answers to the ills. There is a common interest therefore in making a better world, making a different world, reshaping it in a dozen different ways. In this I would suggest that the Third World has now come to occupy its rightful place. It is not a distant partner that charity and goodwill may cure. It is as rightful an actor on the world's stage as Germany and the United States aimed to be in the last quarter of the nineteenth century. It is as rightful an actor as Japan and the Soviet Union aimed to be in the thirties and forties of this century. That is how the stage is set.

I shall conclude by asking where all this may go. In the world of my dreams I like to think of technology as a common heritage of mankind, because this is where each gadgeteer, each inventor, has drawn on 6,000 years of cumulative history of mankind, drawn on its scientists, drawn on the noblest intellectual minds which sought answers to mankind's problems. If technology were to be conceived as the universal heritage of mankind, the solution to the problems would be even easier. The Third World's transition and transformation would be greatly facilitated. But may I submit in all modesty that technology is being transacted between the North and the South not as a commercial article but—I am sure this will be a slightly difficult pill to swallow—with a resemblance to the leasing of land under feudal conditions. Technology is leased, not sold. Technology is leased under restrictive conditions such as were common in the feudal age. The farmer had no security of tenure, no fixed rent, no right to decide what crops to grow, where to market, when to harvest, when to take credit, how to improve the land. The changes in the United Kingdom would not have taken place unless the old agrarian structure had been thoroughly reformed.

If we are remaking the world, it is extremely important that these feudal conditions for the exchange of technology be removed, if not altogether at one stroke then progressively so, step by step. Some of them are so archaic that when they are made public it causes embarrassment for those who impose such conditions on the Third World. I need not go into detail, but this is a cause to which much North-South dialogue has devoted itself. We very much hope that in the period ahead the combination of technological developments, improving the access of the Third World to the available technology, developing skills and national capital goods industries, will together bring about a change in the fortunes of mankind which will usher in a somewhat more equal order.

EDITOR'S NOTE

64 Kondratieff-type cycles?

4.3 The Socio-Cultural Effects of Western Technology in Non-Western Cultures

Intervention by:
Annalisa Cicerchia, February '74 Research and Documentation Centre, Rome

I thought I would use the time at my disposal to talk about Nubians and M'zabites, fishermen and Navajo Indians, attempting to show that they are of great interest for the understanding of certain aspects of the social and cultural challenge of modern technology which seem to me to be fundamental. In the course of the social research which the February '74 Centre, to which I belong, has been carrying out during the last few years, especially on the subject of development, modernization and cultural change, the impact of major technological transformations on the so-called non-Western peoples has come to assume more and more importance. Bishara Khader has rightly said that technology is not a traveller without luggage–i.e. that all technology which is thought up and produced in a certain socio-cultural environment inevitably brings with it noticeable elements of its original environment when it is transferred to a new one. However, what we have been able to establish in this field leads us to suppose that something more will follow, and that the meeting between a technology and a culture is more akin to the collision between two systems than to the mere introduction of a new element into an existing system.

We were therefore led, along with Giancarlo Quaranta (see 4.4), to frame the concept of *cultural stress,* understood as an unexpected and quantitatively significant process, or body of processes, characterized by conflict of values, institutions, norms, instructions and cultural patterns brought about by the assumption on the part of a culture of a specific amount of new information of any kind.

Within this theoretical context we were able to organize the empirical experience by using as criteria the type of controls culture is able to exercise over the massive intake of new information. As I mentioned, it seems to me that it would be useful for our discussions to take into consideration three different forms of response to relations with Western technology. These are represented by, respectively, the population of the Aswan region of Egypt, the Ibadite community of the Algerian M'zab, and the Navajo Indians of the south-western United States.

The building of the gigantic Aswan dam is an exemplary case, not only because of the macroscopic dimensions of the stress to which it gave rise, but also because numerous development programmes in Africa revolve around similar undertakings. The area submerged by the dam basin extends over about 500 kilometres in length and almost 15 in breadth. The huge Lake Nasser was not formed by the flooding of uninhabited areas; on the contrary it was necessary to transfer the Nubians, who inhabited that part of the Nile Valley, to another area. Any operation of this kind, even if carried out in the best possible fashion, involves substantial problems, because no human community can be indifferently uprooted and displaced according to necessity. The transfer of the Nubians however was not even well thought out, for they were deported in a very short time into an almost completely desert area north of Aswan, where the temperature in the hot months reaches intolerable levels.

Old people and children were literally beaten down by the heat, accustomed as they were to the temperate climate of their former homes on the banks of the Nile. 'You know that among us, when someone dies, everyone meets together in the common house. I remember that in the first months that we arrived here, I couldn't even manage to spend one hour in my house because someone immediately arrived to call me, as another old person or baby had just died.'

The Nubians were promised that the new settlements would respect the distribution of the old ones, i.e. that the former villages would be reconstructed as they were. However, in the studies preceding the building of the dam quite a lot of omissions were made, and indeed some real errors; these could not fail to be reflected in the final lay-out of New Nubia. For example, of the five villages termed 'Arab' because they were populated by a particular group of Nubians differing in language and customs from the others, four were registered and the fifth was left out. Because of this the first four were rebuilt very close to one another, but the fifth, Wadi al Arab, which had originally formed one single community with the others, was sited many miles away.

Anyone who has any knowledge of the Nubians' building traditions knows that they build spacious dwellings with plenty of air, often decorated in exquisite fashion. Yet as a compensation for being transferred they received squalid square cement boxes, from one to four rooms in size, in most cases insufficient for the dimensions of the average family.

'The houses were planned by people who had never seen the Nubians,' even the rulers of the Aswan region admit today, 'and the builders took their pattern more or less from the houses of the peasants in the north of the country.'

Furthermore, the new houses are completely unadapted to the extremely hot climate because they do not have the traditional barrel-roof which allows the air to circulate. Their distribution in the village (decided on according to size, so that they are arranged in parallel lines according to the number of rooms they possess) totally ignored the links which formerly existed among family groups.

The cultural effects of this new arrangement are, needless to say, dramatic. Forced proximity causes quarrels and fights. (It should be mentioned that in the past the distance between one family group and another could be as much as a day's journey on mule-back.) Twenty years after the transfer families have naturally grown larger, and the new houses, already too small even at the start, are bursting at the seams. (The census taken of the villages did not include those absent for work at that moment.) Moreover the desert does not offer much in the way of possibilities for building materials, and thus the growth of the villages has been very difficult and very slow.

The doctors of New Nubia have noted with some anxiety the great frequency of nervous diseases, together with numerous gastro-enteric complaints caused by the new environment. In addition there have been many cases of anorexia and psychosomatic disorders connected with the fear of death from heart attacks or from the heat.

In discussions with old people, the images of old Nubia recur as in a dream—it is always fresh and green. In the greater part of the new settlements there is not even a single tree, no grass—nothing.

In formal terms the Nubians became proprietors of a fair number of acres to cultivate. However, the fields are a long way from the houses, in contrast to the past, and the supply of water is totally insufficient. Those who have devoted themselves, with government encouragement, to cultivating sugar-cane have had to learn from scratch and have often found themselves hopelessly in debt to the firms which produce equipment and fertilizers (of which, of course, the land exposed to the flooding of the Nile before the dam was built had no need).

It should not be forgotten, moreover, that the Nubians had commercial relations of some importance with the nomad peoples of Beshari and Ababda, which suddenly ceased when the High Dam was built. From the official point of view the nomads practically do not exist—so much so that no one took the trouble to warn them about the plan for the construction of the High Dam. Thus, as Shahira Fawzy relates, on their return journey from the Sudan the nomads found an enormous stretch of water where formerly they had found their markets and their pastures. They believed that they were witnessing an exceptional flooding of a wadi, and it took more than a year to convince them that the waters would never go down again, and that there would never again be either the Nubian markets or their pastures. Even now the nomads still do not exist officially. Thus these thousands of non-existent men move about in impossible conditions, with their non-existing camels, and risk disappearing altogether if suitable new solutions to their problem are not found very soon.

If the Nubians live in hopes of returning one day to live near the water (and some of them are organizing themselves into associations for the purpose of such a transfer) there is also the paradoxical situation of more than 7,500 fishermen who work on Lake Nasser and who refuse—as far as possible—to set foot on the shores. The banks of the lake are in fact extremely unsuitable for any form of settlement, since they are infested with insects and dangerous animals, and since they are not connected except by water with any centres of habitation. The fishermen of Lake Nasser are not originally from Aswan; the great majority of them come from the districts of Qena and Soaq. Usually they live for 11 months of the year in rowing boats, dependent for all their supplies on the owners of the boats (an extremely small number of people organized in a co-operative). They live on tinned beans and fish.

Even medical care leaves a lot to be desired, above all when we consider that there is a constant danger of bilarziosis on the lake. The organization of work is of a semi-feudal nature; the fishermen work almost exclusively to pay back the sums which the boat-owners claim to spend annually for their maintenance on the lake. Thus the men who work on Lake Nasser, constantly in debt, have barely enough left over to keep their families, who have remained behind at home. The construction of the Aswan Dam, in short, has proved to be the cause of a violent overturning of the pre-existing situation—an upheaval of such dimensions that it is difficult to hope that the culture of the human groups who have been involved in it could ever exercise any sort of control over it.

The immediate problem of the Nubians, the nomads, the fishermen and even of the peasants who now have to buy chemical fertilizers (for the production of which a huge amount of the energy produced by the dam is consumed), instead of the lime formerly used which cost nothing at all, is now that of survival in an environment which even today, 20 years after the upheaval, is extremely hostile.

These disastrous effects cannot in my view be considered just in humanitarian or philanthropic terms. Even from the point of view of the economic take-off of a region which has always been afflicted with the plague of emigration, it might perhaps have been useful to assess the possibility of a different use of the human resources, which in this case seem to have been thought of as mere incidentals.

A different example of the relation between traditional culture and modern technology is provided by the Ibadite community of the M'zab region of the Algerian Sahara. The Ibadites are an Islamic sect which because of persecution in past centuries was forced to abandon the coastal areas and flee to the desert. Here, thanks to an excellent position which enabled the M'zabites to control the whole trans-Saharan route, and thus the merchant routes between the coast and the interior of Africa, an extraordinary accumulation of wealth took place. Thanks too to a particular religious view of work, because of which the M'zab Ibadites are sometimes compared to the Calvinists studied by Weber, the great capital sums accumulated by trade have been invested in recent years in machinery, above all for the textile industry. Special external conditions led the M'zabites to reduce their workforce to the lowest level needed for production, first of all to avoid taking on labourers who were non-M'zabites, and secondly in order not to come under the clauses of the law on the nationalization of all firms with more than ten employees. All this created an extremely favourable soil for the adoption of sophisticated machinery, which today is better in quantity and quality than anything to be found on the coast, for instance. It is astonishing to enter these villages, apparently timeless, which suddenly rise up out of the desert, and where (as in the case of Beni Isguen) the doors are firmly closed at six in the evening, and find there the most competitive forms of textile machinery. M'zabite culture has defended its own integrity with every available means; even today severe laws are in force at both social and religious levels regulating the behaviour of women, who can scarcely appear in public with anything more than an eye exposed; laws also affect the consumption of alcohol and even smoking. However, in relation to the introduction of Western technology the situation is changing significantly. M'zabite culture is a little like a fortress, strenuously defended, in which a tiny opening has been left which in the end is to prove fundamental in strategic terms. The substantial profits from production cannot in fact be invested indefinitely in new machinery. Even if the close social cohesion of the M'zabites makes it possible to ensure a considerable redistribution of wealth within the community, the problem still remains of how to use all that money.

At this point it is important to mention another significant element in the culture of the Algerian Ibadites, for whom there is no sense in producing anything which cannot be turned to the immediate advantage of M'zab. Because of this limited field of vision the problem of using the wealth gained remains unsolved. Thus individual consumption has begun to spread, and again this is linked to Western technology: domestic electrical apparatus, and especially radios, televisions and video-players, etc. These last items are the actual vehicles of alien messages which have now succeeded in penetrating into the M'zabite fortress, with effects already becoming visible, and which will soon become much more significant. Although Algerian television is run by the State, this has not stopped the M'zabites and especially their womenfolk, who stay in the house for the greater part of the day, from becoming avid spectators of such American serials as 'Dallas' or of Japanese science-fiction cartoons. It is clear that television contact with radically different situations from their own will sooner or later give rise to cultural paradoxes, and to serious conflicts over customs and values. Thus little by little the crack in the defence walls becomes a breach; the extremely delicate balance between the traditional and the modern undergoes major changes, and even though the M'zabites might be very reluctant to admit it, the sense of frustration, the feeling of conflict and the desire to get away all make themselves felt more and more strongly.

A third type of relationship between traditional culture and modern technology is the one which has grown up among the Navajo Indians of the south-western USA. These native American peoples, who have been at peace with the USA since 1868, live in a huge reserve, about the size of Belgium; they have about 170,000 people in all.

It could be said that in a certain sense the acquisition of other cultures is a part of the traditional culture of the Navajos: they were known as the great imitators, and adopted Spanish weaving; they borrowed what is today their national female costume from American women during the four years (1864-68) of the deportations to the detention camp of Bosque Redondo; and they transcribed their language into Latin characters when it was used by the Americans as a military code during the Pacific War.

The attitude taken by the Navajos to more recent developments in Western technology has been similar; they have adopted it willingly even in key sectors of their economic, political and social life. However, what is really significant is the fact that the introduction of external elements is always filtered, controlled and even managed in such a way that as far as possible it strengthens rather than destroys traditional culture.

A few examples will serve to illustrate this point.

The most notable case was the use of a computer to memorize the whole very complex system of clan relationships. The Navajo are divided into about 80 clans, linked by various ties which determine matrimonial possibilities. Respect for these traditions is not only still alive among the young Navajos but is facilitated by the data-processing media. A group of medicine men has also been recently 'computerized'; they are gathering the extremely rich tradition of songs and 'blessed ways' which form a priceless heritage of medical and religious science. The computer will make it possible to save from oblivion rites and myths which are indispensable to the whole culture of the Navajo.

Building techniques and town planning also seem to have been effectively wedded to tradition. The Navajo Community College is a splendid achievement, in which the most modern and sophisticated materials have been used, but it was planned according to a traditional scheme and with the advice of some of the medicine men. As in the traditional habitation–the place where all the ceremonies take place, known as the Hogan–the campus has a circular plan, with the entrance facing east. On the eastern side is the main building. Dormitories, refectory, library and lecture-rooms are arranged in the same way as the places for sleeping, eating and carrying out ceremonies are arranged in the Hogan. Furthermore, in the university courses devoted to traditional techniques such as that of the silversmith, the weaver, the potter, etc., the use of videotapes is standard; they are more suited than books to a culture which although it possesses writings is essentially an oral one.

The relationship of the Navajos to extractional technology is less calm. Their reserve has a subsoil rich in coal, petroleum, gas and uranium, and it is above all the extraction of this last which has created various conflicts between the local population and the companies. In general there are two main motives for conflict. The first is, naturally, the problem of radioactivity and the consequent demand by the Navajo that use should be made of equipment which will safeguard the environment. The second cause is the traditional religious respect for Mother Earth, which must not be wounded indiscriminately. The little town of Shiprock was the scene of protests (which even became quite violent) by the Navajos, who have a strong point in the collective ownership of the soil, which is looked after on their behalf by the Tribal Council. Although the question has not yet been fully resolved, it should be noted that recently certain large companies have presented plans extremely advanced from the technological standpoint, which will make it possible to extract the minerals from the soil without the need for large-scale excavating or mining, and with a satisfactory level of safeguards for the natural environment.

While it is still in process of happening, this last example is particularly illuminating in showing how respect for traditional culture and religious belief (which often coincide, especially in the case of the native American peoples, with respect for the environment) is not necessarily in conflict with technological and scientific progress, but in fact can make use of even its most sophisticated achievements.

I believe that the three examples briefly cited here—Aswan, the M'zabites and the Navajos—may be useful to show that technology and culture cannot be adequately understood if they are not considered from a standpoint capable of embracing both of them, for they are in fact two sides of the same coin.

4.4 Technology, Development and Culture: The Need for a Global Approach

Intervention by:
Giancarlo Quaranta, February '74 Research and Documentation Centre, Rome

I am especially grateful to the organizers of the MANTECH Symposium for giving me the opportunity to submit the present communication on behalf of the February '74 Research and Documentation Centre of which I am president.

First of all I must say that I am not an expert in technology. In fact I must admit that until a few years ago I was convinced that the attitude of a social scientist like myself towards technological subjects must be limited to a discreet curiosity, and to knowing how to follow meekly behind at the right moment, so as to leave complete freedom of action to the so-called technological experts themselves.

I am sure I was not the only one who thought like this. Similarly, I do not believe that I am the only one to have noticed, fortunately, that the old attitude, which had an element of compartmentalization in it (technology for the technologists and society for the sociologists), is not only full of gaps but in very many cases is completely mistaken.

Furthermore, upholding the philosophy of 'to each his own' implies sugaring the pill to a great extent. We social scientists have in general a very poor opinion of the social and cultural effects of great technological interventions, above all in the developing countries (I need only refer to the age-old problem of the gigantic dams built in Africa, for example); and we are accustomed to think of the arrival of Western technology in a so-called 'traditional' country as being akin to the arrival of a cyclone which overturns everything in its path.

From our own point of view I do not think that we are entirely in the wrong. On the other hand, technologists cannot deny that they have often had to deal with a social and cultural environment which did not react to technological changes in the way which other social and cultural environments had already reacted. Technologists have often confronted difficulties in teaching new technologies, mistrust in the human communities most directly affected, and even forms of genuine hostility, sometimes fomented and directed (as a member of the Club du Sahel told me only last year) by the sociologists themselves, who are hardly to be found at the moment when their opinion is really needed to lay out a project, but who rediscover all their verve and vitality when it is a matter of recording the errors of others. This I cannot deny: from their own point of view the technologists are also in the right.

So far I have been talking in terms of a dichotomy, of 'us' and 'them'. Now even though I do not intend to propose a general embracing session, since the difficulties and the differences are not the result of ill-will but of precise historical and scientific causes, I think that we can nevertheless consider ourselves to be united today by the subject which has provided the title of this Symposium—'The Social and Cultural Challenge of Modern Technology'—above all, may I add, when face to face with the imponderables of development.

The relationship between technology, culture and development is undoubtedly one of the Gordian knots into which the future of our planet is being tied. The gross inadequacy of the solutions so far put forward to define this relationship calls for a radical change both within the framework of practical day-to-day politics and also in the field of research.

I am well aware of the lack of specialists in this subject—a lack due, moreover, to the fact that only in recent times has it been thought necessary to treat and deal with the three issues, technology, culture and development, as a single whole.

I would therefore now like to stake a claim in favour of the creation of a new field of specialization of this kind, which will be capable of considering all three elements as one system. For this purpose I will seek to outline in summary form some considerations, the fruits of both theoretical research and *in situ* studies with the February '74 Centre, about the nature of the interaction between technology, culture and that particular form of socio-cultural change which we call development. These studies have been conducted from a standpoint which aims to achieve a constant improvement in the machinery of our knowledge, especially in the field of the social sciences, of the complexity and the many dimensions of social aetiology.

Over-simplistic explanations, or those which reduce issues to their lowest terms, are among the greatest dangers facing all of us, technologists and social scientists alike. If we add a stone to or take it from a pile, what remains is still a pile, and at most it will be a little larger or smaller. But the elements and the structures of a cultural and social system are not like the stones in a pile in their interrelations, and a technology is not a stone which can be added or removed at will.

Furthermore, if the relations between technology and the socio-cultural environment demand more complicated calculation than merely addition or subtraction, this is not a defect or a handicap, but only a different way of organizing reality.

In this context technology, because of its disposition to transform, change and organize material reality, always implies the setting in motion of new blocks of social organization, and thus of new cultural patterns.

Technology may be regarded as a cultural system *sui generis,* since it involves systems of learning in itself, and, more importantly, since it is generated and managed according to the cultural patterns from which it is derived. Furthermore, since its prerogative is to develop both the quality and the quantity of its products, it transforms the culture from which it originated to such an extent that the relationship between technology and cultural change can be defined as the constant relationship between systems.

As a cultural system, technology possesses its own symbols, myths, rites, rules and models, similar and parallel to the culture which generated and developed it. During any modernization process, for instance, by which modes of production are altered by new technological elements, the mentality of the people or outlook of culture are necessarily modified. Technology, then, has a specific 'gravitational field', both cultural and social. It can restructure the cultural system into which it is inserted in the same way as a new stellar mass would do on entering a planetary system.

If modernization is the process of cultural change prompted by new information pushing forward so as to insert itself into the culture understood as a system, then the change takes place once the new technology has been inserted into the system and interacts with the receptive mechanisms of the existing culture. The way the new information filters through into a culture depends on whether the new information penetrates the receptive organs of the system—that is, whether it penetrates such areas as mythico-ritual and symbolic-linguistic structures, and those most closely linked to the geno-type, such as kinship structures.

No transfer of technology can therefore be limited to a mere commercial relationship between a purchaser and a seller, nor can it be a relationship merely between technicians. The social subjects involved, which determine the nature of the exchange, are those having in their hands the control of the 'receptors' of the culture concerned. Any transfer of technologies from an industrialized country to a developing one will inevitably pose the problem of the relationship between a Western culture and a non-Western one; or to put it in another way, the ultimate aim of certain processes of industrialization and economic openings can be called into question because of the neo-colonial aspects that underlie it, and because of the 'acculturation' which it imposes.

This is more likely to be the case when the pool of technological information (which in any case bears the stamp of the culture of its origin) does not get filtered by the basic structures of the recipient culture, thereby producing mechanisms of positive (and therefore bad) feedback. Although outwardly there is apparently an increase in the technological store of knowledge, these mechanisms are responsible for the destruction of the culture and hence for the loss of national identity.

This being said, development can be understood as a process whereby new information is accepted but also controlled—thereby it is selected and inserted into the traditional context, filtered by the receptors of the system and then co-ordinated with the traditional pool of information.

At this point we need to pause for a moment and consider the relativity of the concept of development. If development literally means reaching a better or richer state of being through the exploitation of available potential of resources, the question then is: 'What should develop, and for what purpose?' The question is complex, and the answers given so far indirectly reveal the one-sided and dominant view of development held by public opinion. Why otherwise would only a specific number of the thousands of activities, resources, social groups and interests (all of which can, in theory, be 'developed') have been selected for the privileged attention of government plans?[65]

What has happened, in fact, is that the Third World countries have concentrated on importing Western technologies and cultural patterns. They have tended—each in its own way—to accept cultural aspects imposed on them by a foreign dominating power. This has led in turn to their abandoning their own ethnic heritage, to clash between imported technological practices and local customs and to a forcibly induced increase in consumption and imitative models, obviously at the risk of collapse.

The idea that 'modernization' (with its implications based on ideology and economics and its ethnocentric and mechanistic biases) is the sole development strategy is therefore too flagrant a misconception not to warrant correction. Only when this correction is made will it be possible to equate 'technology transfer' with something positive, and to deploy the connected development in its literal sense of the expansion of the internal potential of a given economic and social whole.

It may be observed that development itself is tied to a direct and reciprocal relationship both with and between technology and culture. Technology (to be understood in this instance as a certain technico-instrumental capacity proper to industrialized economies and Western society) is first and foremost a necessary requirement of development, and as such it is also its precondition. It is of course a matter of fact that technology is not in itself culturally neutral, but it always relates to the model of development adopted. As an instrument dependent on economic and political decisions, technology can either serve certain areas of change which interact with local culture and traditions, or alternatively those which impinge on them in a very indiscriminate and harmful manner.

It is obvious, then, that development itself, seen as the priority choice for expansion among a whole variety of possibilities, is a function of the politico-cultural decisions determining the path which collectivity will take through interventions in the form of social technology. Technology, development and culture can be conceived as large systems dependent upon and linked together by functional relationships.

In view of the above, technology can be said to be an agent of development, or development a function of technology—at least for the cultures which produced it. For developing countries however it may be that the opposite holds true. As far as they are concerned technology is a function of development, i.e. only when certain levels of development have been reached can higher technology be produced or available.

The problem of development is two-edged: on the one hand it is counterproductive to attempt it without the transfer of technology, for when the effort made is purely endogenous it always reaches a critical threshold, leading to the deterioration of resources and of the environment at a greater speed than with foreign technology. On the other hand, the transfer of technology means exporting it from countries which possess it to those which do not, with all the obvious political and economic consequences this entails.

This dilemma certainly deserves an answer of some kind. Technology can be an agent for development only if it generates mechanisms of negative feedback. But this is possible only if the recipient culture is in a position to insert the new pool of information into the traditional institutional, religious and family context so that the two elements adapt to each other in a reciprocal and harmonious way.

All the considerations adduced so far serve only to strengthen the need to take a new look at the approach to the system made up by technology and culture within the context of development. Such an approach is possible only with a correct use of social sciences, founded on patterns of explanation which do not reduce the human situation to any single dimension.

Such models will be useful to the extent that they are built on a deeper awareness of their language and the logical processes in which they are grounded. These models will also have to be characterized by a higher degree of formalization in order to allow computer-science approach. Such an approach seems to me indispensable to processing data in a new way from both a quantitative and qualitative point of view. This involves a serious critical reflection about the type of employed inferences and requires, on the one side, normative analysis to be added to causal analysis and, on the other side, standard logic to be flanked by non-standard logic (that is normative, modal and deontic).

The conviction that the function of social sciences need not be relegated to mere wishful thinking, not to simply taking note of the failures of technological intervention, is becoming more and more widespread. Nevertheless, little else has been done in this field while social research has remained at a low level of reliability—all too often it has provided over-general 'recommendations' prior to the intervention, and then registered the failures when it was already too late.

It goes without saying that the ability of the social sciences to play a determining role in economic, political and technological planning is tied to their scientific capacity, i.e. their ability to formulate analyses and reliable predictions on the realities they study as they are being transformed by technology.

I should like to end with an affirmation that I am sure we would all concur with: that the social and cultural challenge of modern technology is not only a challenge to our operative creativity but above all a challenge to know seriously who (or what) is man.

EDITOR'S NOTE

65 Material constraints?

4.5 The Potential for National Resources with Reference to International Trade

Barry M Grime, Director,
English Clays Lovering Pochin & Co Ltd

Introduction

The title of this paper prompts questions like 'Which developing countries is he going to talk about?'

–the oil-rich countries–gentle giants like Saudi Arabia or enigmatic ones like Nigeria

–the least developed, less advantaged countries like Bangladesh

–the rapidly developing countries
with reasonable cashflow like Korea or Taiwan
with cash problems like Brazil.

Another likely question is 'Which national resources is he going to talk about?'

–oil
–minerals
–agricultural products
–people
–geographic position, or even
–clean sources of air and water.

Finally, 'How is he going to bring out the potential for international trade across such a matrix of countries and resources?'

I would like to start by considering briefly the general world climate of relations and confidence in which we are all operating.

I want then to declare my hand on growth and planning and then deal with the matrix problem: talking about general prospects for international trade as they affect the range of developing countries and the range of national resources. There appear to be a number of significant factors at work, some less clear than others, which will vitally affect trade prospects right across this matrix and will affect each country individually, in ways impossible for me to discuss in the timescale available.

Finally, I have prepared some desiderata which may spark some discussion: they are essentially issues on which I believe it is worth trying to achieve shared values between partners in developed and developing countries when trying to exploit national resources.

Climate and Confidence

Any discussion of the potential for national resources must take into account the climate of relations and confidence in our spaceship world. The vital importance of the climate can be inferred by the Honda Foundation initiative in sponsoring this MANTECH Symposium on the social and cultural challenge of modern technology. This climate of relations and confidence has been much in evidence with our speakers so far.

Indeed the importance of 'putting our act together' on a world basis has been the increasing concern of respected writers in recent years, notably:

Club of Rome, *Limits to Growth*
Schumacher, E F, *Small is Beautiful*
Toffler, Alvin, *Future Shock* and *The Third Wave*
Report to the President of the USA, *Global 2000*

and in a different vein

Beckerman, Professor Wilfred, *In Defence of Growth*

–to name just a few.

Yet in the last six months the second Brandt report *Common Crisis* has demonstrated that we are failing miserably.

This same view is expressed only slightly less passionately in recent utterances of

The IMF and the World Bank–who can't make the books balance
UNCTAD–who can't get us to help each other significantly
GATT–who can't stop protectionism; and
the EEC Lomé Convention–who in September are going to try for the third time to set up an effective aid system between the EEC and the Third World.

These reports are littered with the problems involved in promoting trade and mutually satisfactory growth for all parts of the world.

Why Go For Growth?

Any discussion of the potential for national resources has to be based on some assumed scenario for growth in business activity and trade around the world. The issue of high or low growth rate brings into consideration the issues so well opened up in the several classic works to which I have just referred.

As I see it we must have growth if only to achieve capacity to supply the growing world population and make inroads on deprivation. How else do we pay for new plant, medicine, water supplies, aid–the list is endless. These things are not easily paid for in a recession.

At the individual level we can ask ourselves:

1 Would we like some regular growth in 'scope' and in material benefits in our daily life?

2 Would we be more at ease in this global village if we were succeeding in 'doing more with less'–in using our resources?

If one agrees the answer is yes to both these questions I believe our guiding principle can be 'to go for growth, while aiming to do more with less'.

In case this leaves you with a suspicion of being a selfish view from the developed world I suggest we should recognize that growth in developed countries (GNP) is the key to creating a market for the underdeveloped world and thereby greatly increasing its own growth rate (Figure 8). 'Careful growth is good for us all' or, to quote Abraham Lincoln, 'You don't help the poor by destroying the rich'.

If you ask for a target figure I can only say: the sustainable rate of the day. It was high single figures and seems likely to be low single figures in the eighties.

How Should One Go For Growth?

This is a more difficult question to tackle than 'Why go for growth?' I have no neat personal solution and I am conscious of the current agonizing in the financial world on advisable growth in money supply and on levels of interest rates particularly in the USA. I want however to take a position since the answer affects what I say later.

The Japanese model is of a consistent government policy of directed long-term market research and directed R & D towards supporting a National Plan. Within this plan there is ample evidence that industry and in particular the major trading houses have freedom to react to market forces and execute their own plans–and indeed that planning creates the environment for commercial initiative.

In recent years it has become more obvious that Indonesia as a developing country has greatly benefited by some 16 years of consistent central planning combined with free enterprise. Sri Lanka is now following a similar pattern. In the UK we are seeing recognition of directed R & D in the work of ACARD, the Cabinet Advisory Committee on Applied Research & Development, which has been supported recently in the Fellowship of Engineering by Sir Alistair Frame's paper making the case for a National Strategy for Technology for the UK. However, most nations are a long way from the audacity of the Japanese in publishing what they intend to be good at and by when–including many areas beyond the currently fashionable use of biotechnology.

The lessons for the developing countries from the accumulating evidence appear to be:

to know your national resources thoroughly

to plan rigorously to exploit these resources through directed market research and directed R & D

to create a climate in which your industry and in particular major trading groups can respond commercially in the nation's interest.

One can foresee such improved national plans progressively becoming a major help in improving industrial and agricultural regional plans for areas such as the ASEAN, ANDEAN and ECOWAS groups and helping their growth prospects.

What are the General Prospects for Growth and International Trade?

These are prospects to be taken into account in planning by all of us, not least by developing countries:

Energy

Almost any technical issue has to start with a consideration of energy. I think we are realizing the validity of Professor Thring's conclusion in 1977 that man must come into full equilibrium with the environment by the time the fossil fuels are exhausted, which will be by 2200 at the latest even if we allow for the contribution of renewable energy resources. Although this was written in 1977 and the year 2200 may be a long way off, particularly for the disadvantaged of the world, I believe that most people can with education still be convinced on this point. The present oil surplus should not lull us into a false sense of security. The energy balancing effect must be an underlying assumption in any long-term strategic planning for us all in this 'global village' and is in fact a restricting factor in the quest for growth mentioned earlier.

Metals–More with Less

There is ample evidence that conservation, equipment rebuilding and recycling is increasing. For example predictions of world needs of copper to the end of the century have already been cut from three times to twice the present rate. There is now a belief that substantial further savings could lead to surplus production capacity for many years ahead. One can ask where this leaves major mining companies wanting to expand and also developing countries with reserves they see as an encashable resource? Many of you in this room will know the answer: in a dilemma.

As well as the effects of savings and recycling we have the substitution effect. The security of supply of high alloy steels has been a constant worry to the developed world, with its reliance on cobalt, vanadium, manganese and the like. This factor plus straight technical needs can be seen behind the development of substitution materials. The newly emergent silicon carbide whisker material *Tokamax* is reported to have 50 times the flexural strength of steel and to be capable of withstanding 1600^{o}C: it is already in production at over 30 ton/month. Any planning group must have a problem in judging the significance of this factor but the signs already are that it could be massive.

In essence then it appears that new opportunities for developing countries in metallic minerals could be fairly limited and are likely to be mainly in import substitution.

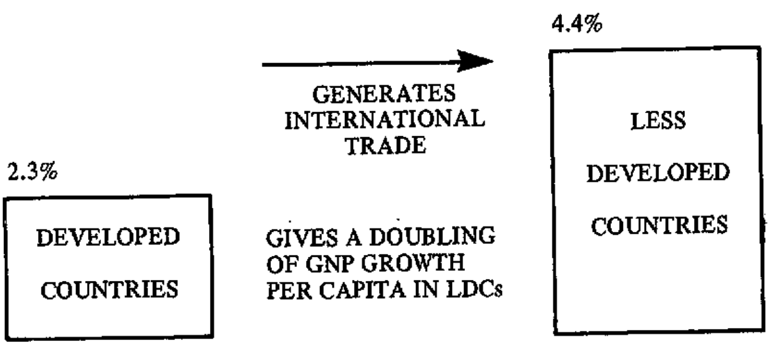
More Use of Industrial Minerals

The use of industrial minerals is now increasing more rapidly than that of metallic minerals (Figure 9). The broad trend as countries develop appears to be as in Figure 10, suggesting a need to develop industrial minerals production. The changing pattern in Spain, a relatively developed country with good mineral statistics, is a specific example where construction minerals account for 50 per cent of the growth of industrial minerals and 50 per cent is in minerals having specific physical or chemical properties and includes agriminerals (Figure 11). However, the growth itself has its dangers, as I shall now show.

Bandwagon Effect–the Danger of Over-Capacity

Because of the market-orientated nature of the minerals business it seems that new project development teams in various companies and countries study the same body of data and technical literature and reach similar conclusions about what should be done. The ultimate result is that they realize, generally too late, that they are all building plants to supply the same market and gross over-capacity develops, which takes years to work its way out of the system. Classic

Figure 8: Average Real Growth Rate (percentage) GNP Per Capita 1970-79



SOURCE: 1981 WORLD BANK ATLAS

examples are potash and fluorspar where technical opinions expressed in the late sixties and early seventies led to excessive plant investment, causing severe overcapacity and depressed prices.

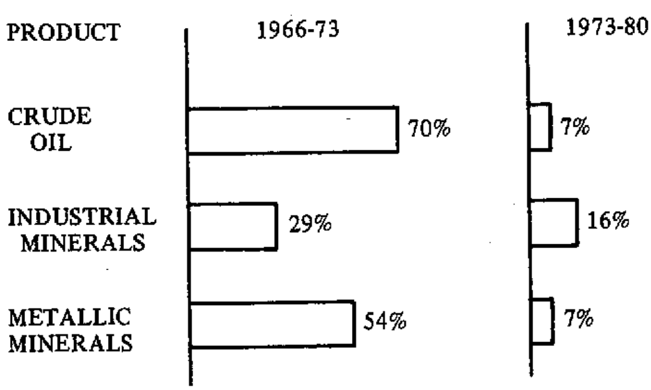
The bandwagon effect has become even more severe in recent years, arising from:

–less developed countries concentrating on metalliferous minerals as their most easily encashable resource

–international funds supporting these aspirations

–new investors such as oil companies joining the fray with established mining companies.

Figure 9: Average Growth Rates in World Production



SOURCE: THE ECONOMIST WORLD BUSINESS CYCLES 1982

Figure 10:

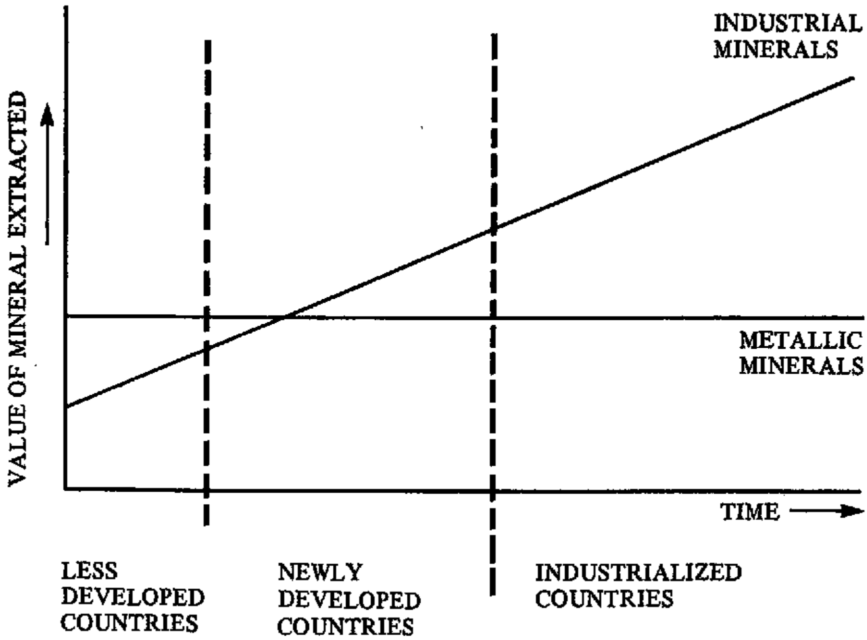
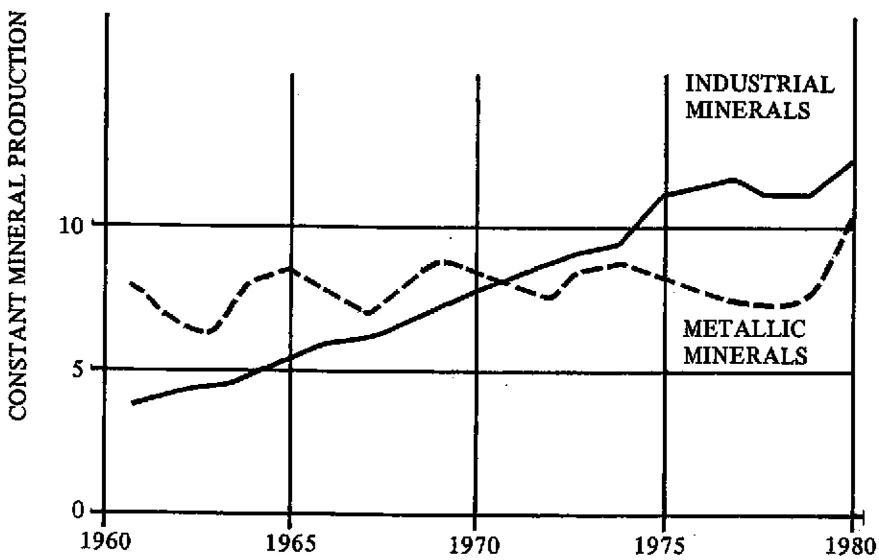


Figure 11: Spanish Mining Production Value



When demand falls off special stockpiling arrangements are increasingly required to allow continued production. This bandwagon problem is one of the issues underlying the whole discussion.

Small is Beautiful

I believe we are also seeing a 'small is beautiful' effect coming through advances in technology which will affect us all. For example a mini steel works can now be supplied to developing countries, meeting many of their basic steel needs at 25 per cent of the cost of a fully integrated steelworks. Davey McKee already have an impressive record in this respect. Such plants are capable of taking in recycled scrap plus direct reduced iron pellets and melting, continuously casting and rolling simpler sections.

The same is true of smaller package breweries through improved instrumentation and control systems, and it seems likely that the fruits of technology will become generally available to developing countries earlier in their evolution and at lower cost, helping in earlier import substitution.

Strategic Competition Effect

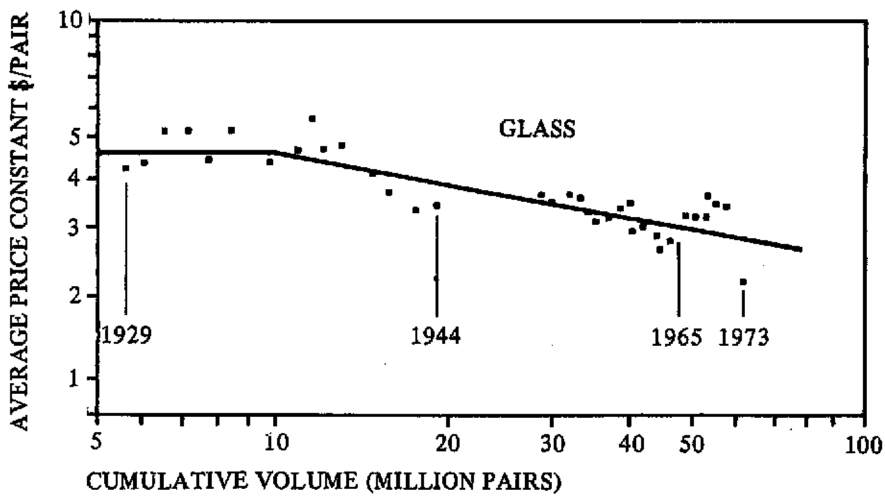
The supply and demand issues I have illustrated emphasize the importance of making use of the techniques successfully developed to identify competitive threats and opportunities. A growing understanding of price experience curve effects is, I believe, sharpening people's wits on competing strategically rather than allowing competition to evolve. Let me give examples where the technique has given early warning of strategic options.

Let us start with the price experience curve for glass spectacle lenses (Figure 12) and compare this with the price experience of plastic lenses, first introduced in 1965 (Figure 13). The price follows the same trend of 20 per cent reduction in real terms per doubling of experience: this is probably known to many of you as a key indicator of any successfully developing product.

Now consider this experience for plastic lenses overlaid on that of glass lenses over the period 1965-73 (Figure 14). I suggest that there were deducible from these combined curves some basic competitive strategic decisions in 1971 and 1972. The plastic lens supplier might have accelerated or decelerated his development from seeing these data according to his knowledge of other plastic lens producers, but the glass lens manufacturer had a much more difficult task with the burden of major investment behind him. Closer to my own business I can provide an example of our experience in developing a new range of high pressure filtration technology for dewatering china clay (Figures 15, 16 and 17).

I know that a similar story is unfolding on medium-size wind generators compared with conventional power generation, and in oil and gas drilling where environmentally clean oil-based drilling fluids working with synthetic polycrystalline diamond contact (PDC) bits are sometimes halving drilling times.

Figure 12: Price Experience Curve: Multi-Focal Glass Spectacle Lenses



The prospective effect on capital goods demand for exploration rigs is suddenly becoming very significant.

This form of presentation can help to bring home the starkness of the established product position and the courage required in handling a new product, and I see it as a vital ingredient for developed and developing countries planning how to exploit their resources in any new market. It can be applied to the developments opening up in the communications and biotechnology fields and on the next frontiers as they emerge, e.g. the next generation of solar-electric converters.

Figure 13: Price Experience Curve: Multi-Focal Plastic Spectacle Lenses

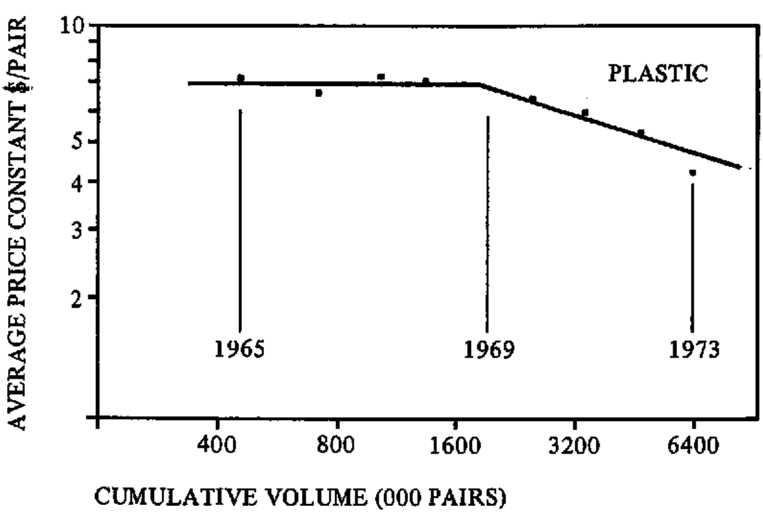


Figure 14: Price Experience Curve: Multi-Focal Spectacle Lenses

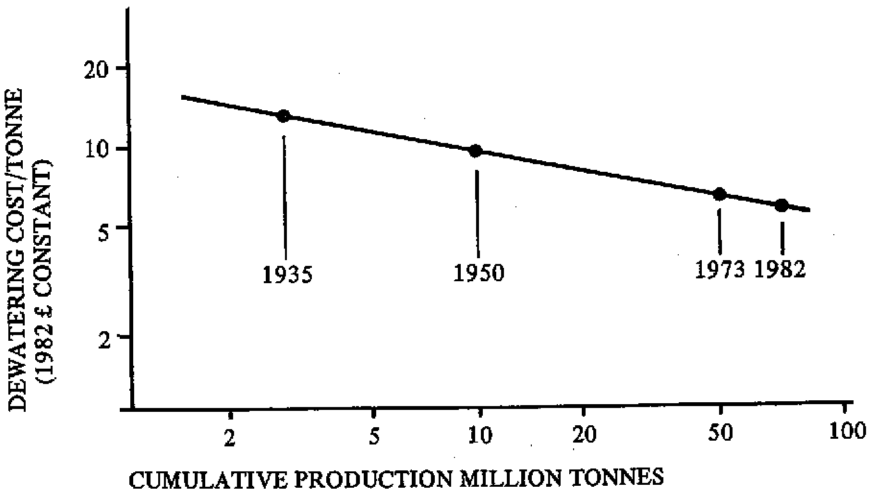


Figure 15: Cost Experience Curve: China Clay Dewatering Costs Using Low-Pressure Plate Filter Presses

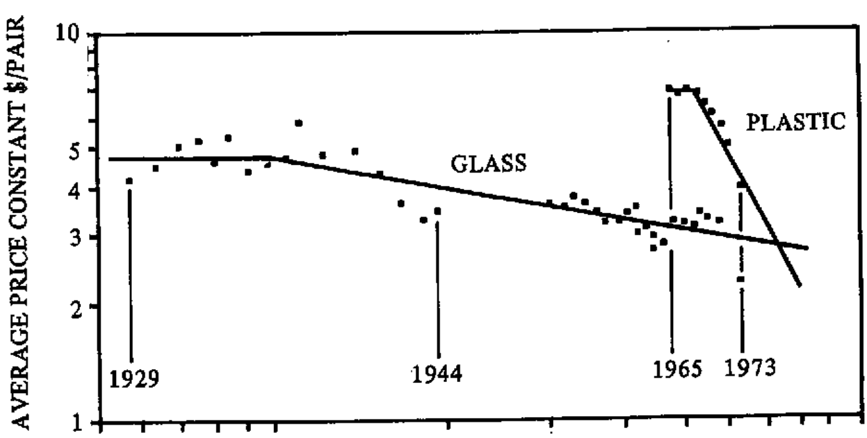


Figure 16: Cost Experience Curve: China Clay Dewatering Costs Using Tube Presses

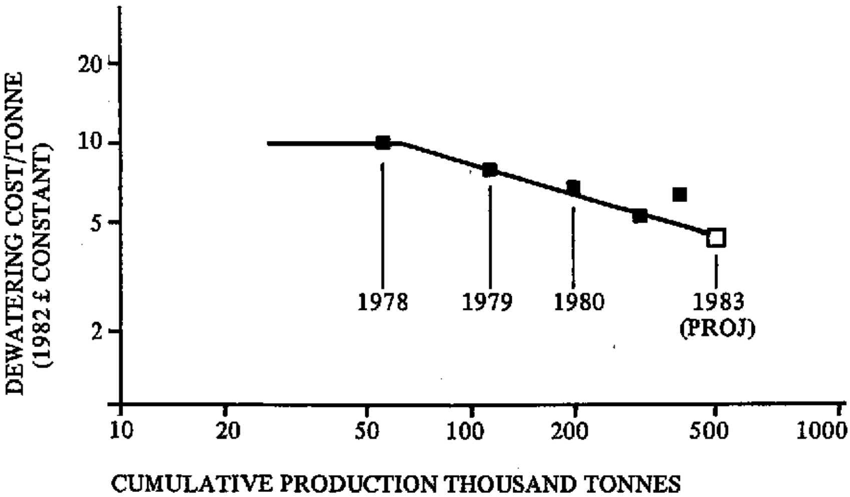
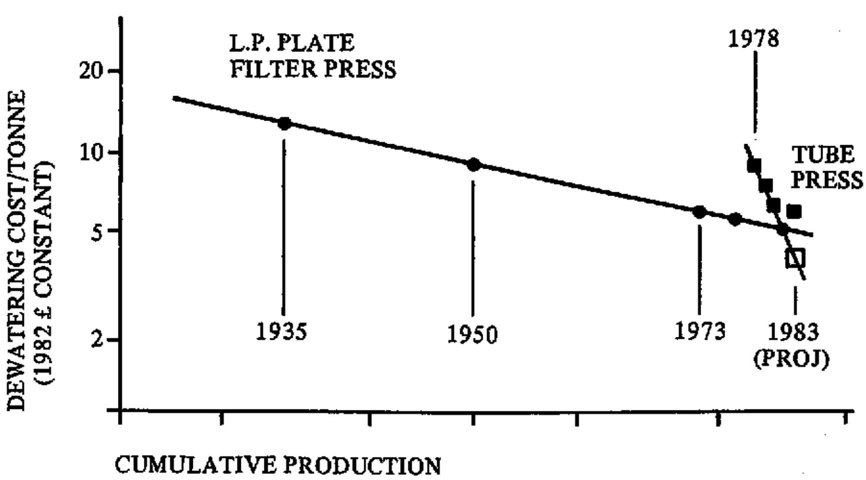


Figure 17: Cost Experience Curve: China Clay Dewatering Costs



Political Factors

There are obviously some major factors affecting international trade prospects. First, developing countries want an increasing share in their own resource development, yet they still need financial and technical help from developed countries. This suggests that for many processed materials output may have to stay static in developed countries and growth may have to be met from new installations in developing countries.

There there is the problem of expropriation. The record of the last 20 years is not a credit to some developing countries and a lever is needed to improve the situation. Joint ventures with local partners and financial participation by international funds, possibly with IMF or World Bank scrutiny, seem to be emerging as at least a partial solution.

Third, cartels are a reality. They are one of the biggest dilemmas to be handled in any planning. There is no doubt that the OPEC cartel, like others before it, has hurt a lot of people, but it has also brought us to our senses in making more economic use of our resources and could yet prove to have been beneficial.

Successful Exploitation of National Resources

In recent years my company has had many contacts and discussions in developing countries with a view to establishing kaolin and other mineral plants. Occasionally there has been an opportunity to join with a local company of similar size in a major venture, to build a sophisticated large-capacity plant with immediate export potential. More often we have felt there has been an opportunity for a local man with drive and technical ability to start a small, simple operation servicing local markets which could well grow into something more important.

We, and I suspect many like us, have been somewhat cautious and tended to go for a few controlling interest ventures. In today's political and technical climate we can see such operations having a significant interest for ourselves in the early years, but offering the local man a major share of the action in a fairly short time scale, leaving us with a continuing interest and some preferred role in international marketing. The key here is the entrepreneur with a technical bent operating in a sympathetic social and governmental climate. He responds to market requirements, first in his own country and later perhaps overseas.

How then can the developing countries obtain the technology they need for their economic development and what should be borne in mind by the prospective partner from the developed world? I would offer the following thoughts as possible shared values for both parties:

Planning

1 Recognize that the renewed careful growth of the developed world is the only route to creating substantial markets for developing countries. Aim to do more with less.

2 Develop national strategic planning and strong industrial groupings.

3 Concentrate on basic domestic markets—early entry into world markets is a high-risk strategy.

4 Be very clear on the strategic competitiveness of your resources and your specific ideas—destructive conflict comes when you don't have an edge!

5 Use cash from international funds, to help credibility and security!

People and Partners

1 Develop local entrepreneurial and technical skills.

2 Adapt technology to the local environment in a developing country. A simpler, more labour-intensive manually operated plant can be much better to start with than a highly automated plant.

3 Keep business units small and keep a low 'foreigner' profile.

4 Partners should be willing to plan gradual transfer of ownership to the local partner and recognition of the external partner in international marketing.

Conclusion

To conclude, the evidence is that successful use of the natural resources of the developing countries will firstly be made easier by the renewed (but balanced) economic growth of the developed world: however, successful use of natural resources will really be achieved only by the growth of a fluent entrepreneurial and technological group of people of its own. It needs a few key people with vision to make use of those natural resources.

Any programme of national strategic planning should aim to identify those countries in which a country could have a competitive advantage in producing goods for its own use and later export, and should then seek to create the kind of internal business climate and external relationships in which technologically minded entrepreneurs from both the developed and developing world will naturally, and with confidence, be drawn to exercising their talents.

4.6 Effective Use of Agricultural Technology in the Developing Countries

Brian A May, Dean, Faculty of Agricultural Engineering, Food Production and Rural Land Use, Cranfield Institute of Technology

Agriculture, together with forestry and fisheries, supplies the world's food, wood and renewable raw materials, providing directly the means of livelihood for almost half the world's population. It has been estimated that by the year 2000 a world population of more than six billion will require an agricultural output some 50-60 per cent greater than in 1980. Demand for food and agricultural products in developing countries will double in the same period.

For many countries earnings from agricultural exports are vital. Trade in manufactured and processed food products whose raw materials come from the land is a major flow. There is substantial trade in inputs to farming, for example fuel, machinery, fertilizers and crop protection chemicals. An efficient and productive agricultural sector is thus essential in developing countries, primarily to meet increased food requirements and to contribute to sustained economic growth.

Attainment of production targets and meeting economic performance standards will require the effective application of agricultural technologies on a massive scale. Innovations will include the transfer and adaptation of existing technologies, and possibly the development of new technologies. Such transformation also implies a major change in institutional and social relations. It will mean an effort to create an effective framework of policies and services facilitating and encouraging growth in production. It will require rationalization of the respective roles of the private and public sectors in contributing to the needs of production and for infrastructural support.

In order to achieve sustainable growth in food production in developing countries, crop and livestock outputs must be increased. Since crop production contributes around 75 per cent of total output, it can provide most towards improved agricultural performance. Globally there are four main ways of achieving additional crop output:

—increasing the arable area

—raising the proportion of that area harvested each year

—increasing the yields from each unit of land harvested by intensified production

—raising the proportion of harvested crops actually reaching the consumer.

In each case effective application of agricultural technologies plays an important role, although the situation in terms of which source to apply varies considerably from one region to another. Broadly speaking, Latin America can probably derive more growth in output from expanding arable area than from the combined effects of increasing yields and cropping intensities. The crowded Far East, with very little room for expansion and an already high cropping intensity, must depend upon high yields for most of its increasing production. Arable area in the Near East cannot be expanded significantly, and here most of the increased production will need to come from higher yields, and most of the remainder from cropping intensity. Africa can achieve gains from expanding arable area, improving cropping intensity and increasing yields. In all regions of the world gains can be achieved through improved storage and handling systems.

Land and land tenure systems are major considerations in terms of growth in output and effective application of agricultural technologies. In 1975 the Far East was using around three-quarters of its potential arable land, while around two-thirds was in use in the Near East. In Africa and Latin America only about a quarter of the potential arable land was cultivated. Although these regions are relatively well endowed with land generally, there is a very uneven distribution within them, especially in Africa.

As new land is brought into use, governments will need to provide more infrastructure and incentives to encourage investments in technology-based agriculture. They will also perhaps need to discourage squatting, and small land holdings subject to traditional land tenure arrangements. A land reform directed at bringing under-used land into more intensive and efficient production is likely to offer the cheapest and most equitable way of expanding cultivated areas and should take priority over expensive schemes to settle remote and ecologically sensitive zones.

Higher yields and cropping intensities can be attained by optimizing the use of existing and new agricultural land through increased outputs and improved management. The inputs, together with their technologies, range from water and fertilizer to improved seeds, crop protection and mechanization. Of all these required inputs, water is perhaps the most important. With adequate quantities yields can be increased readily and more than one crop grown each year. As demands for water expand, technology concerned with water conservation and efficient use will need to be more widely applied.

It has been estimated that fertilizers were responsible for more than half the increase in yields in developing countries between 1965 and 1976. There is a clear relationship between higher or increasing applications of fertilizers and above-average agricultural production. The use of fertilizers has been growing more than twice as fast in the developing as in the developed countries. Fertilizer use expands most rapidly on irrigated land, where it produces the greatest returns, and much more slowly on rain-fed lands, especially in low rainfall areas. Techniques associated with fertilizer use are therefore important. Correct timing of application and placement of fertilizer close to the root zone of plants can produce the same yield increase as double the amount scattered over the field. Institutional changes should therefore accompany increased fertilizer use; for example, ensuring that farmers know of the benefits, that supplies reach them and they have access to credit to enable fertilizer to be purchased.

Seeds are the focal point around which strategies to boost crop yields can be built. Their response to land, water, fertilizer and pests will determine the success of all other inputs. The development of seed quality therefore needs to take place alongside improvements in other inputs. In some situations where farmers are either unwilling or unable to apply other inputs improved seeds can lead the way to adoption of additional technologies.

For improved seeds to make a greater impact seed research will have to follow broader lines than in the past. The first wave of the Green Revolution concentrated on a handful of crops, wheat, rice and maize, and produced varieties that yielded well only when they were well watered, well fertilized and well protected against pests to which they were more susceptible than the old traditional varieties. A second wave of research is now well under way to correct these drawbacks. Ideally the new varieties would be adapted to the level of purchased inputs which is realistically likely to be available in a given area at a given time. There is also a need to collect, preserve and use traditional cultivars and wild relatives which are fast disappearing, so as to provide a base for future genetic diversity.

Human beings have serious competitors for their crops in developing countries. Crop protection is thus of great importance in accelerating usable crop production. Losses from pests and diseases in the field have been estimated at 20-40 per cent of crops worldwide, and may be higher in developing countries. In the past chemical control of pests and diseases was regarded as a panacea, but this has led to problems which are all too familiar, such as the emergence of resistant strains and the persistence of harmful residues. At the same time trends in agricultural production, such as the move to monoculture, with a consequent reduction of the number of varieties in use, were actually increasing the danger of pest and disease attacks. Some developed countries found that although they were using ever higher levels of the pesticides, losses caused by pests and diseases were increasing. It was in this context that the concept of integrated pest control was evolved. This approach minimizes the use of pesticides by combining them with other protective methods, including cultural practices such as removing or ploughing-in stubble to prevent pest survival in the field, and rotating crops. Biological methods include encouraging the natural enemies of the pest, developing resistant strains and the common-sense idea of using pesticides only if pest damage rises above an economically significant threshold, and ignoring damage if it is only minor. But the integrated approach still includes the judicious use of pesticides, and so, because many farmers in developing countries use no pesticides at all, a considerable increase in their use is foreseen.

There is likely to be significant increase in machinery use at farm level in future to meet timeliness criteria, remove labour bottlenecks and match other inputs for increased production. More attention will need to be given to the design of machinery for the conditions of developing countries, and especially to the needs of the small farmer. Mechanization will need to be backed up by an efficient management system, from the training of enough tractor drivers and mechanics to the supply of fuel oils and spare parts and provision for speedy repair. In ecologically sensitive zones the use of machinery must be combined with very careful soil and water management to prevent erosion and adverse changes in the water table. The nature of mechanization expansion will need to be related to developing countries' concern for retaining labour-intensive strategies in the agricultural sector. Such strategies will need to be carefully balanced with the concept that from the point of view of labour productivity in agriculture, and hence of income levels in farming, it would be preferable for the labour force to diminish in numbers, as in the developed countries, rather than increase.

The fourth main source of additional crop output is to increase the proportion of harvested crops reaching the consumer. Crop losses continue after harvest at almost every stage of the chain leading from field to table: during harvesting, drying, storage, milling and cooking. The average level of loss has been estimated at 10 per cent for grains and grain legumes and 20 per cent for less easily preserved crops such as roots, fruit and vegetables. Individual variations in the level of loss can be very great. Technology is available to reduce loss at every stage and at every level from the small farmer to the big city warehouse. For example, seeds can be bred to resist spoiling, more efficient drying procedures can reduce moisture content below the level at which moulds and bacteria grow, and storage containers can be improved. Pesticides are probably essential, but methods must be developed for distributing them in the limited quantities that small farmers will require, and for teaching farmers their safe and optimal use.

The demand for meat, dairy products and eggs is likely to rise faster than the demand for crops in developing countries, despite the implications in terms of energy cost. Livestock production systems in most of Africa and Asia are highly inefficient and offer much scope for improvement. In much of Africa and the Near East larger animals are reared by specialized nomad tribes, separate from arable farming. Animal health is poor, with high mortality in early life and slow weight gain. Pastures are badly managed, overstocked, burnt over and not fertilized. Over-grazing is one of the principal causes of desertification. A vast area of Africa, 700 million hectares, is virtually unusable for livestock production because of trypanosomiasis carried by the tsetse fly, a disease fatal to cattle, horses and sheep, and in humans the cause of sleeping sickness.

Technology is available to increase livestock production in four main ways:

1 Breeds can be improved and made more productive and disease resistant. Artificial insemination and embryo transplants can help with this.

2 Animal health can be improved by better veterinary service coverage and greater emphasis on disease prevention and control.

3 Research, training and extension work can lead to better management of herds and of water and pasture resources. Pastures can be reseeded with leguminous and drought-resistant species, and herd numbers can be brought into better balance with the carrying capacity of the range.

4 Finally, the most important, there can be greater use of cultivated fodders and concentrated feeds to reduce dependence on scanty and remote grazing areas.

In the interests of production efficiency, the possibility also exists of closer integration of livestock and crop production in developing countries, together with, in some instances, forestry and other agricultural activities.

Agriculture is only a modest consumer of energy. It accounts for 4.5 per cent of total commercial energy use in the developing countries and 3.5 per cent in the developed countries, excluding food processing, storage and transport. The use of commercial energy in the developing countries in agriculture production is only about one-quarter of the amount used in farming in the developed countries, and this differential is reflected in differences in yield levels. For any policy intended to transform developing country agriculture to become much more dependent upon commercial energy may seem paradoxical in an age of energy shortages and high prices. It is however essential if agricultural production is to increase adequately. In view of agriculture's very modest share in total energy consumption it is also a very reasonable increase. If it is necessary to allocate scarce energy, agriculture must be assured of its supplies at equitable prices. This does not mean however that agriculture should use energy carelessly. As the use of the expensive energy-based technology rises, it is in the interests of farmers (as of everyone) to use it with maximum efficiency.

There are many opportunities for improved efficiency in all the major uses of commercial energy in agriculture, and for diversifying energy sources by wider use of renewable resources. Apart from the fuel use of wood, the global contribution of agriculture to energy production in commercial forms is likely to be small, probably less than five per cent in the next few years. It is already evident however that in some countries energy from agriculture could become important. Longer-term developments at present seem uncertain, but they could have a major impact on world supplies and prices of some food and feed commodities, and this in turn could affect the whole agricultural economy.

What about research? Attaining the output goals depends to a large degree on effective diffusion of technical innovations in agriculture production systems in developing countries. It is therefore essential that the research basis of technological innovations be strongly supported. Furthermore, return on investment in agriculture research can be high, but this is not always the case in developing countries. Agriculture research in developing countries receives very limited resources (about 0.5 per cent of the agricultural income in 1980). In 1980 research allocation was less than a third of the corresponding investment in developed countries. The research base of the agricultural technologies should therefore be increased in developing countries to concentrate more fully on the urgent issues, and those which have the greatest chance of high pay-off, while still leaving sufficient funds for more basic and long-term investigations.

Research will also need to consider aspects of marketing and pricing policies in relation to the adoption of agricultural technologies. The relevance of research to national and local needs may be greatly improved by developing feedback systems through which farmers can be consulted about their needs and about the performance of new technology in practical situations. Farmers may also be involved in the research and development work at an early stage.

Past research has tended to give priority to export crops or irrigated crops. Perhaps more attention should now be given to the needs of arid regions, to rain-fed areas, to areas with problem soils or climates, and to subsistence crops such as legumes, roots and coarse grains, as well as to fruits and vegetables, which can improve the balance of diets.

The improvement of pasture varieties to increase the carrying capacity of ranges is another priority for some countries. In the last resort however efforts along these lines will remain disappointingly unproductive, at least on a wide scale, unless farmers have the means to apply the new technologies and incentives to incur the extra costs and to run the additional risks involved.

My final comment is on meeting the cost of applying agricultural technologies. Over the years investment in the form of aid, both multilateral and bilateral, has become an important part of the international framework of agriculture and will play a key role in the future modernization of agriculture in the developing countries. Difficulties can arise when large-scale, traditionally administered aid funds are invested directly in agricultural production. More attention might therefore be given in future to concentrating the use of such funds in areas of infrastructure and general technical assistance. Costs associated with agricultural production could then increasingly be met by private investors, both local and foreign. Such investments would include the provision of working capital for farmers through banks and credit agencies, and technology inputs through importing agencies and local manufacturing, servicing and marketing enterprises. Foreign investors and industrialists would need to recognize the interest of developing countries in achieving growth in joint ventures based on shared foreign and local equity. Political leaders in some developing countries suggest that the days of direct exports from the North to the South are rapidly declining for all but a few specialized industries and sophisticated technologies. Even in such cases an increasing amount of local work is undertaken through licensing arrangements. It is through such joint ventures that the necessary commercial base may be developed for sustained growth in agricultural production, supported by aid-funded infrastructure.

Conclusions

It is suggested that there are seven main requirements for applying agricultural technologies effectively in developing countries.

—research: to maintain the flow of basic ideas and information from which existing technologies may be developed, and possible new technologies formulated

—development: to advance technologies in a form which will bring them within reach of a wide range of farmers

—training: to provide the technical and managerial skills necessary to exploit the technologies in agricultural production

—instruction: to give regular and practical instruction and demonstration in the field to farmers

—aid funds: to build an infrastructure within which the necessary inputs to profitable agriculture can be provided, and from which markets can be reached

—commercial investment: to provide inputs to farmers to undertake the work of agricultural production on commercial terms

—governmental leadership, which will support, facilitate and encourage this approach in the interest of sustained levels of agricultural production.

Achieving a rapid transformation of agriculture in developing countries through effective application of agricultural technologies is probably the only means of winning the race between increased food production and population growth. Commercially orientated transformation is likely to strengthen the economic base of agriculture, thus contributing directly to national economic growth. Successful transformation of agriculture in this manner can probably feed the predicted twenty-first century populations in developing countries but is unlikely to employ them, at least directly. In the past, semi-stagnant agricultural sectors have held back industrial development in some developing countries. A technology-based approach to agricultural transformation may therefore be a prerequisite of sustained industrial development in growth in other fields.

It is estimated that in a hundred years' time more than 80 per cent of the world's population will be living in developing countries. The sustained growth facilitated by a rapid and commercially orientated transformation of agriculture could thus become an indirect but vital means of helping to meet future employment needs.

Chapter Five

SOCIAL ASPECTS OF TECHNOLOGY IN SOUTH-EAST ASIA AND JAPAN

Chairman: The Rt Hon The Lord Sherfield GCB GCMG

Editor's Summary

The fifth session of the MANTECH Symposium was entitled 'Social Aspects of Technology in South-East Asia and Japan'. In view of the particular importance of technology in modern Japan (as well as the Honda Foundation being a Japanese organization) it is not surprising that six of the seven speakers were from that country, the seventh coming from Malaya.

The first paper, entitled 'Technological Society and Cultural Friction', was presented by Dr Shinroku Saito, Professor Emeritus at the Tokyo Institute of Technology and, *inter alia,* Chairman of Japan's National Space-Shuttle Utilization Committee.[66]

Professor Saito began by tracing the progress of technology from man's earliest realization of the value of tools (marking one of his first differences from other animals) through the taming of fire and the use of other natural elements (wind and water) as sources of power, in parallel with superstition, fear and the development of religion—all contributing to the gradual evolution of communication by signs, speech and then the written word, and to the assembly of skills for thinking, predicting and planning future actions on the basis of past experience. This was how cultures began to take shape, and initially there was no serious friction between one evolutionary trend and another. But in fact different cultures were evolving differently in different places, and it was when one came into contact with another that friction became inevitable. 'Always,' said Professor Saito, 'there is a resistance to the alien culture which invades the blank portions of the home culture.'

In any such environment, he continued, science itself was selfless (and neutral). Science was nevertheless the basis of technology, and because technology could be part of an alien culture the spread of its effects through society made friction inescapable. Disquiet concerning new technology was thus to be expected and should cause no surprise. And despite man's adaptive capacity, which has enabled him to absorb many previous cultural shocks, he was (or very soon would be) faced with two crises. The first would be a tendency for societal groups, and particularly those based on the 'family unit', to collapse under the impact of advanced information technology. (People would be able to collect information, through their own different and individual channels, at any time and any place, so that families would disappear as information sources.) The second crisis, consequent on the first, would be that as future society reached 'technological saturation', human beings would become entirely controlled by the internal life information incorporated in themselves together with external technological information, '. . . just as insects incorporating all necessary life information are controlled by such information'.

'This is a problem,' concluded the professor, 'which intelligent man should consider calmly. But the present gives very little time for man to decide how to continue to be man.' It was at least encouraging that he appeared to believe such continuation—given the right decision—was possible.[67]

Professor Saito's extremely stimulating and intellectually provocative paper was followed by an equally impressive report from another (but certainly no less practically important) 'part of the spectrum'. Professor Ungku Aziz, Vice-Chancellor of the University of Malaya, presented a fascinating account of how changing employment patterns in his country were affecting the attitudes and conditions of young people—in this particular case, young girls from peasant country homes.

His paper[68] was in fact mainly a report on an experiment, conducted by his university, following the lives over a number of years of young girls who had allowed themselves to be persuaded to leave the normal life of peasant parents' homes for the brighter 'city lights'. Most such girls in Malaya were recruited, at ages between 16 and 25, to work in the new 'high technology factories' springing up in the industrial areas of the country. Some (the comparatively small fraction having sufficient funds) were able to enter university where a suitable initial qualification earned them a State grant. On graduation they could easily find employment offering salaries as high as ten times those of their parents, giving them the entrée to a growing stratum of young élite. Professor Aziz reported on his project with understandable satisfaction: it bore witness to the creation of a completely new body of highly skilled factory workers and junior executives, urgently needed and vital for the future wellbeing of Malaya.

Discussion

The temporal proximity, fascinating subject and masterly presentation of the last paper led to its virtual monopoly of the subsequent discussion. A first question to Professor Aziz concerned religion, giving him an opportunity to stress the 'easy-going religious tolerance' practised in Malaysia in this as in most other matters affecting society as a whole.[69] It was true—and probably inevitable in any such liberal environment—that deep passions could sometimes be aroused over religious or other 'fundamental' questions (hence the rioting in 1969, not since repeated). Generally speaking however extremist groups of whatever nature or philosophy were not well received by the people, who preferred moderation in all things, the 'golden mean' of Confucius.

A question from Professor Harold Lawson (Linköping University) concerned forward planning in Malaysia and whether this was comparable with the substantial current planning effort in Singapore. The question produced a somewhat scathing reply, to the effect that the cost of such operations, often leading to extravagantly ambitious and practically unrealizable proposals, rarely encouraged confidence that those responsible 'had their feet on the ground'.

On the other hand modest forward planning, such as was the ultimate purpose of Professor Aziz's study project, could be of considerable practical help, though even here the cost (of the order of £100,000) was quite high in relation to the expected benefit. Planning designed to increase both the size and the quality of Malaysia's technical and industrial workforce, as part of a general plan 'to make conditions attractive for the kind of industries we want to attract', was in fact a necessary part of the country's development programme; and here the professor seemed more content with what was being done. He agreed wholeheartedly with what had been said in the previous session (Chapter 4) about sending students for training in the colleges and universities of advanced Western countries, and said it was Malaysia's policy to change, radically and as rapidly as possible, the current situation where '. . . out of 5,000 qualified, professional engineers, there are only 50 Malays'. The plan was to raise the national percentage to 40, and for this purpose a system of local and foreign scholarships was in operation. 'Last year,' he said, 'we sent 3,000 students to America . . . we have 17,000 students in Britain, and are thinking of sending students to Germany and France.'

Also, with substantial financial help from the Japanese government, Malays from peasant areas were being trained in the Japanese language, with the intention later of sending some hundred students a year to study science and technology in Japanese universities. A much more viable investment, at least for the immediate future, than in grandiose planning far beyond practical possibility!

Replying to a question from Dr Harold Chestnut (US General Electric), Professor Aziz confirmed that the young women referred to in his paper were 'mostly the daughters of peasants . . . from rural areas'. Four-fifths of them were Malays. They came from the 'lower portions' of the social scale, so that when they acquired new skills—for example in electronics—they constituted an addition to the existing 'higher level' workforce coming from middle-class urban homes.

However, the professor stressed that other openings were available to the determined country peasants. For those who could acquire a first educational qualification (equivalent to a British A-level) university scholarships could take them to the highest academic—and subsequently administrative or technical—levels.

A last question came from Professor Shuhei Aida (Honda Foundation Director), who surely put into words the thoughts of many of those present by enquiring what effect the 'industrialization of the Malaysian peasant girls' was having on their native culture.[70] Was there, asked Professor Aida, any special industrial policy in Malaysia based on culture?

Professor Aziz replied with one word: no. 'In fact,' he continued, 'this is a great problem. Many of the factories move into tax-free zones, where they can set down a factory just like a spaceship, and they are not interested in culture. They are interested in disciplined workers with nimble fingers, and they pay reasonable salaries, and that is all.'[71]

In an endeavour to compensate for this, considerable efforts were being made by members of universities and associated institutions to sponsor dance groups, music groups and similar activities based on traditional native cultures, and to persuade the media—especially television—to support or where necessary help revive these traditions.

Sometimes peasant girls from the factories, who had previously practised such activities in their home environments, welcomed the chance to continue by giving performances in the universities. Thus for them the universities were cultural centres where they had an opportunity to pursue something which they believed (rightly) to be particularly and uniquely theirs.

But these native cultures in Malaysia were in confrontation and competition with the almost overwhelmingly superior forces of external cultures: on the one hand those from China—very powerful, very active and very well financed; and on the other hand 'the whole of Western culture, coming through the media in a not very attractive quality'.

The problems posed were easy to see and not difficult to describe. They were much debated in circles of intellect and culture; but their solutions remained (apparently permanently) elusive.

The next paper was by the last questioner, Professor Shuhei Aida, whose presentation (though nominally concerned only with Japan) was in a sense the technological complement to Professor Aziz's story.[72]

Professor Aida began by suggesting that of all the possible and extremely important impacts of advancing technologies, those related to electronic information processing and communication were the most likely to affect (and be affected by) cultural or intellect-based traditions and activities. That was why recent technical advances in these fields were of such vital social significance—particularly the spectacular reduction in physical volume and costs of equipment, combined with enhanced technical capacity and greatly increased rapidity of response to data input and output demands. All these improved techniques, together with developing ability to place and maintain communications satellites in precise (geostationary) orbits round the earth, would certainly increase the capacity, reliability and hence the uses of long-distance information transmission and exchange.

More mundane but no less significant developments included electronically operated 'home banking', library operations, consumer shopping and—perhaps the most important—home schooling and further education.

This led the professor to a particular concept of information which embodied what he termed 'feeling data', a class of data comprising both numerical-type data and '. . . some form of evaluation or classification based on the results of macroscopic observations'. Such data already played a major part in human-to-human communication, and could be expected to become increasingly important in electronic intercommunications systems, which were themselves becoming increasingly involved in 'holistic' information exchanges between human intelligences. Indeed, Professor Aida took the concept of such holistic exchanges even further, linking them with the forms of communication between 'man and his maker' which are fundamental to theistic beliefs.

It would be inappropriate for a non-oriental to attempt in a few lines to pursue this further, particularly in view of the professor's final remark: 'Japan's religious basis is very different from that of the West. Thus we have a completely different concept of communication in Japan compared with the Western countries.'

Another contribution followed from Japan, that of Professor Kazuhiko Atsumi, Director of Medical Electronics at Tokyo University and a pioneer in his country of computer-based medical records to enable any doctor, consulted by a patient at any time anywhere in the area covered, to obtain the patient's medical record, including former treatment(s), by interrogation through a local access terminal.

Dr Atsumi's paper[73] briefly considered the possibilities, and problems, of setting up such a system for the principal hospitals throughout the ASEAN (South-East Asian) area, a system which, he said, could provide maximum benefit with the minimum of resources. However, such a system would clearly require substantial initial investments–including the use of at least one communications satellite, several linked computer networks and related data-collection and transmission systems based on large numbers of microcomputers. Nevertheless it could be brought into existence by stages, provided its initial structure were designed to allow expansion as necessity required and circumstances permitted.

Professor Atsumi has for some years now been advocating this type of medical information system, already in operation in some other countries besides Japan, notably parts of Sweden. In his paper he did not touch on attitudes to 'automated diagnosis' either of patients or of doctors, both known to have questioned the (real or imagined) loss of personal interrelationships such a system could imply. While in fact there seems no doubt whatever that the necessary technology is already available it may still prove essential, if confidence and trust are to be maintained, to find a way of preserving these much-cherished personal interrelationships.

Two other interesting proposals were included in the professor's paper. The first was for the 'recycling', in the medical services of ASEAN countries which could not afford large purchases of the very latest diagnostic and treatment equipment, of 'previous generation' equipment currently standing idle in the hospitals of the most advanced Western countries. Such equipment could be modernized and adapted to meet different operating conditions comparatively easily and cheaply.

Professor Atsumi's second and particularly interesting proposal was to use nuclear-powered ships to carry emergency aid, both medical and more general, to ASEAN areas where natural disasters had deprived large sections of the population of food, shelter, power and other supplies. Although he did not say so, it might be relevant that Japan possesses a nuclear-powered ship which could be adapted for such purposes on a 'pilot' scale.

Next, and as background to Professor Atsumi's presentation, one of his co-workers in the Tokyo Institute of Medical Electronics, Professor Toshiyuki Furukawa, had prepared a short historical analysis of medical training in Japan from the start of the Meiji Era (1868) to the present day. This account[74] was particularly interesting because it also covered the general development of scientific and technical training, and for those not very familiar with Japanese history over the past century it offered a new insight into how that nation had achieved, far more rapidly than the other highly developed nations of today, its own industrial revolution and associated scientific and technological expansion. For details the interested reader is referred to the full text of the paper: suffice it to note here that the key to all had been education, education moreover within a system which had given considerable attention to expected future demands in the various technological and other disciplines which together comprise a truly literate society.

That this orientation had not led to protests over infringement of liberty in choice of careers was a tribute to success in convincing young people that a scientific or engineering choice was best for them (cf. the comments of Professor Hambraeus on this matter in the second session). Professor Furukawa's paper also drew attention to the very high proportion in Japan—compared with industrialized Western countries—of first-degree graduates in the applied sciences in relation to holders of degrees engaged in research. Japan had embarked on 'mass production of the manpower necessary to improve scientific technology for practical use', whereas the other countries (notably the United States and Britain) appeared to have preferred 'mass production of B and C class scientists' to support the 'development of class A scientific research'.

Professor Reikichi Shirane, President of the Telecommunications Science Foundation in Tokyo, next contributed a speculative view[75] of the 'Advanced Communications Society' of the twenty-first century, still almost two decades away but—at least in Japan—already here in essence.[76] The professor foresaw an almost universal use of personal computers, not just individually but as active access terminals coupled to much larger systems with which the information flows would certainly be in both directions. The larger systems would provide for exchange, for those who might wish it, of constantly updated and upgraded information in virtually every field of knowledge and intellectual activity. Moreover, Professor Shirane foresaw a plurality of information networks, so that no one could have a monopoly of communication and users could escape what many regarded as a serious danger—the danger of controlled information leading to a controlled society. 'However advanced the technological systems may be in the future,' concluded the professor, 'most of the critical planning and defining of objectives, the collecting and editing of information, etc., will still depend on man. It may be said therefore that the highly advanced age will be an age in which man's intellectual faculties will play a decisive role.' For anyone with doubts as to who or what was going to be in charge of the future, this was certainly most reassuring.

The session concluded with a fact- and figure-packed review, by Professor Toru Yoshimura of the Saitama University Graduate School for Policy Science, of the relationships between 'Economic Growth and the Technological Revolution'. This was no theoretical forecast of what might happen in the future (though it had its lessons for such exercises) but a factual record of what had happened, in Japan and elsewhere, and a list of questions to be answered concerning the future expansion of science and technology for the national benefit.

More than half this paper[77] comprised tables and graphs illustrating the evolution of Japanese expenditure on research and development during the past two decades; comparison with equivalent evolution in other 'major countries' (France, the German Federal Republic, the UK, US and USSR); the distribution of that expenditure, in Japan and the other countries, by sector (university, research institution, industry) and by type of work (basic research, applied research, development research); the relative shares of industry, government, research institutions and universities in funding these programmes in the various countries; and the numbers of workers (researchers, assistants, technicians, etc.) involved. All these data are of profound interest, and make the professor's text particularly worth study. Just two points may be noted here:

> Japan, with virtually no indigenous resources of oil, had managed by rigorous price controls to maintain a real growth rate of more than five per cent per year every year since 1976.
>
> In the five years from 1975 to 1979 Japan had achieved a 42.8 per cent increase in labour productivity in the manufacturing sector, whereas the increase in the same area was less than one per cent in the US and England, and approximately 25 per cent in Germany and France.

Naturally such remarkable expansion had not been universally welcomed elsewhere. But it had certainly helped to focus world attention on some of the social and cultural consequences of 'explosive' technological development, hence on some of the new and daunting challenges presented by that development. The subject of MANTECH in fact.

Discussion

This last and the other papers of the session provoked considerably more discussion than in the previous sessions, partly owing to the encouragement and tolerance of the chairman. The most commonly raised subjects concerned the organization and financing of research and development programmes, motivation and communications in research and industry, and technical education and training. In this last field there seemed general agreement that Japan had been more successful than most other countries (all other 'advanced' countries) in persuading a large portion of her youth that a career in science and technology was a valid fulfilment of life's purpose rather than something to be avoided as 'dirty' and even immoral, while thinking beautiful thoughts on the way to disaster.

However, the first intervention concerned Professor Atsumi's proposed integrated medical system for the ASEAN area. Professor Sixten Abrahamsson (Swedish Medical Research Council), who had been closely involved in the more geographically limited system in the Stockholm region of Sweden, recalled that several similar systems had been established in various countries, but that extending them beyond a single hospital unit had usually proved difficult, so that they had remained local rather than regional systems. Yet the real economic and social benefits of such systems must surely increase as more hospitals and medical units over a wider area participated. Professor Abrahamsson believed the advantages of this wider integration were not yet appreciated by many doctors and (above all) administrators.

Professor Atsumi agreed. Within Japan this was generally understood, and the government was setting up a 'network of health-care systems on a regional basis'. Both hardware and software for the computers were expensive, and efforts were being made to develop 'common' software for use in a shared system.

Financial problems had also delayed progress with the ASEAN project. However, with the recent arrival of comparatively inexpensive and easily programmed microprocessors, the prospects for progress were more encouraging. Use for the system of the planned ASEAN communications satellite had been offered, and this took the proposed system from the realm of dreams to that of practical possibility.

Relations between industry, education and research were the subject of an intervention from Professor Harold Lawson (Linköping University), who drew attention to the 'tradition' in Japanese industry that 'university graduates are given at least two years' education by the companies they start to work for', a supplementary education unparallelled elsewhere in the world. However, these well-equipped young scientists and technologists tended to be transferred, often before their fiftieth birthday, to administrative positions, their services then being lost to further research and development.

Professor Yoshimura confirmed both these facts, maintaining that 'on the job' post-university training was normal not only in Japanese industry but also in government offices and other administrative institutions. The role of the universities, he maintained, was 'to produce high-quality students' by 'developing' those with ability and 'screening out' those showing less promise. However, schools of science and technology were regarded more as finishing schools for their graduates, although frequently further training was still expected—and offered—after entry into industry.

As for the transfer of successful R & D personnel to administrative posts, Professor Yoshimura said it was considered beneficial for industry to be run by people with practical understanding and competence in the technologies involved.[78] He believed universities could benefit from similar employment of more professionally experienced personnel, and indeed two 'technological universities' had already been set up with teaching staff drawn from industry.

Turning to the 'traditional universities', the professor was precise in his remarks: 'We do not expect much,' he said, 'from those of our administrators who have studied [only] at university—especially social science graduates.'

This prompted Dr Robert Frosch (US General Motors Corporation) to point out that the quality of science and engineering graduates also varied widely in other parts of the world. 'In some places,' he said, 'a Bachelor of Science degree merely means that the education does not include any qualification in a foreign language. There are schools which award Bachelor of Science degrees in home economics. In some cases it is a science degree, but in some cases it is not. There are Bachelor of Science degrees in physical education. In some cases it is science and in some cases it is sports. The same is true of a Bachelor of Science in business administration.' This might well explain at least a part of what Professor Furukawa had described as '. . . the great number of Bachelors of Science in the United States and Great Britain'.

Whatever might be the truth in this matter (and there could be little doubt that the United States situation described by Dr Frosch had its parallels elsewhere) it could hardly affect the fundamental axiom that progress in science and technology was unachievable without scientists and engineers, and that the quality of that progress was dependent on the quality of those scientists and engineers. It was no less axiomatic that new research and new discoveries were of no practical use to mankind unless and until they could be applied to the resolution of its problems.

It was for these reasons that Professor Umberto Pellegrini (Milan University) proposed some research on the application of research—on 'how to apply the technologies we already know'. The advanced countries, he said, were bombarding the developing countries with material investments of hardware; but they were neglecting to invest in men, although by definition men comprised the very basis of society.

The professor wished to see a renewed effort in the transfer of appropriate technology,[79] in which information and information technology must clearly play parts of increasing importance. That technology had made possible, at last and after centuries of centralization on societal structures, a new form of decentralized structure which would prove the antithesis of what had gone before. That above all was why 'appropriate technology transfer' must not comprise the advanced countries disburdening themselves of their obsolescent technologies and equipment, but must instead involve a determined effort to transfer the most suitable technologies from the recipient's point of view, however ultra-modern (or perhaps old and unrefined) these might prove to be. 'I hope,' concluded Professor Pellegrini, 'that Japan, Europe and the US will increase expenditure on R & D, but mainly on studying how to apply R & D, on how we can apply technology to different countries.'

Professor Aida (Honda Foundation) was in strong agreement. 'Engineering,' he said, 'starts from human feelings and philosophy–then comes technology, then engineering.' The need now was for feedback to the human mind, so as to generate new concepts of industrial policy rather than new hardware systems.

Professor Thomas E Sheridan (MIT) also supported Professor Pellegrini, wishing to see more attention given to 'the philosophies' of information technology and communication. Evidently impressed by Professor Aida's earlier references to 'feeling data', he pointed out that the inclusion of this element implied response or two-way communication–the interaction between transmitted information and its recipient(s), as had been emphasized by Professor Shirane.

From a 'simple' technical viewpoint, that meant two-way communications channels with increased bandwidths. For many years it had been possible, at least in America, to hold symposia such as MANTECH without bringing all the participants to the same physical place, and this simultaneous two-way sound and vision transmission already provided some degree of 'feeling data' exchange: in addition, elementary vicarious physical contact was feasible if not commonly practised. 'In my laboratory,' said the professor, 'we have a system where we can shake hands in Massachusetts with someone in California through a mechanical two-way manipulator device.' But he believed there was need for 'something much more subtle than simple bandwidth, that (so far) we have not been very successful in embodying in the technology'.

However, Professor Sheridan also saw a possible danger, in that the exchange of 'feeling data' by electronic means might damage–or even destroy–the direct personal communications which underlay so much of present-day social interaction. The Japanese, he noted, had been particularly successful in 'embodying close personal communications between workers and managers in making production happen'. Were they worrying, he asked, whether the intervention of more electronic communication might upset this 'very wonderful personal communication that they have achieved'?

Professor Reikichi Shirane agreed that the question was extremely important, particularly for the Japanese who regarded their workplace as a community, often (for those who had left their original country-village communities to work in industrial areas) the main or only community in their lives.

The professor did not believe the new electronic communications (the 'electronic cottage' or the 'home office') would change this, though certainly they would be helpful in enabling handicapped people, those suffering from temporary minor illness or those with young children in their charge to continue working–and to maintain their liaisons with their workplace communities–via electronic home terminals.

'Intellectual activity in an office,' concluded Professor Shirane, 'involves discussion among many people, and people understanding each other. This important function relates to the place of work, and is very important indeed. It is something that cannot be replaced by gadgetry.'

To which Professor Aida added: 'Although the word "communication" was imported into Japan from abroad, we have our own concepts of communication in Japan. Communication between man and man can be maintained only on the basis of mutual human trust, not by contract. We are a very spiritual society in Japan.'

The remainder of the discussion was principally concerned with Professor Yoshimura's paper, beginning with an intervention from Mr Barry Grime (English Clays Lovering Pochin & Co), who sought clarification of the relationships between Japanese universities and industry. He was particularly interested in the professor's hopes for a 'competitive environment' for the universities and the research institutions, and wished to know whether these institutions agreed that they could be more effective, and whether they were willing to change.

Rather than answering these questions directly, Professor Yoshimura preferred to explain why the university environment was not competitive. It was, he said, owing to the system of funding university research, which was institutional and automatic irrespective of whether the research produced results. This could encourage the researcher to pursue dilettantish byways, or simply to become lazy.

The system was in complete contrast to that in United States universities, where institutional funding was 'low or unstable and researchers must seek out project funding'. Professor Yoshimura believed that optimal funding lay somewhere between the American and Japanese extremes, and that this would provide the 'competitive environment' which he advocated for his country's universities.

Replying to a further question from Mr Grime, the professor explained that the low expenditure per researcher in Japanese industry, as opposed to a university researcher (Figure 31), was due to earlier industrial traditions which did not regard basic research as important. 'The seeds of research,'[80] he said, 'were brought in from abroad and the emphasis was on development.' Industry had also believed that basic research could be a 'risky area', involving long lead times even for successful developments. The view was easily understood if not defended: it would probably prove necessary for basic research in industry to be given some government support before expenditure reached similar levels to those in universities.

These remarks provoked a number of observations from Dr John Collingwood, who began by stressing the vital long-term importance of basic research, without which all the subsequent benefits (or 'disbenefits') of applied science and technology could not be conceived, let alone realized. Pointing out that all human action depended on incentive (even 'instinctive' action depends on instinctive incentive), Dr Collingwood believed there were three obvious incentives to do research: curiosity (which he thought very rare today); publication (which though strong in universities was less important in industrial research); and the esteem of colleagues, which he considered the most important of the three—although all too frequently absent and especially in laboratories where the research was government-sponsored and funded.[81]

He concluded from this that basic research in industrial laboratories 'on any other basis than that of wanting the results within the company' was a waste of money, and he felt it would be better for most research work to be done in universities, sponsored and financed by industry or government or both.

Professor Yoshimura was unable to agree. He said that a recent OECD study of the origins of technological innovations had in fact shown it to be rare for new discoveries to be made in universities, even in the United States where much basic research was carried out in these institutions. Of 529 Japanese discoveries examined in the OECD study, only one had been made in a university. This suggested that universities were far better at providing basic training than at doing basic research, which need not imply condemnation of the universities.

The matter of incentives was taken further by Dr Robert Frosch (US General Motors), who said colleagues visiting Japan had reported that government-paid university professors, should they undertake extra-mural consultancy work for industry, were not allowed to receive additional fees. Dr Frosch believed this must be an important disincentive: by contrast, it was common in the United States 'for a Professor of Engineering or Science to add to both income and prestige by working with industry'.

In reply to this Professor Yoshimura said that although such a restriction on receiving external fees did exist in his country, it applied only in 'national public institutions', which comprised only one-fifth of all universities and colleges of higher education. Professors in 'private institutions' were not subject to such rules, which in fact were in course of being relaxed to avoid state-paid professors being at a disadvantage.

Professor Harold Linstone (Portland State University) also had a comment on Dr Collingwood's remarks, pointing out that because industry must normally be profitable or go out of business, it was not surprising that research offering no early prospect of profit failed to receive enthusiastic support. However, an arrangement that was being increasingly adopted involved joint industry and university research teams working in 'science centres'created for the purpose. Professor Linstone cited a number of such centres currently in operation or being established.

Professor Yoshimura said this was a concept not yet adopted in Japan, although research co-operation between government and the private sector was the subject of much current discussion.

Concerning investment in research, Professor Bradley Richardson of Ohio State University reminded the meeting that greater investment did not necessarily lead to better results. He believed that 'very careful targeting' by the Japanese administration was ensuring a more effective use of funds than in the US or the UK and other European countries, although such comparisons were made difficult because separating the costs of defence research from the overall programmes of these countries was virtually impossible. Professor Yoshimura's charts made no attempt to do this: nevertheless there was a strong suggestion that Japan was getting 'more for less'.

Professor Yoshimura agreed, but also pointed out (a) that Japanese government expenditure on research, although very large, was mostly confined to nuclear reactor safety studies, space development and marine development; and (b) that very little of this funding reached private industry, which was therefore mainly dependent on its own resources for its own research. However, a more complete and co-ordinated policy for all technological research was now being followed, and some important breakthroughs were to be expected.

Finally in this session, there was a brief return to speculative enquiry as Professor Olaf Lidin (Copenhagen University) posed the question of what could or should be done with 'all the rubbish' which the advance and expansion of communication seemed inevitably to stimulate. The question had in fact been raised by the Senior Fellow at the opening of the Symposium, and Professor Saito had been able to offer some reassurance when he said: 'Individual human beings will be forced to absorb unlimited amounts of information by the information society, but they will gradually learn that they are capable of selecting the information they require.'

Professor Lidin observed that Europe, and 'advanced' countries elsewhere, were already flooded with rubbish in the literature and the media, and he had noticed that the Japanese scene was rapidly developing in the same direction. He wondered what his Japanese colleagues thought of this trend, and whether they shared the optimism of Professor Saito.

Professor Aida admitted that he found the situation very worrying. The information society, he said, was based on 'three Cs—Communication, Control and Command, and I—Intelligence, but not on information'. Perhaps not everyone would have agreed with this, but no one could dispute Professor Aida's complementary and concluding remarks: 'We need intelligence more than information. That is clear.'

EDITOR'S NOTES

66 For the full text of the paper see page 211.

67 Professor Saito's paper, and his conclusions, are particularly difficult to present in summary form, and reference to his full text is strongly recommended.

68 For the full text see page 219.

69 The question to Professor Aziz was based on a different view, in a recently published book, suggesting a significant revival of Islamic practices among Malaysian women. That, maintained the professor, was both inaccurate and misleading; for example, of the 1,800 Muslim girls in his university only five 'preserved themselves' totally covered in their dress.

70 The question was clearly only a particularized form of the general one comprised in the title of the MANTECH Symposium.

71 Transfer of technology in action?

72 For the full text of Professor Aida's paper see page 228.

73 For the full text see page 231.

74 See page 233.

75 For the full text see page 237.

76 The author of the present commentary, following his first visit to Japan many years ago, recalls describing it on his return to Europe as 'the country where the future has already arrived'.

77 See page 240.

78 Cf. remarks by Professor Feshbach and Dr Frosch in Session Three.

79 'Appropriate' in Dr Patel's sense of being correct for a given application at a particular time, without closing options for other technologies as they became more appropriate to changed circumstances.

80 Plus some of the fruit?

81 Cf. Professor Yoshimura's earlier remarks. Dr Collingwood might have added that the esteem of senior—even non-scientific—colleagues could prove a very powerful incentive indeed when expressed in terms of increased salary, responsibility, or investment in the research.

Incidentally his downgrading of the incentive, within industry, of publication must surely have been based only on European experience. Those familiar with the American computerized 'Citation Index' could hardly dismiss this (despite its manifold and manifest anomalies) as industrially insignificant!

5.1 Technological Society and Cultural Friction

Shinroku Saito, Professor Emeritus,
Tokyo Institute of Technology

Preface

The Industrial Revolution which put forth buds in England in the latter half of the eighteenth century gradually began to sweep over the whole of Europe and America, thereafter penetrating into Japan, Russia and other countries. This fact most eloquently testifies to the scale of the impact technology produces upon society.

The major factors facilitating the expansion of the Industrial Revolution were that people wanted to realize an 'advanced society', an 'affluent life', 'efficient functions' and a 'bright vision for the future'. As a result of the Industrial Revolution the agricultural revolution, traffic revolution and urban drift of population advanced, causing changes in production and employment and sweeping aside the previous feudal economic ideas. However, democracy divided into bourgeois and socialistic camps, each camp adhering to its own values without giving approval to those of the other. Under such circumstances, because of premonitions of war, people have always been frightened.

Technological advances have recently been dramatically accelerated. The 'information age' threatens to reduce the importance of the three major elements of life, namely food, clothing and shelter. Such a high-technological society is already close at hand.

At this moment, therefore, we must reconsider what technology means to society and culture, in addition to preparing ourselves in anticipation of the life and psychological friction which the advanced information age is likely to create for individuals who are the microscopic elements from which that society and culture are formed. It is in this context that I would like to refer first to matters relating to technology and science.

Technology as Skill

When did the being called *Homo sapiens* come in contact with technology? We must trace a path back to remote antiquity when man used his hands as tools to remove small branches from trees or to throw stones for one purpose or another. Man's hands were really tools. After he acquired some actual tools he faced the problem that the tools he had obtained were not capable of doing everything he wanted them to do. He then achieved his purposes by improving the tools in his possession. He may have tackled larger branches by using something sharp which was harder than the branches he wanted to cut down. At this point his activities assumed a form quite different from those of other animals.

Contact with fire made the differences between man and other animals increasingly conspicuous. Man did not come into contact with fire suddenly or by chance. The phenomena of thunderbolts, volcanic activity and spontaneous combustion in the forest were everyday occurrences. But while other animals feared fire and did not approach it, man approached and began to utilize it. He did not touch fire directly but acquired a primitive control using pieces of stone, kindling and other things.

Some time later he became capable of making fire when and where he wanted, for whatever purpose. It was about this time that 'skill' and 'thought' were born in a primitive way. However, man was unable to adapt himself properly to the overwhelming strength of nature. There had been an extremely long prehistoric era during which man believed that gods and goddesses existed in nature who created fear to escape from which he offered prayers to them. Deities of blessing and of protection derived from those of fear, and formed a primitive polytheism.

At these stages technical skill in workmanship naturally made progress, and the images of gods and goddesses of fear and evil were left to posterity. Most of the people living at this time did not have a written language or other methods by which to hand down their history to future generations.

Even though technical skill was the result of many years' toil and experience, the people living in those times thought it had been given by a god of blessing in the infinite past, and such skill was attributed to the god who governed technical skill.

Man recognized the passage of time, seasonal changes and the orderly movement of heavenly bodies. He also came to know that even technical skills were repeated according to a fixed process, so that when experience was accumulated and properly adjusted it was possible to make predictions. The gods, with their anger, arbitrary manner or grace, responding to the acts and desires of man, began to appear as the deities who governed the laws of nature; thus most classical science was born in the name of the laws of the gods and goddesses.

Constancy and Friction

When a degree of constancy was thus introduced, that is to say when science appeared for the first time, nature–the overwhelmingly powerful object of man's fear—could be divided into predictable nature and unknown nature. A portion of predictable nature was gradually turned into controllable nature, and technical skill was gradually established as technology, beginning with those facets of technical skill which could be controlled. What made this conclusive was the development of languages as communication media, and the progress of symbols, signs and ancient hieroglyphs.

By virtue of languages and these other information media the basic conditions required to collate fragmented knowledge from various places and ages were achieved: history was introduced to man. History is closely connected with the events of today: we can learn of the past without the experience of living in the past. But will it be possible for us to carry the past into the future? The present is something like a thin skin separating the past from the future.

It is not impossible for the past to penetrate through this thin skin into the future, provided the future has the same structure as the past. However, historic events extracted arbitrarily from the past will not necessarily be in accord with future events, since there are aspects of the past which are not necessarily desirable and there will be aspects of the future which will be desirable. Therefore the present should not merely be a thin skin which unconditionally permits the past to be carried through to the future. It should be a selective thin skin capable of distinguishing between the desirable and the undesirable past.

The eyes for selecting the past, namely the criticisms of history, gradually bring about the establishment of primitive politics and a legal system. These should not only judge current events, but should also be in line with those future events which man deems desirable. Although these may not mean the same thing to both the ruler and the ruled, and they may or may not operate in a positive manner, man will come to recognize the present as a point of contact between the past and the future. It is at this time that the search for rationality and objectivity will begin. In other words, cultures begin to take shape as history itself is shaped. When one culture comes into contact with another cultural friction is always caused; there is a resistance to the alien culture which invades the blank portions of the home culture.

Science and its Laws

We have discussed the birth of culture and friction among different cultures in a very classical way. In a more refined concept, friction is a form of exchange. When a culture is capable of tolerating the antithesis on one hand while enduring the pain of friction, the culture can attain full growth dialectically. This conceptual structure has repeated itself in later times and even today in connection with the growth of culture. This is the reason why the author has sought the roots of culture in ancient times in a very simple manner: he hopes he has succeeded in explaining his position with reference to culture and the relationship between culture and technology.

The flowering of scientific cultures has created modern Europe. Europe gathered the sources of knowledge from the Middle and Near East, from Greece, India and China, until together they formed a large river. Of all the cultural ideas, that which has been handed down from generation to generation is that of 'corroborative evidence'. Substantiated theories have made it possible for the small streams of knowledge gathered from various places to converge without causing any inconsistencies.

Now, in place of the overwhelming nature, science increasingly threatens to overwhelm and control man's future. How should we cope with this situation? As far as the expression of natural science and technology is concerned can we think of the present as a link through which the past can be transmitted to the future? Or should we think that nothing but science can penetrate through the present as a window on the future? In order to discuss matters from this standpoint, it is necessary to discuss science, technology and the scientific mind separately.

With respect to science, a positive view of nature involving men is taken. This is the case with medicine, psychology and the life sciences. The positive consistency penetrates through the present as a window to the future. As with the heliocentric theory of Copernicus, discussions of the past are identical to discussions of the future. In order for the law of nature to be universal it is necessary to be reproducible and repeatable. Anything experienced only once that cannot be reproduced or repeated cannot be scientific.

It may be said, therefore, that science is purely objective, and that a culture which exists on the extension of experience is denied by science. Such a culture may be accepted as tradition, custom or emotion, but cannot be allowed to pass through the window to the future. It is destined to be forgotten sooner or later.

All conventional cultures differ from modern comprehensive science, and this is attributable to the fundamental nature of science. Moreover, by virtue of its corroborative evidence, science penetrates into culture in an interpolative manner without being resisted by culture. This phenomenon has not occurred in history.

The contact of different cultures began with criticism of the incompleteness of each. Whether a culture refused to accept another culture as an invasion from a different dimension, or eventually accepted it as a revelation of a new world, was a problem to be faced by the cultures involved. However, only the pliant cultures which absorbed such refusals and acceptances as transitional phenomena have continued to survive. In European society in particular, things Greek and things Roman repeatedly underwent exchange and substitution. But today, when scientific culture has accumulated enormous power, such exchanges and substitution are not possible. The rule of this overwhelming science has made all other things insignificant in comparison.

Among other things the utility of technology, which combines science and technocracy, has already brought about large changes in human society. In improving and controlling nature through agriculture, the 'slash-and-burn' method and the farming method using fertilizer belong to the same dimension, despite the fact that there was a very long period between their development. If only one of them is to survive, it will be farming using fertilizer. The idea that the farming method with more utility will survive will not change.

This idea is based on the same principle on which the slash-and-burn method continued for several thousand years until replaced by the mechanization of the Industrial Revolution, electrification and the use of chemical fertilizers. As a final stage of the Industrial Revolution, society is now advancing towards a highly advanced information age.

The new technological innovation differs from conventional technological innovation which was always accompanied by expansion of the material economy. It should perhaps therefore be considered the forerunner of a completely new age which will terminate and replace the Industrial Revolution.

The information age promises the ability to analyse and integrate all matters in an objective manner beyond the scope of man's intellectual faculties and mental activities, and it seems certain that technological innovation will expand regardless of approval or disapproval. We may well witness the collapse of a culture and the beginning of a new age: the age of the information revolution.

Technology and Man

Let us return to what technology means to man. The term 'information revolution' is not intended to exaggerate the implications of the coming information society through the use of the word 'revolution'. Man sought sufficiency and expansion in food, clothing and shelter through the agricultural and industrial revolutions.

The information revolution however has something not found in those revolutions. We have to recognize that it belongs to the dimension in which physical distribution (the basis of the conventional distribution economy) also belongs. Since the information revolution is directly connected with technology itself, the objectivity of science threatens to overstep the confines and the scope which man has created for it. We must question whether confrontation with the information revolution is going to harm or even alienate man.

First, how can confrontation with technology harm man? Techniques and technologies have changed his life. Parallel with changes in his economic life, the structure of social life has changed continuously throughout ancient times, through despotic early history, the monarchical medieval era and the democratic modern age. Technology has altered the family environment from groups, divisions and large families to small families based on husbands and wives. The nuclear family and ageing population are not exceptions. Since these changes were in step with the industrial economy, they occurred slowly in ancient times and more rapidly in modern times. Today most people can observe great changes in their lives. After World War II the pre-war family system was enormously changed: in Japan it virtually collapsed.

Although blood relationships have naturally (and necessarily) survived, the concept of a head of family as its spiritual leader has largely disappeared, and the views of old people are often disregarded. Man in the remote ages must have seen the collapse of leadership within tribes. Changes in modern times are so rapid that people are responding in different ways, a fact which causes emotional and psychological problems. Even those who have quickly adapted themselves may well feel sad about some of the changes in their environment.

Many families are annoyed when their children become juvenile delinquents. Such families often lack 'folk ways', and today there is nothing to replace those missing elements of life. Poor school education and the cultivation of sentiment, especially for infants, cannot catch up with rapid changes and their families do not have folk ways common to all the members of the family. These are factors which often make young people cause continuous trouble. It could be said that this is the result of continuing Industrial Revolution penetration of every civilized country in the world today.

In the fields of both politics and economics, the existence of the family as the basic social unit is still generally accepted. But when the high information society appears people will be able to collect information, through their own different channels, at any time and any place, and families may well tend to disappear as sources of information. Even among parents and children information will be strictly isolated, and so will values.

Life science (the 'science' of living), which was launched at the same time as the information revolution, may be expected to make progress. However, such progress will be highly technical. People will enjoy the technical benefits, but it will not be capable of uniting family members again. It will analyse life in a more objective way. The information and life science complex may gradually rob human beings of their identities, just as they may lose their role as information assessors.

Man and Science

We have discussed how the development of science will rob human beings of their identities. In accordance with the argument presented, the past and the future may be expected to merge completely into each other. There will only be repetition: 'time' will disappear.

It is possible to give two different examples. The first comprises the Mayan and Aztec civilizations, which disappeared suddenly at the peak of prosperity. There are several possible explanations. When prosperity reaches saturation point, and when it is impossible to escape from the repetition of the same pattern, 'time'—leading to tomorrow—will disappear for that particular culture.

Secondly, each species of insect, amphibian, fish, etc. has a fixed pattern of laying eggs, ontogeny and growth, to the extent that the ecological information incorporated cannot respond to environmental changes. Physical time still passes, but the already complete information controls the individual, and it has no 'time' of its own.

The basic problem raised by the information revolution facing human beings today consists in the implications of 'time' and man. Similar to the first example given above is that of the future society which has reached saturation point in terms of technology. With respect to the second example, human beings, structural microscopic elements of society, will be controlled by the internal life information incorporated in themselves together with external technological information (overwhelmingly by the latter), just as insects incorporating all necessary life information are controlled by such information. The simultaneous development of information technology and life science is expected to make possible the incorporation of environmental adaptation information also.

What is science? Regardless of its developments, the unchanging cycles of nature continue to exist, and stars in the sky continue to appear and disappear. It may not simply be repetition, and it may be that time is moving only in one direction with the impulse of the 'Big Bang' as the starting point.

Nevertheless science is a view of nature truncated in accordance with the bio-theoretical treatment adopted. Although scientific methodology expanded the bio-sensing functions of man, it is not possible to substantiate the existence of other methodologies which have no or weak reactions to the functions.

Primarily science has made progress passively by accepting proposals as to how science should be, and it cannot therefore give answers with respect to the objects that act actively upon it.

It appears that science has developed to the extent that it can explain anything, but in fact it can explain objects only in a patchwork fashion from the three approaches of Newton's dynamics, the theory of relativity, and quantum mechanics.

Technology permeates all cultures, societies and individuals because of its utility. Even if technology is made scientifically precise it will still be technology and not science. The contact between science and technology is maintained by man, who actively wants to improve his own functions.

The author has used the terms 'passive' and 'active' without giving them definitions. Passive things are characterized by strong self-denial, diffusibility, differentials, entropy, etc., whereas active things are characterized by strong self-assertion, astringency, integrals and 'negentropy'.

In technical terms, passiveness is seed-oriented while activeness is need-oriented. Accordingly activeness is not satisfied at all. Man has made progress by solving in a passive manner problems he confronted actively. Although science and technology appear to be very similar, they are separate and independent, the basic difference between them being that science is always passive and technology is always active. It is for this reason that technology is understood to be need-oriented.

Earlier in these remarks, reference was made to a catastrophe which the information revolution might produce. The problem of juvenile delinquents must have definitely changed family relationships. If the conventional family relationships are used as the standards for value judgments, such a change in family relationships might be called the collapse of the family. However, that raises (or leaves) the question of spiritual relationships between family members. What is love, and what is peace of mind?

These questions must be asked in the name of man. The identity of the individual must be restored.

Conclusion

This paper has not been concerned particularly with what is happening today socially, culturally and regionally, but rather with man and technology as factors in the problems of society and culture in general. The reason the author chose to develop the theme of society and cultural 'friction' in this way is that activeness itself characterizes both man and culture, and when the identities of man and culture are maintained and expanded, social and cultural friction always follows.

From this standpoint the 'unit social component' may be reduced to the individual human being, who may then be robbed of his identity. Apprehensive of this possibility, the author has referred to matters relating to families.

Individual human beings will be forced by the 'information society' to receive unlimited amounts of information, but they will gradually learn that they are capable of selecting the information they require. About this time the foundations on which conventional politics and economics rest will probably change dramatically.

In view of this the author has not concretely referred to friction caused by technological transfer to either the less developed or the least developed countries. He fears that the native cultures of societies whose cultural foundations are weak may be completely destroyed by the very strong impact of technology. History illustrates such situations in remote times. There will probably be no drastic relief measures. It is to be noted however that the advanced countries are basically in the same position.

When all ideological societies become meaningless, what sort of society will come into existence? This is a problem which intelligent men should consider calmly. But the present gives very little time for man to decide how to continue to be man.

5.2 The Impact of Changing Patterns of Employment on Culture and Society

Ungku A Aziz, Vice-Chancellor,
University of Malaya

It is a commonplace that changes in employment patterns alter patterns of culture and society. This broad generalization remains a mere cliché unless we can clarify the three main concepts involved: employment, culture and society. Clarification should produce lucidity and avoid the obfuscation often associated with the grey world of logomachy. This paper is therefore based on concrete examples.

I am conscious of the perils of trying to define words like 'culture' or 'society'. Nevertheless, in the fond belief that it may be of some help to the uninitiated, I am setting down my understanding of these esoteric terms.

In this paper, 'culture' embraces the way of life of the female factory workers. I am interested in the essential elements that influence their minds and determine their behaviour. The term should be interpreted sufficiently widely to include language, eating habits, dress and recreation.

'Society' includes social relationships. In a multi-racial country like Malaysia, where rural-urban patterns overlap with ethnic distribution and where ethnically oriented occupational specialization is common, it is noticeable that changes in the patterns of social relationships can determine the pace of change. Social relationships include not only those with fellow workers and supervisors but also with neighbours and with the family back home. Incidentally, one of the two prongs of the Malaysian Government's New Economic Policy is to reduce the strong coincidence of economic function with ethnic community.

'Employment' is gainful work. Here we are mainly concerned with gainful employment by women workers in the electronics industry.

Further, abstractly, I have to go back one step, upstream so to speak, and state my assumptions about underlying changes in employment patterns. In this case the employment situation is actually changing because technology is changing in Malaysia. Even with the onset of the recession there is no significant percentage of unemployment. This is partly due to the substantial pool of non-citizen workers.

We can now rapidly proceed to the point of technological change that is relevant to this paper without embarking on a marathon chase from the quest for fire, through the invention of the wheel, into the agricultural and industrial revolutions and so on. Indeed, this paper is concerned with the electronics age or, more specifically, with the day of the integrated circuit.

Malaysia, the country I have selected to illustrate my ideas, is somewhere in the middle of the electronic age. Industry is not yet robotized nor are computers widely used. The most germane industry is concerned with the assembling of integrated circuits and semiconductors which are then shipped to the four corners of the earth as part of the global assembly line.

To come to the core of my topic: we see more than 100,000 women workers who have changed their occupations from that of unpaid family worker, involved in a variety of farming tasks, to uniformed, disciplined, regularly paid factory worker who lives in a large or small town. The social and cultural changes experienced by these women, most of whom are between 16 and 25, are extensive. Therefore a thorough examination of the socio-cultural aspects is most relevant for a proper understanding of what is currently happening in our economy. Even more so, the impact of these changes on the whole nation, especially on the significant proportion of it that comes from peasant stock, will become increasingly important during the next decade.

Speculative though it may be, the rapid tempo of change impels me to try to peer into the crystal ball to discern the fate of the nation, especially of the Malay people, in the medium-term future. We should note that ethnically the bulk of the women workers are Malays. They will be the mothers of tomorrow. Constraints of time and space restrain me from explaining the reasons for this ethnic and gender concentration. Briefly, this is one of the consequences of the implementation of the New Economic Policy.

Before we can examine the interplay of ideas and facts or of pious hopes and realities in the Malaysian situation, a couple of brief questions may be asked. First, why concentrate in this paper on women workers and not the whole labour force? Second, why concentrate on Malaysia and not take the Third World generally or at least the South-East Asian region?

This is simply a case of the economics of presentation. In my judgment the concrete is easier to present and to be grasped than a broad generalized picture with perhaps an excessive number of chords of reservations played up and down the scales of economics. I also confess to a preference for discussing things I know directly rather than what has been culled from the works of others. These are my personal idiosyncrasies.

One scenario of the employment sectors of interest in the current decade is as follows. At the beginning young rural workers are tapping and processing rubber, or cultivating rice plants, or working in a variety of cottage industries, frequently without regular remuneration or properly defined conditions of work.

Escape from this situation is open to those who manage to secure a secondary education. This is mainly confined to the daughters of the better-off peasants. They can seek employment in the public service sector as clerks, secretaries or teachers. A somewhat larger number can drift into the private service sector as housemaids, waitresses, etc. However, for the great majority, say 70 per cent, of the age group between 16 and 25 there is no opportunity for a change in occupation or even for any form of rural-urban migration. At the beginning this is the basic pattern for the Malays, about 80 per cent of whom live in the rural areas.

Then, historically speaking, among a host of developmental activities, two events occur in chronological sequence. From the middle of the 1960s secondary education becomes widely available to rural girls. Tens of thousands of girls reach the middle level of the secondary education system and many succeed in obtaining the Lower Certificate of Education. Significant numbers stay on another two years to obtain the Malaysian Certificate of Education which is comparable to the British 'O'-level. Quite a number qualify at the 'A'-level and proceed to enter the universities—but that is another story.

Thus (perhaps unintentionally) we created a substantial supply of educated rural girls whose traditional learning-at-home way of life was interrupted. These girls were ready for regular employment away from their homes. There were rather limited employment opportunities for educated women in the rural areas. Therefore they entered the industrial labour force. Because they were, and indeed they still are, 'first time entrants' into the labour market their presence at the threshold of that market went somewhat unnoticed by the manpower planners and labour statisticians.

The new employers, mainly the multinational industrial companies, were establishing electronic plants extensively in Malaysia in response to the powerful blandishments of the government which planned to expand the manufacturing sector as part of its plans for rapid economic development. More particularly these new employers who wished to conform to the requirements of the New Economic Policy needed precisely the type of labour that the peasant girls had to offer.

Fortuitously the availability of a growing number of industrial jobs was matched by an increasing demand for work from women workers, who as one advertisement put it possessed 'nimble fingers'. In fact from the mid 1970s the electronics industry grew at such a pace that there was a chronic labour shortage.

Even in the present so-called recession, apart from some fractional unemployment which is mainly geographical, there is still a labour shortage in a number of employment sectors in the manufacturing as well as the service industries. Unfortunately I cannot digress into the niceties of the economic paradox that seems to have arisen.

Here I am concerned with the social and cultural consequences which occur when a peasant's daughter becomes an electronics factory worker. I shall examine these changes in four situations:

daily cycle
economic nexus

cultural complexities
social relationships.

Daily Cycle

At home the young women's life is dominated by the diurnal cycle of family and village life. Although a number of activities may be tied to the clock, there are many periods of the day when there is a great leeway in starting or stopping times. Feelings of fatigue or drowsiness can be assuaged by occasional naps. Snacks may be taken as and when vendors pass by or feelings of hunger rumble in the stomach. The day is occasionally punctuated by random events such as accidents on the nearby highway or visits by politicians. Otherwise it is one long drudge to be survived by eating, sleeping, carrying out household chores or gossiping with friends and neighbours. The biggest escape is thought to be marriage when one might be able to run one's own household instead of being ordered around by mother, grandmother, elder sisters, etc. Money comes in the form of gifts from parents who may buy one's clothes, shoes, etc. There would not be any regular pocket money or income even if one were involved in regular production activities such as tapping and processing rubber.

Nowadays the new escape is to seek work in a factory. The young girl hears about employment opportunities from a relative or friend who has become a factory worker, or she may be contacted by an employment agent who may be a political worker. There are also regular advertisements in the newspapers.

Some girls simply go to the big city and tramp around the factory areas enquiring at factory gates about jobs. Once they are employed the new discipline dominates the daily cycle of life. In good times the electronics industry is characterized by round-the-clock production. Most workers will have to serve on night shifts. Clocking in and out requires a respect for time that is measured by the minute rather than by the hour. Since many of the girls have to travel some distance to and from work, they must arrive on time at the places where the factory bus picks them up. They must learn how to travel home alone at night. Bus stops are favourite places for unscrupulous males to prey on these girls.

The rigours of work shift timetables are not easily accepted by the body systems of the women workers. Insomnia, gastritis and a general sense of stress affect many workers during the initial period. Most adjust and they have their youth to pay for any discomfort during this process.

The impact of changes in the daily cycle can be perceived during the period of adjustment. In the long run most of the working women survive the psychological stress. However, there are many instances of mass hysteria.

The relatively large distances of travel widen the scope for different patterns of social relations including the practice of having boy friends or the institution of dating.

Essentially, because the daily cycle is changed, the women involved become more willing to consider and accept other changes. The tighter time observation is soon learnt even if this interferes with hormone balances, sleep or menstrual cycles.

Economic Nexus

Under this heading two aspects of change can be examined, production and consumption. Or, from another point of view, we can examine new patterns of employment and income as well as how the new worker distributes her wages between purchases of a variety of commodities and saving.

In the first instance the new worker would have grown up into the world of rural work. There would be a wide range of activities that she would be expected to undertake and she would be taught to do them properly by her elders. These could range from carrying out tea and snacks to workers in the paddy fields, or planting and harvesting paddy, to mat weaving on the verandah of the house. At 15 a girl could be tapping rubber before dawn some 20 days a month. All the jobs have to be done by someone because the typical rural family lives in a state of poverty, whichever way it may be measured by the statisticians.

Although the woman worker may make empirically quantifiable inputs of labour, which have a known market price, she will not be duly recompensed by her family because according to a rather convenient custom between members of the family, especially where girls are concerned, there can be no *berkira* or accounting. It would be unfilial to suggest cash remuneration for such work. Nevertheless, if the same girl were to work for another party in the same area she would be paid wages or given a share of the value of the crop.

The first big change on entering factory work is the receipt of a regular cash income. At first this must seem exceptionally large because it is compared to a base of zero. It would be misleading to think that rural women in family employment receive nothing at all in return for their work. Occasionally parents or elders will make gifts of clothing or even cash when the family visits the nearby town, especially on a market day when vendors with all sorts of semi-durables converge on the town. Or there may be rare visits to the big towns.

Of course the cash wages must be used to buy food and pay for rent. Our typical factory girl will probably share a rented room with six to eight other girls. Those working on night shifts will roll out their bedding and sleep during the day while those on the day shifts will use the room to lay out their bedding to sleep at night.

Much of the food is purchased from hawkers or eating shops near the living area or the factory area. If the girls are in a hurry they buy packets of 'crunchies' which they munch while they are travelling or even at work, although this is prohibited by most factory rules. The better-run factories have canteens but this is not universal.

On holidays or their off days the girls go window-shopping and may buy shoes or clothing, especially the first pair of jeans which may not be allowed in the home village. Cosmetics and semi-durables like radio-cassette players, electric fans or jewellery are also bought, sometimes on hire purchase. The girls are now free to spend their money as they wish. Some part of their wages is saved. The methods of saving range from opening a National Savings Bank account or investment in the Government Unit Trust (ASN) to keeping cash with the parents so as to accumulate enough to acquire a piece of land or buy some cattle as traditional forms of investment in the rural economy. Some workers give money to their parents or support siblings in the education system.

This economic change has a dramatic influence on the personality of these working women. They become more self-confident and after a few bitter experiences quite hard-headed, even hard-hearted. They soon learn that there are differences in net take-home income as between the different employment systems. Some employers offer free transport, work uniforms and subsidized canteens whereas other employers drive workers to fulfil ever-rising productivity targets with severe penalties for failures in product quality.

The most striking impact of the whole gamut of economic changes is the general response that they will never return to the rural economy. However difficult city life may be, however disciplined the factory employment may be, however boring repetitive work on an assembly line may be, the urban way of life is still preferable to family work in the peasant areas.

It is relevant to mention the fact that these thousands of Malay women workers are not yet organized into trades unions. Their conditions of work are not negotiated. If they are unfairly dismissed or penalized there is no representation to take care of them. This issue is frequently discussed in the current local newspapers.

Cultural Complexities

We should bear in mind that for more than half a millennium our chosen country, Malaysia, has stood at the confluence of four great religions of mankind: Buddhism, Christianity, Hinduism and Islam. It may improve our tenuous grasp of the matrices of cultural developments by noting that during the last three decades the nation has undergone rapid modernization in almost every sector. Linguistically, Malay has been the lingua franca throughout the archipelago ever since Chinese, Arab and European travellers have kept records. Today Malaysia and Indonesia have a common spelling system and there are co-ordinating links for language development so that educational systems, public administration as well as the market-place can communicate in one common national language. While English is the language of international diplomacy and commerce, Chinese, including four or five of its major dialects, dominates the internal commerce as well as the construction industry. Some sectors conduct their affairs in Arabic or Japanese. It is not strange therefore that language can be seen as an avenue to promotion as well as the fiery torch which can light nationalistic sentiments. It can become a tool for progress as well as an obstacle to national unity.

What happens when our newly educated peasant daughters become relatively sophisticated city girls? They are as ready to buy well-illustrated fashion magazines with even Chinese or Japanese texts as they are to listen to pop tunes in Western (cowboy, that is) slang.

One might sound rather 'square' if one were to comment that it is unfortunate that these tender minds are exposed to the thinner end of the wedge of the so-called modern Western culture. I would unashamedly expose my values by suggesting that although it is possible for young Japanese workers to drop their age-old traditions and to go in madly for French or American styles for a few hours or days in their excitement, the Malay girls are not so adaptable. As I see it the Japanese can neatly fit back into the well-defined structures of their own strongly established culture. Maybe they are more prone to schizophrenia than our Malay girls. For these slim-rooted young girls to go is to go-go all the way. All they really care about is what is new or novel and this is the be-all and the end-all of the cultural matrix within which they currently exist.

We have studied the magazines and papers that they regularly purchase and we have made content analyses of many hours of radio programmes. The vapidity and the superficiality of the bulk of the material is mind-boggling. Even more serious is the lack of any education programmes, at a level that they can accept, about moral values, nationalism or self-confidence. It is in my humble opinion disastrous to hand over the responsibilities of social engineering to the media or to religious pseudo-fanatics. They lack realistic social objectives or are weak on presentation methodology. All they can do is exhort people to adopt norms of behaviour that are the exception rather than the rule in society and in some cases may not be relevant to the Malaysian time and place.

Social Relationships

The most obvious change that the peasant's daughter will experience when she migrates into urban employment is that she escapes from the cocoon of family and village life where all relationships are meticulously defined exogenously and endogenously. To a considerable extent the working girl in the city is free to 'do her own thing'. Fellow workers, room-mates and neighbours will expect a minimal fulfilment of certain norms of mutual behaviour. Otherwise they will not interfere. The advantages of independence and a sense of freedom are somewhat offset by the absence of elders, aunts or sisters, who may just listen to an outpouring of one's problems or give useful advice on health care, etc.

My colleagues have given some attention to the modes of counselling informally created to replace the traditional forms available in the village.

A significant number of girls will try to return home at weekends at least once a month. However, these visits may be restricted by the need to do overtime work which is not really voluntary.

Relationships with the opposite sex have been radically changed. In many rural communities the opportunities for social interaction with young males who are non-relatives would be virtually non-existent, although furtive encounters take place around the farms. On the other hand, in the towns casual acquaintanceships can be developed at the factory gates, bus-stops, coffee shops, in shopping plazas or at botanical gardens or fun fairs. The newspapers regularly report instances where impressionable young girls are conned out of jewellery or cash or more serious things by clever young men.

Marriage in the village will be carefully arranged by parents. Their main intention will be to get their daughter married while she is still a virgin and before nothing untoward has happened. The working girl seems to prefer to wait two or three years before getting married. Then she postpones having a family for another year or two. Most factory girls either find a potential fiancé who then gets his family to make the customary approaches for an engagement which culminates in a marriage, or they have an engagement or even a marriage directly on their own and duly inform their parents.

The strength and quality of the links with the girls' families vary. Those who have strong ties and who return home at weekends may marry someone selected by the family. If the bridegroom is a soldier or working in the public or private sectors, she may have to give up her factory job. However, if she chooses a fellow factory worker then, while the ceremonials may take place at home, the new family finds a place in the city in a flat or in a squatter area. Most of these working families will continuously strive to better their material conditions. For example, they will fill their living areas with the paraphernalia of modern civilization including a gas cooker, electric fan, transistor radio or TV, furniture, etc. Since the phenomenon of the electronics woman worker is not much more than six years old, it is difficult to be certain as to how stable these families will be, how their children will grow up and be educated and how the health of the women will fare in the long run.

Some of the better employers organize sports, games and parties for the workers. For the other workers there are the typical attractions of city nights.

One question that frequently engages the eye of the tabloids is the so-called new morality of girls who are termed 'Minah karan' (i.e. electric Mary, etc.). From our studies we can say there is no evidence to show that factory girls are more prone to what is euphemistically termed 'deviance' or prostitution or promiscuity than other girls or boys. Girls are girls. Whether they are university lecturers, public relations officers, policewomen or secretaries, they are all like fruits or eggs: they have good and bad ones among them.

There are many village girls who have been casually divorced by soldiers or other itinerant persons whose occupations render them mobile. Before there was factory employment such girls formed the main supply of waitresses in bars, and some became prostitutes, massage parlour workers, etc.

The ambition of the typical factory girl is to better her economic condition, make a decent marriage and raise a family in the city. She realizes that, unlike the young Japanese working woman, she will have to continue earning for most of her potential working life. Average incomes are low and the revolution of rising expectations is always knocking at the door.

The annual dinners and games organized by the employers promote some inter-racial mingling but it is not enough for the establishment of serious inter-ethnic friendships. Language and eating habits are perhaps the most serious constraints.

From reports of directly participating observers, Malay working girls do not have antipathetic attitudes towards Chinese or Indian girls. They would even accept them as room-mates.

Conclusion

From this brief presentation it should be clear that the Malaysian case is unusually interesting because of its tempo of change and the complexity of active elements involved. By selecting the special instance of female factory workers we are able to observe social processes which would otherwise take decades to work themselves out evolve rapidly in a short period of about five years.

It is my impression that any broad conclusions which may be drawn from this paper are equally applicable, albeit in specifically different forms, to other workers including males, various races and a range of modern industrial occupations in the region.

5.3 Future Possibilities in Telecommunications and Their Impact on Society in Japan

Shuhei Aida, University of Electro-Communications, Tokyo, Director, Honda Foundation

I wish to say something about the fundamental concepts of information, starting from the general thesis that information is based on culture. I shall first speak about some aspects of information in Japan.

Information came to Japan with civilization. About a hundred years ago we adopted the Chinese word *Joho* to describe both affective (intuitive) and cognitive information. I would like to discuss the roles which both may play in the coming civilization of the twenty-first century.

All social systems inevitably involve some forms of communication. Today many, such as transport, traffic and information transmission, involve and demand electronic telecommunications. As a consequence telecommunications technology, control technology and command technology have dramatically advanced, particularly with the development of computer technology. As we all know, these advances have made long-distance communications, including space communication, first possible and then more reliable. At more mundane levels the home banking system and the home schooling system, which today are among the most important developments in Japan (as in many other Asian countries), are becoming continually more comprehensive and efficient. Information systems have begun to find their way into our homes, and it is considered that the influence thus produced will be immeasurably large.

These latest technologies are based on the progress of electronics which has given us integrated circuitry (IC) and large-scale integration (LSI). Thus progress in electronics plays a very important part in the development of information technology.

The progress of semiconductor technology is illustrated by the fact that the degree of integration has doubled every two years. This is a basic factor in the development of information technology, leading to reduction in system volume, cost, response time and other limitations, bringing improvement in many directions. In addition optical fibre technology makes possible many truly revolutionary developments well beyond the limits of former telecommunications techniques. Optical fibre technology makes it possible to transmit voice, data and several images together: the technology will undoubtedly have a tremendous impact on communications as a whole. Both data transfer and international relations will certainly benefit from the improved communications efficiencies which must result.

As with optical fibre technology, progress with large-capacity communications satellite technology has benefited remarkably from progress in space development. There is no doubt that world communications systems will function more effectively in the near future, when sufficient communications satellites, automatically tracked by earth stations, have been placed in appropriate orbits round our planet.

Continually improving information technology is of course affecting many other aspects of life, including consumer shopping, booking aircraft seats, personal library operations, banking services and schooling, all of which will eventually be possible without leaving the home.

Office automation in Japan, and also in other Asian countries, is similarly undergoing remarkable changes as a result of applied information technology. In particular this will soon make it possible to search out and collect any sort of information on a global scale. It often happens that collecting data and extracting information on the basis of the data collected are less advantageous cost-wise than finding the necessary information and having it transmitted to a place designated at the time when it is required. Computers and communications technology may be expected to progress in step, opening completely new possibilities for the use of information in the civilizations of the future.

Now I have to say something about the relationships between data, information and communications. All, of course, are essential concepts in information technology, which inevitably has important cultural aspects. Let me say something about information.

Information comprises data, and data (in modern information parlance) generally comprise numerical values and classification standards for the results of physical or other measurements and analyses. Such data serve as starting points for defining, evaluating or making practical use of various scientific phenomena. But there is another form of data, found in the field of human systems engineering. I have called these data 'feeling data', and they comprise information of the type known in Japan as *Joho,* which I have already mentioned. Mori Ohgai, a very famous writer in Japan, proposed *Joho* as an expression meaning information: *Jo* means 'effects' or 'feeling', and *ho* means 'facts', 'truth' or 'reports'.

These 'feeling data' are very important in relation to developing information and communications technology. As opposed to 'raw numerical data', 'feeling data' may be considered as numerical data combined with some form of evaluation or classification based on the results of macroscopic observations. This is the concept of 'holism', embracing the 'atomisms' of experts in their respective fields. It is of course a more generalized concept, though 'raw data' remain a fundamental prerequisite without which there can be no technological development.

The word 'information' is somewhat anthropological in meaning, and the conception of information is normally strongly based in culture and on social structure, which serve as 'bridges of thought' between individuals and societal civilization. A Japanese philosopher has said in this connection that data combined with human feelings produce information ('feeling data'), the only true form of communication between man and man. Anyone who handles large amounts of data will appreciate the appropriateness of this concept.

We may assume that future measurement and analysis techniques will be more advanced than they are today, so that enormous amounts of data will be collected, processed and adjusted by computers in every conceivable field. One example will be the field of medicine. Yet more measured data will not in any way change the information being measured and analysed. The final evaluation (diagnosis) will be made when someone produces 'true information' by regarding the data as predicting any change which may take place in the near future. What is important here is the 'sensitivity' of the people involved. Accordingly it will be of growing importance for those involved in decision-making based on data (in whatever field) to cultivate sensitivity, so that the data may be properly used to produce information of real value for both the individuals and society.

In any communication between machines, such as computers, data are necessary and sufficient elements. In communication between men however the essential is information.

Incidentally, the word 'communication' is also a word of foreign origin in use in Japan. It seems that the original meaning of the word was linked with religious communication. In Christianity this (in the form of the Holy Communion) is a unification of a person and God. It is a form of communication in which man's information is not merely transmitted from person to person: those who receive such communications should be aware of sharing them on a wider basis.

In realistic terms it is important to build a mechanism in society using information based on data, so that people can carry out activities with a common purpose and a common conscience. Communication between men can be maintained only on the basis of mutual human trust, which far exceeds formal contract. Karl Jaspers compared this to the Chinese word *jin*, meaning that communication between man begins with the spiritual coexistence of two people.

Japan's religious basis is very different from that of the West. Thus we have a completely different concept of communication in Japan compared with the Western countries.

5.4 Medical Co-operation Programmes for ASEAN Countries

Kazuhiko Atsumi, Director, Institute of Medical Electronics, Tokyo University

This short paper mentions three specific programmes in the field of regional medical co-operation:

–introduction of microcomputer systems in principal hospitals
–remodelling and revival of used medical equipment
–disaster aid by emergency nuclear ships.

Introduction of Microcomputer Systems in Principal Hospitals

When one considers measures for health protection, medical treatment, welfare, disaster actions, etc. in the ASEAN and neighbouring countries in South-East Asia, communication networks linking these countries to permit the flow of information present an urgent problem.

The fullest possible systematization of information will produce maximum benefits with the minimum of resource investment. The system will then serve as a basis for the medical resources allocation required if these countries are to carry out their policy of medical co-operation to the fullest possible extent.

The future development of this concept will require the introduction of high technologies such as satellite communications, large computer networks and optical fibre communications. What is required to serve present needs is a system of regional information networks commensurate with the extent and characteristics of the regions.

A first step will be to install several microcomputers in medical centres and in the principal hospitals chosen to provide centralized functions in the countries concerned. Basic data regarding health and medical services will then be input (fed in) to the computer systems, so bringing them into service. The microcomputers will be used as 'intelligent terminals' connected to central computers in the various regions.

Considering the low-cost, high-performance, easy-access and free-language features of the microcomputers now available, large quantities of these microcomputers can be applied in the ASEAN countries. The issues central to these countries will be the opening of training centres and the development of software, which the advanced countries will be able to assist in providing.

Remodelling and Revival of Used Medical Equipment

At the present time many types of medical equipment installed in the advanced countries undergo frequent and rapid model changes. In large advanced hospitals medical equipment which only a few years before was the latest available can consequently be kept idle in the corners of laboratories without having been fully utilized. Such equipment however is often sufficiently advanced to provide entirely satisfactory service in all cases except where the very latest high performance is required.

It is planned to recover such idle equipment from the advanced countries to be serviced for reuse. During the servicing remodelling will be carried out commensurate with the level of the medical requirements of the developing countries (requirements concerning power supplies, water, humidity, air conditioning or changed engineering or technical needs for operating staff). Procuring such equipment will certainly prove easier (and hence more appropriate) from the viewpoints of function, cost and proposed use than purchasing the latest and most expensive equipment.

A scheme for the recovery, transport, remodelling and repair of such equipment is now being investigated. As this project makes progress, repair shops, parts-supply bases, equipment display grounds and training centres will become necessary in the ASEAN countries.

Disaster Aid by Emergency Nuclear Ships

Many of the countries in South-East Asia have access to the sea and it is easy to approach their shores by ship. Nuclear-powered ships are fast and have many advantages over other ships in undertaking aid operations following disasters. They have a source of abundant energy, and in emergency can supply large quantities of power continuously over long periods.

By establishing specific technological facilities in nuclear ships, such as that to convert sea water into fresh water, aids to food cultivation and pharmaceutical production (utilizing biotechnology for example), such ships will be able to act as mobile centres for the supply of water, food and medicines.

Schemes such as this, in which the ASEAN countries are showing considerable interest, offer a new and promising way to utilize nuclear power for peaceful purposes.

5.5 Medical Progress and Social Development

Toshiyuki Furukawa, Institute of Medical Electronics, Tokyo University

The importance of international co-operation has been widely recognized in many fields. However, the development of such co-operation in concrete form is normally achieved through a series of trials and errors. For this reason it was considered useful to analyse the contributions made by medical policies to the rapid modernization experienced by Japan a century ago, at the same time examining changing trends in education, particularly in the field of medicine.

Medical Treatment Incorporated in the Educational Policy of the Meiji Government

The educational policy of the Meiji government, when analysed today, includes some points of vital significance. Especially interesting is the fact that priority in higher education was given to the training of doctors. In the first year of the Meiji Era (1868), amidst the confusion following the so-called 'bloodless revolution', the medical school of the shogunate government was taken over by the new government. On 11th April of that year Edo Castle changed hands, and on 9th June the medical school was taken over by government troops. By 26th June its activities had resumed, and on the 17th of the following month it had also absorbed the school of Japanese and Chinese medicine which had been established in 1765. A medical school and a hospital were set up in Osaka in the same year, while the 124-bed hospital in Nagasaki, formerly operated by a feudal clan, was reorganized into the Nagasaki Medical School. The already mentioned medical school of the shogunate government became the University School East Branch in December 1869, and later developed into the Faculty of Medicine of Tokyo University.

The Meiji government, in institutionalizing higher education, gave priority to medical science. In addition, following consolidation of their political power, they promoted the establishment of the college of economy, and then the college of engineering. It may be assumed that the Meiji government, in their efforts towards modernization, recognized that it would be most effective first of all to win the hearts of the people by protecting their lives and health, and by stabilizing their society. The objectives of the college of economy were to study the scale of domestic consumption and production, and of overseas trade, and to train personnel who would eventually take charge of developing modern business. Once the volume and distribution of supply and production had been measured, the production structure of modern industry was built by the graduates of the colleges of engineering.

This higher education was clearly directed at fostering future leaders, and in fact in the early Meiji Era the graduates of medical schools occupied leading positions in a wide range of social activities, including the political and military fields.

Another educational policy pursued by the Meiji government was the large-scale training of mid-level technicians. In this case the establishment of the agricultural school was given first priority. As for the training of technical engineers, emphasis was placed on the education of apprentices and workmen and then higher education gradually provided training for low- and mid-level technicians, in a well-thought-out scheme to maintain a proper balance between the leadership and worker groups.

Looking at the transition of the school system for training technical engineers, the institutions in operation in the 33rd year of Meiji (1900) included four years of primary school, two years of higher primary school, five years of middle school, three years of high school and three years of college and university. In engineering-related schools the overwhelming majority of students at that time was divided between second technical school (five years after graduation from primary school), apprentices' school (four years after primary school) and technical supplementary class (three years after primary school). A group of technicians to support the foundation of modern technology was thus formed under this school system.

When college and high school decrees were promulgated in the 7th year of Taisho (1918), the numbers of students in second technical school, apprentices' school and technical supplementary class underwent a rapid decline, and the numbers of students in first technical school suddenly began to increase. On the other hand, in parallel with rising international tensions, the numbers of students in the colleges of engineering and technical colleges began to increase rapidly from the 13th year of Showa (1938). The numbers of students in first technical schools and the faculty of engineering at universities also saw a steep rise, reaching a peak in the 20th year of Showa (1945) when Japan had lost the war.

The number of students in these schools dropped drastically in the immediate post-war period, but with the implementation of a new school system in the 24th year of Showa (1949), the numbers of students in the engineering faculties of new-system universities and new-system senior technical schools again began to show a rapid increase.

The above will offer some explanation of the success enjoyed by Japan in the training of production personnel, taking the country from the lowest ebb of world-war defeat, through postwar reconstruction towards becoming a modern nation. At the same time a policy to give priority to higher education in medicine worked effectively, and it became recognized as reasonable that to achieve commercial success an educational policy and curriculum somewhere between medicine and engineering was appropriate.

This Japanese experience in modernization could have important significance for the developing countries at the present time, when the shortage of mid-level technicians and mid-level executives seems a basic impediment to rapid modernization.

Progress in Society and the Situation of Medical Health

As was disclosed in detail at the DISCOVERIES Symposium in 1982, when international statistics of social indicators were analysed by multi-variate statistical analysis, various indices which reflect the standard of living, especially wealth and the volume of information, are closely related to life-span. These are the indices of national income per capita, gross domestic production per capita, the amount of energy consumption per capita, the amount of electric energy production per capita, estimated circulation of daily newspapers per 1,000 inhabitants, the numbers of television and radio receivers per capita, calorie intake per capita per day, protein intake per capita per day, expenditure on education per unit of GNP, the number of students in higher education, and crime rates. In addition the mortality rate resulting from heart and cerebrovascular disease also has a close relationship with average life-span.

The numbers of persons per doctor and per hospital bed show the closest relationship with mortality rate, also confirming (happily) that medical treatment lowers this rate. Medical treatment is also lowering the infant mortality rate and that resulting from tuberculosis. A more remarkable result of this analysis was that birth rate had a close relationship with illiteracy rate.

Putting all accounts together, medical treatment can become an effective preventive mechanism against the causes of death found in developing countries. At the same time, in order to limit birth rate it would seem an absolute necessity to promote the concept of health among the people. Moreover, the controlling factors of life-span in a country or society are the prosperity of and the information available in that society and it is understandable that in the developed countries the control of adult diseases has significant meaning. Clearly medical research and medical health activities are essential factors in maintaining social standards, and the fact that the Japanese Government has been making positive efforts since as early as the Meiji Restoration to train medical personnel is of the highest importance.

It is evident that information plays a significant role in the 'adjustment' of health and population, and this fact has important significance for the developing countries. The literacy rate in Japan has been extremely high for a long time. The origin of this dates back to the reign of Yoshimune (1716-51), the 8th shogun of the Tokugawa family, who proclaimed the government ordinance to establish Terakoya (private elementary schools in the Edo Period) throughout the country, and ordered the mobilization of priests of Buddhist temples and lordless samurai to instruct the people on how to read and write, and to teach the Nine Chinese Classics. It is interesting to compare this with Prussia, where in 1763 Frederick the Great started enforcing compulsory education for his subjects in order to strengthen his country. It is assumed that the high literacy rate among the Japanese at the time, and the widely accepted code of ethics to study diligently as a virtue, exerted tremendous influence on the assimilation of modern civilization.

The Development of Basic Research

When we look at Japan's 100 years of modern history, we come across the major problem of insufficient basic research. The number of researchers in Japan is not small compared with the United States and European countries, but the number of persons who obtain science and engineering degrees in the universities is surprisingly large compared with those countries. Bachelors of engineering, graduates of the engineering departments of universities, number 74,000 compared to 53,000 in the United States. The engineering departments of Japanese universities were continuously enlarged during the post-war reconstruction, and in particular the number of electronics-related departments and their graduates is now several times larger than in the United States; Japan has trained the mass production of the manpower necessary to improve scientific technology for practical use.

However, doctors of engineering in Japan are proportionately much fewer than in the United States and Europe. The difference in the number of doctors of science is especially great: 8,040 doctors in the United States against only 782 in Japan (2,263 in Great Britain and 2,580 in West Germany). What is more remarkable is the large number of bachelors of science in the United States and Great Britain. It would seem that the mass production of B and C class scientists is supporting the development of class A scientific research.

To summarize, with Japan's history of modernization as yet only 100 years old, it has proved essential to adopt an educational policy which stresses the importance of application. However, further speedy improvement is necessary, and it is now hoped that developments in basic research in Japan will lead to greater national contributions towards scientific discoveries and breakthroughs.

5.6 Viewing the Twenty-First Century Advanced Communications Society

Reikichi Shirane, President,
NTT Telecommunications Science Foundation

As a description of Japanese society in the twenty-first century I would like to choose 'Advanced Communications Society'. Just as young radio enthusiasts formerly predicted the advent of the mass-communications age in the twentieth century, young boys today are enthusiastic about personal computers (called *paso-con* in Japan).

However, there is a basic difference between the situation of young radio enthusiasts in the past and today's *paso-con* enthusiasts. The former mainly listened to radio passively but the latter actively operate technological systems as information transmitters themselves and act on *paso-cons* individually, independently and creatively.

Incidentally, it is to be noted that the year 1983 has been designated World Communications Year (WCY) by the United Nations.

The McBride Committee of UNESCO (established in 1977) studied problems relating to the control of information by the news agencies of some advanced countries including AFP, UPI, Reuters and Tass. The information gap between the South and the North was discussed by the committee, drawing the world's attention to the communications field.

Not only were conventional broadcasting and printing media discussed by the committee, but also the electronic 'new media' resulting from the recent rapid development of communications technology which is likely to produce a large impact on world communications. In order to convey to the world the necessity for agreed policies and related activities, the United Nations established World Communications Year as already noted.

In this way a uniform world approach, relating to the probable significant changes in the field of communications before the end of the twentieth century, was called for by the United Nations.

The theory of the information society made its first appearance in the world in Japan in 1963 when Tadao Umesao published 'The Theory of the Information Industry' in the monthly magazine *Chuo Koron*; with this as a stimulus interdisciplinary research on the information society was launched.

Unfortunately, however, the problems relating to industrial pollution, environment and resources (including the oil crises) arose thereafter, and an anti-technology attitude prevailed in Japan. But because of the importance given to the theory of the information society, in Europe and America in particular, study of the subject was not abandoned. In fact it began to be treated as a realistic social question rather than a vague subject for futurology studies.

Communications and information technology made faster progress than expected during the 1960s and 1970s and the age of the 'new media' mentioned above had already begun. The words associated with *paso-con* games, office automation (OA), local area networks (LAN), advanced information system (AIS), etc. are image words symbolizing these new media which will play important roles in constructing a highly advanced communications society for the twenty-first century.

In preparation for this communications society, the 1980s will prove to be the age of new communications media. A variety of experiments are expected to be conducted (some are already under way) and trial-and-error approaches and selections will be made.

The 1990s will be the age of full-scale new business and the conditions for the new information industry will be clarified. The twenty-first century may then be confidently expected to be the age of a new society based on advanced communications: the advanced communication society will have arrived.

It is difficult to predict and describe this new society, but I shall now try to suggest some details. First, communications media will be abundantly available and the freedom of selection by users will dramatically increase. A variety of users' desires for information will be provided for, dependent on their age, sex, occupation, specialization, hobbies, life style, etc. Users will thus be able to free themselves from the control of information transmitters, and instead will dictate the form of the information market, so that the market will have to be reorganized.

Second, the control of technological media will be weakened and information transmitters will have to consider what kinds of information they should provide. It will be an age where emphasis will be placed on the quality of information.

However advanced the technological system (including electronic systems) may be in the future, most of the critical planning and defining of objectives, the collecting and editing of information, etc., will still depend on man. It may be said therefore that the highly advanced age will be an age in which man's intellectual faculties will play a decisive role.

Third, the roles of the existing communications media—the print media (comprising newspapers and magazines) as well as broadcasting and telephoning—will have to be reassessed. Big changes may be expected.

The finance industry, including banking and investment in securities, and some sectors of the physical distribution industry, are already showing signs of change, and will be reorganized with respect to their primary functions: again, big changes may be expected.

Finally I would like to say that in this highly advanced society conventional economic and social theories based on goods, funds and energies will show that they have aspects which cannot be analysed or described. This is one of the most significant problems which future generations will face. For this reason it will be necessary to have a philosophy and world view based on and responding to the basic characteristics of information.

It is already desirable to set targets for the respective time frames involved, to seek social indicators and conduct a wide range of research, as the new age is already near at hand.

5.7 Economic Growth and the Technological Revolution

Toru Yoshimura, Dean, Graduate School for Policy Science, Saitama University

Success of Industrial Policy

In recent years Japan has been highly regarded in the international arena because of her overall competitive economic strength and continuous ability to achieve growth. Generally recognized as a nation highly dependent on oil, Japan has above all been able to cope successfully with the rapid rises in the price of crude oil.

Japan's real growth rate has exceeded five per cent every year from FY 1976. By controlling the increase in prices following the second oil crisis, Japan was able to surmount the difficulties. In the five years from 1975 to 1979 Japan achieved a 42.8 per cent increase in labour productivity in the manufacturing sector, whereas the increase in the same area was less than one per cent in the US and Britain and approximately 25 per cent in Germany and France. Moreover, Japan achieved an increase of 9.2 per cent last year. In particular attention should be given to Japan's high productivity, based on the high technology revolution and quality control, which exceeds that of other industrialized nations. On the other hand, this high productivity has resulted in friction in the international economy, especially in the field of steel, automobiles and electronics, and has impacted on world trade in the field of advanced technology, as in the so-called 'silicon battle'. It is expected that in the near future Japan will stand abreast with the US and Europe and become the leader in the field of bio-industry based on the most advanced technology of genetic engineering and biotechnology.

Science and Technology in the 1980s

Examination of the past patterns of technological development and innovation in Japan has shown that the new technologies which promoted the quantitative expansion of industry were adopted from foreign countries and assimilated during the 1960s. One of the leading sectors in this period was the electrical products industry.

Since environmental protection and safety were advocated in the 1970s, the budget flow and other forms of information have shown that considerable investments were made in technology for anti-pollution measures, while the implementation of novel energy-saving technologies was promoted by investing in development projects. The 1970s were also characterized by technologies related to such knowledge-intensive industries as computers and integrated computer systems, and the integration of computers in steel production, as seen in the activities of the League of Congressmen for the Information Industry.

From the 1980s it is probably most important to consider how to utilize a number of existing advanced forms of technology for the revitalization of the world economy. From this viewpoint the problems related to science and technology in the 1980s are obvious:

1 How should technology be developed as a 'propeller' in maintaining and improving national security?

2 How should strategy be determined for making contributions to solving global and societal problems?

3 How should vitality be maintained for the development of society through the creation of new industries related to 2?

4 How much stress should we place on contributions to international co-operation?

It is also necessary to develop a series of unique and basic new technologies, as well as creative technology for the coming generation. Such development can only be achieved through the efficient pursuit of complex research and development in which basic, applied and developmental research are integrated.

We, the Japanese people, have been introducing technologies whose capability and stability were proven in Europe and the US. These technologies were often employed in the production process and utilized for the creation of new products after making improvements and supplementing them. Japan has been best at this type of R & D, and has actually invested a great deal of money in it.

However, in developing advanced technology in the future, the promotion of basic research intended for particular purposes is indispensable. Nevertheless it is extremely difficult to increase the amounts of funds for basic research within the current system in Japan. Some relevant statistics are annexed to this paper.

Conditions for the Activation of Basic Research

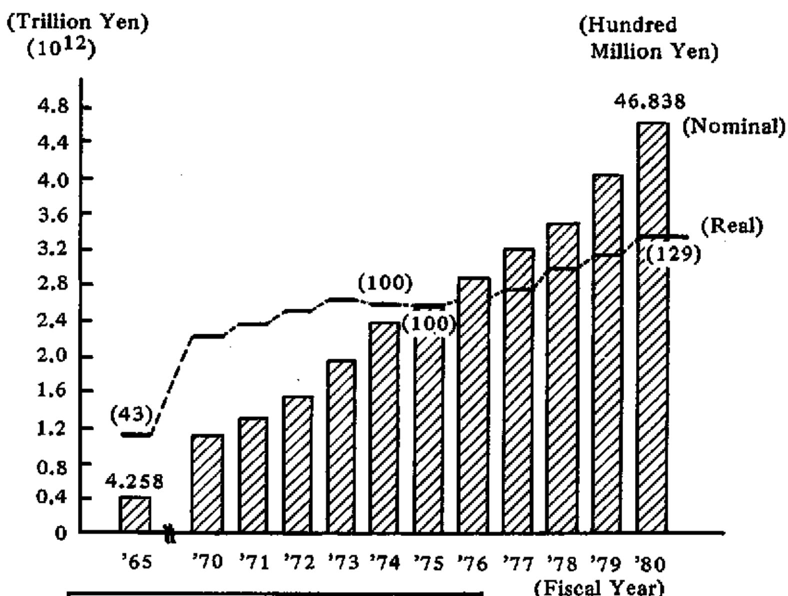
For basic R & D activities in Japan the most inactive institution is the university, which exhibits low-level efficiency, followed by the National Research Institutes.

On the other hand the industrial sector shows a relatively high level of efficiency.

Under these circumstances the basic R & D expenditures are not flowing to the locations in the private sector where the most active research is expected. However, it would be rather difficult to require private industries over the next ten years to invest large amounts of money in their basic research. This should therefore receive government funds. In other words, the progressive policy already implemented by the Ministry of International Trade and Industry (MITI) should be adopted more generally. The mechanisms of the flow of money to the private sector, developed and practised by MITI, should be implemented by other government agencies.

Secondly, in order to make the best use of universities and National Research Institutes the strengthening of co-operation between the industrial, governmental and academic sectors is being strongly urged by the Council for Science and Technology as well as by the Economic Council. It is important to make these sectors competitive, and policies which create such a competitive situation should be implemented in order to show the low posture of universities regarding research activities. Therefore, determining how to create such a competitive situation is a second suggestion for improving the current situation.

Figure 18: R & D Expenditures in Japan



Average Annual Increase Rate		
Fiscal Year	Nominal	Real
'65-'70	22.9%	15.2%
'70-'75	17.0	2.9
'75-'80	12.3	5.3

Figure 19: R & D Expenditures in Major Countries

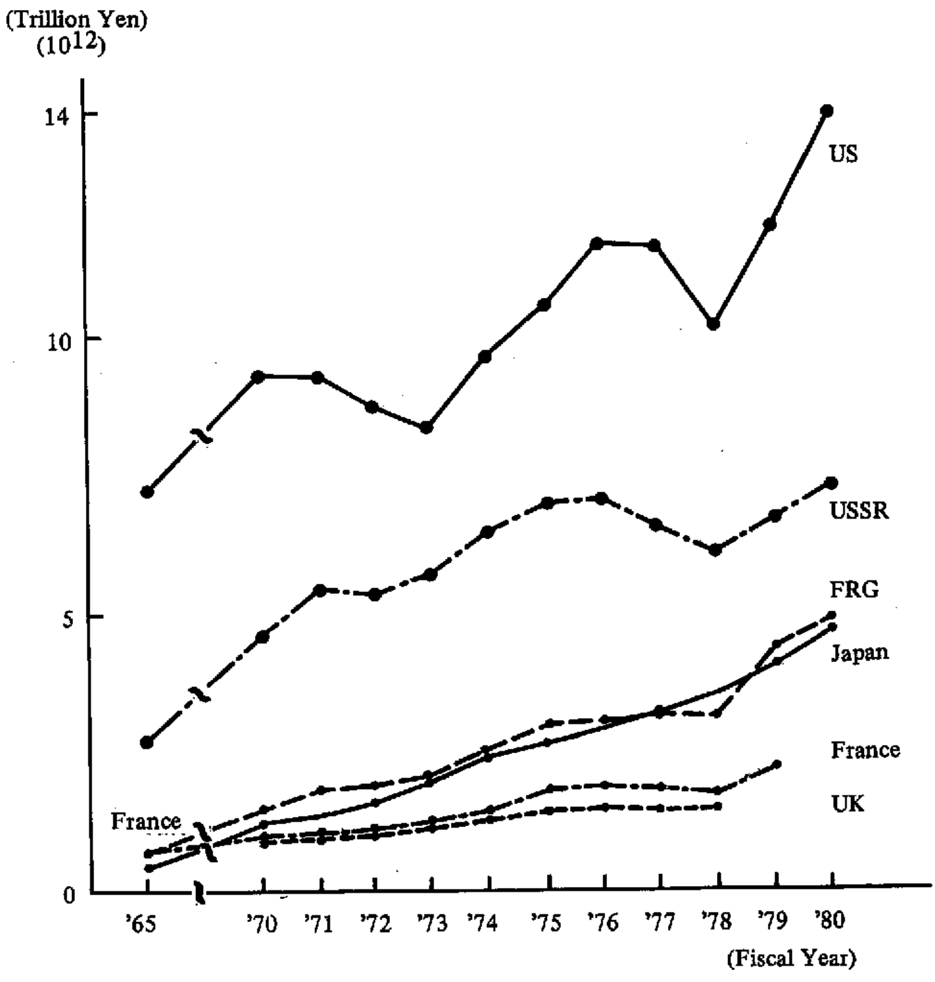


Figure 20: Changes in the Ratio of R & D Expenditures to National Income in Major Countries

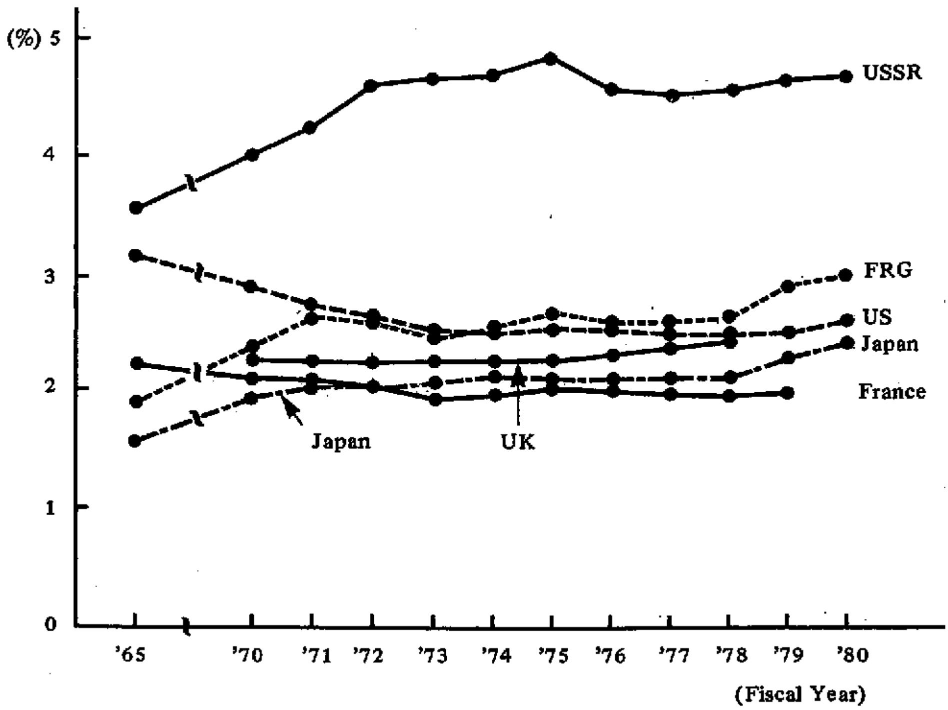


Figure 21: Distribution of R & D Expenditures by Sector of Performance

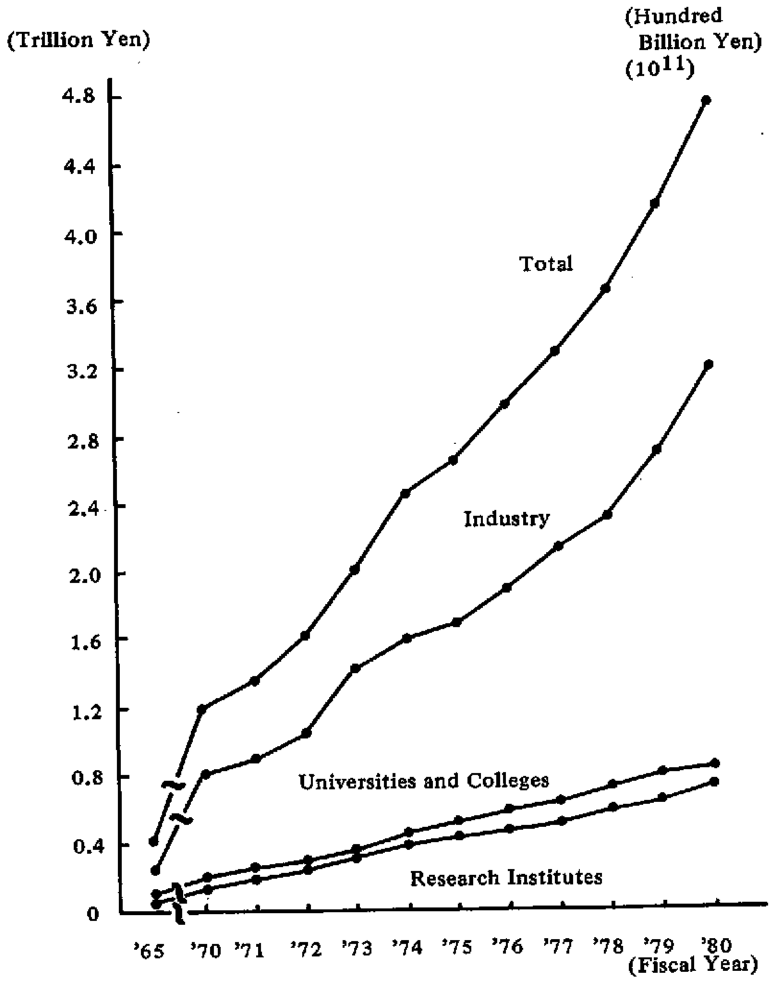
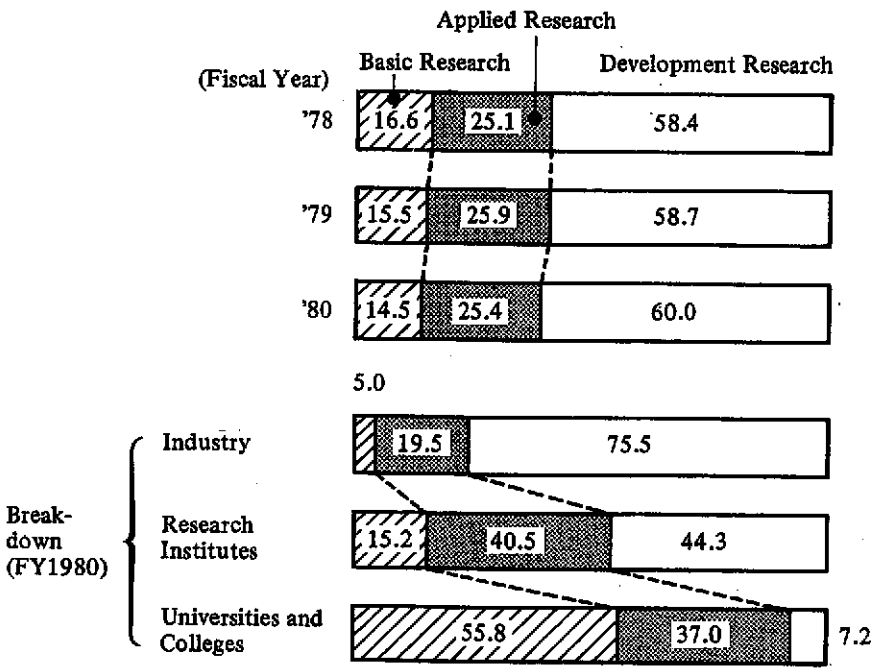
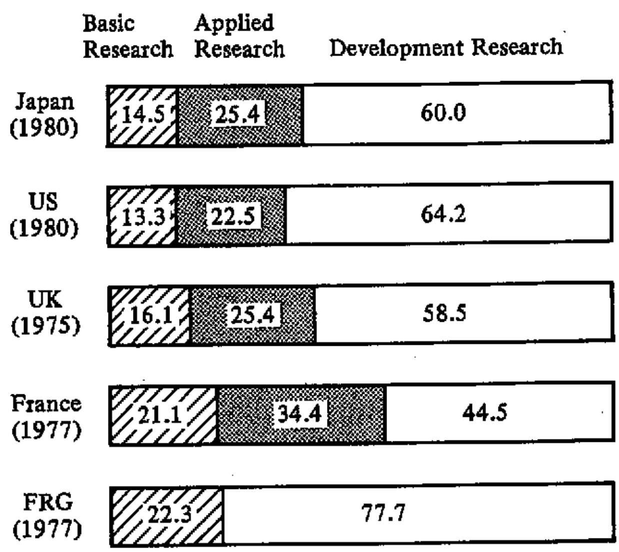


Figure 22: R & D Expenditures by Type of Work (percentage)



Source: Statistics Bureau, Prime Minister's Office, 'Report on the Survey of Research and Development'

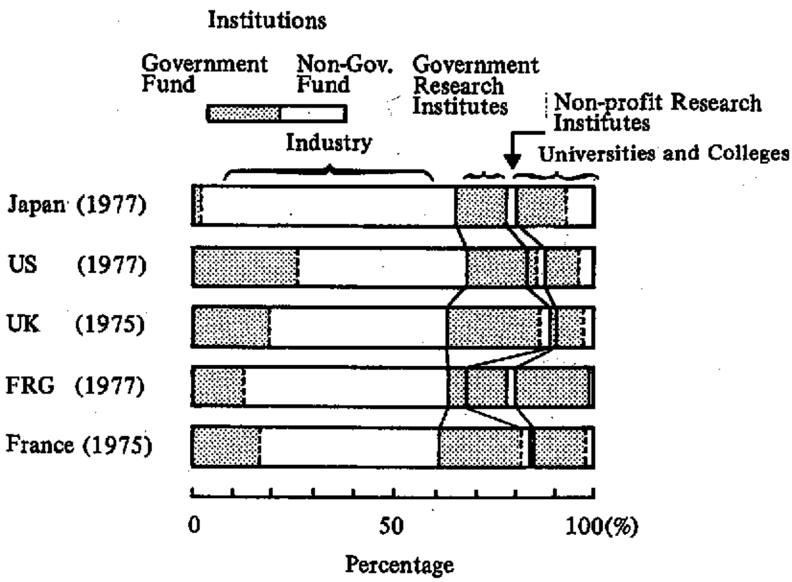
Figure 23: R & D Expenditures by Type of Work in Major Countries (percentage)



Note: 1 Data for the US are estimations.
2 No distinction is made between applied and development research in FRG.

Sources: OECD 'International Statistical Year'
Statistic Bureau, Prime Minister's Office, 'Report on the Survey of Research and Development' (Japan's data)
NSF, 'National Patterns of Science and Technology Resources 1981' (US data).

Figure 24: Percentage of Government Funding in R & D Expenditures by Sector of Performance



Note: Japanese public corporations are included in government.

Figure 25: Share of R & D Expenditures and its Funding Sources in Major Countries by Sector

Sector / Nation (year)	Expenditures				Funding Sources				
	Industry	Government	Non-profit Research Institutes	Universities and Colleges	Industry	Government	Non-profit Research Institutes	Universities and Colleges	Overseas
Japan (1977)	65.2	13.1	2.2	19.5	65.8	27.4	0.3	6.3	0.1
Japan (1978)	64.2	13.6	2.3	20.0	65.0	28.0	0.4	6.4	0.1
US (1977)	69.7	14.3	3.3	12.7	46.0	50.5	1.4	2.1	-
US (1978)	70.3	13.9	3.2	12.6	46.1	50.4	1.5	2.1	-
UK (1975)	62.7	26.6	2.4	8.4	40.8	51.7	2.6		4.9
FRG (1977)	68.4	15.2	0.2	16.2	55.6	41.3	0.2	-	2.9
France (1977)	60.3	22.8	1.4	15.5	41.1	52.7	0.6	-	5.6

Note:

1 R & D expenditures in the US and France include those for research in the humanities and social sciences.

2 French university funds are included in those of the government.

3 As in the classifications by OECD, Japanese public corporations funded by the government are included in government.

4 Although OECD's statistics are based on the data submitted by each country, there may be some differences in comparison with the domestic publications in each country owing to differences in definition.

Figure 26: R & D Researchers in Japan

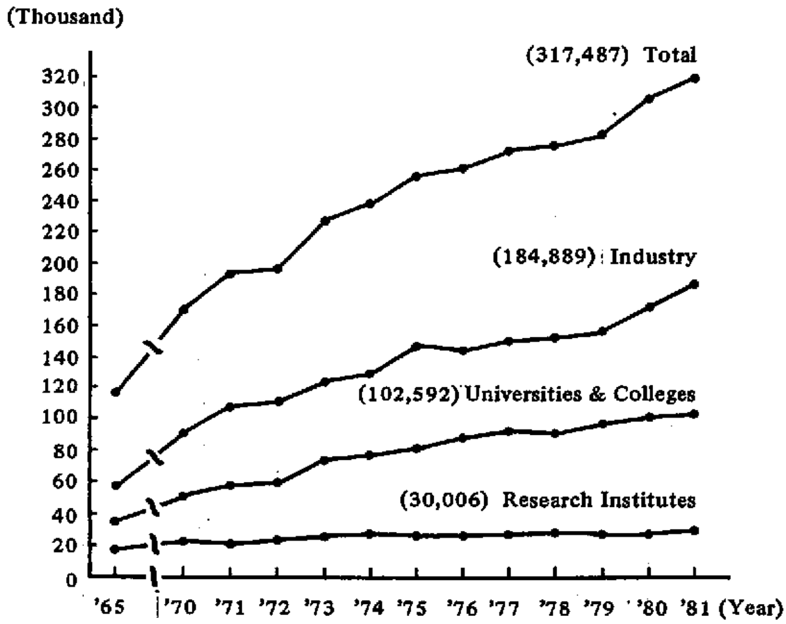


Figure 27: Workers Engaged in R & D

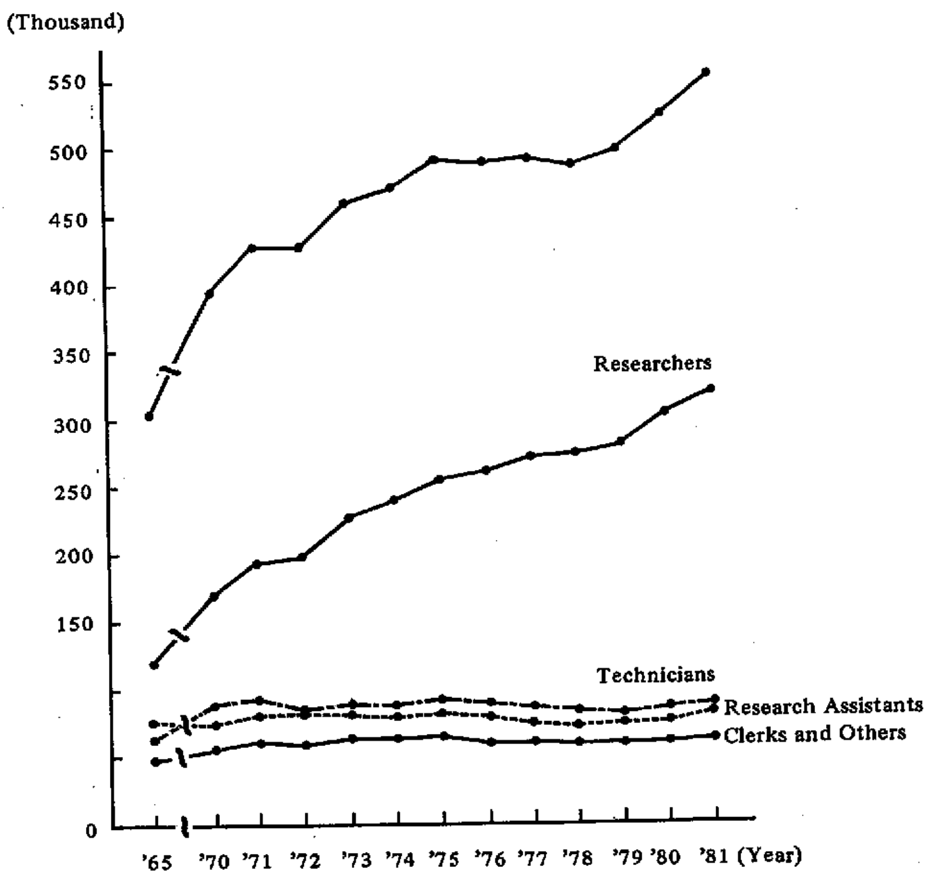
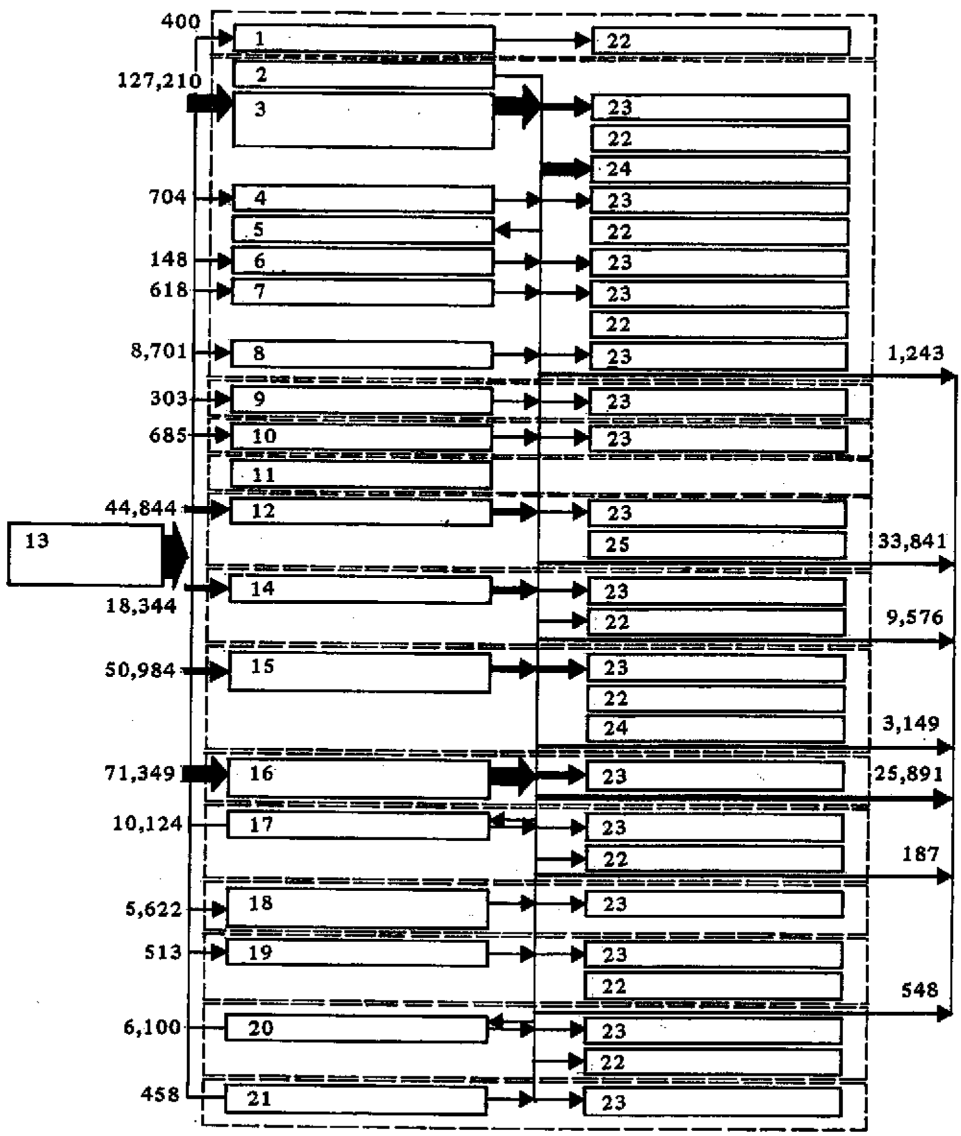


Figure 28: Budget for Science and Technology by Ministries and Agencies



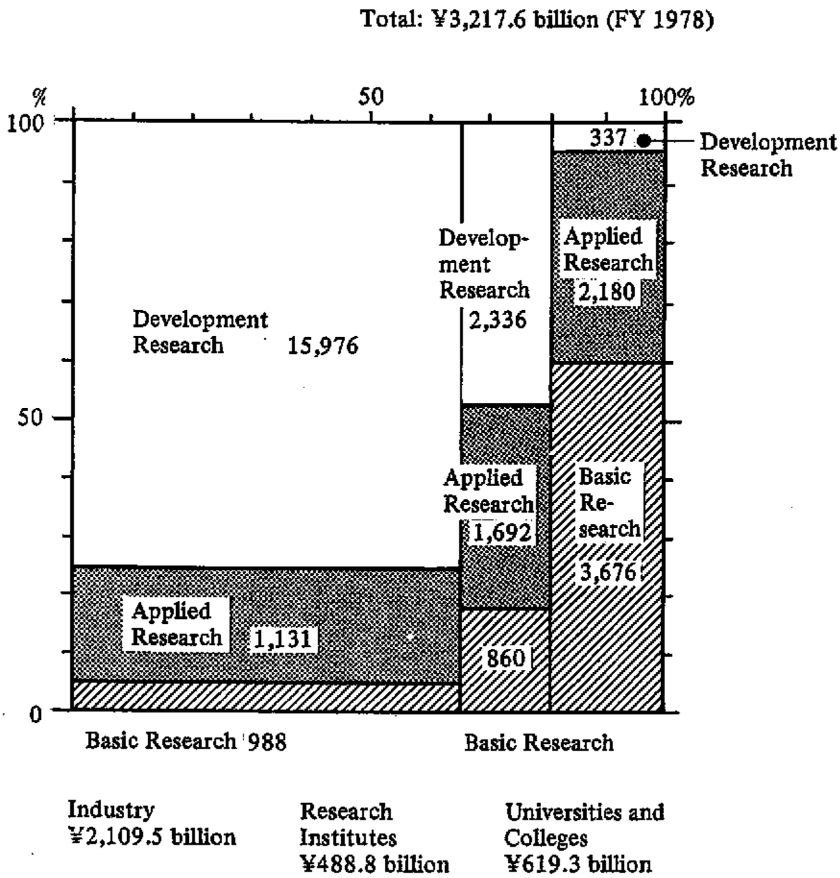
Figures within the boxes refer to the key on page 253. All other figures are in million yen.

KEY TO FIGURE 28

1 Diet
2 Councils, etc.
3 Science and Technology Agency
4 National Police Agency
5 Defence Agency
6 Hokkaido Development Agency
7 Economic Planning Agency
8 Environment Agency
9 Ministry of Finance
10 Ministry of Justice
11 Ministry of Foreign Affairs
12 Ministry of Education
13 Promotion of S & T ¥347,108 million
14 Ministry of Health and Welfare
15 Ministry of Agriculture, Forestry and Fisheries
16 Ministry of International Trade and Industry
17 Ministry of Transport
18 Ministry of Posts and Telecommunications
19 Ministry of Labour
20 Ministry of Construction
21 Ministry of Home Affairs
22 Affiliated Organizations
23 National Research Institutes
24 Public Corporations
25 National Universities

Source: 'Future Research Study Plans for Japan' (1979)

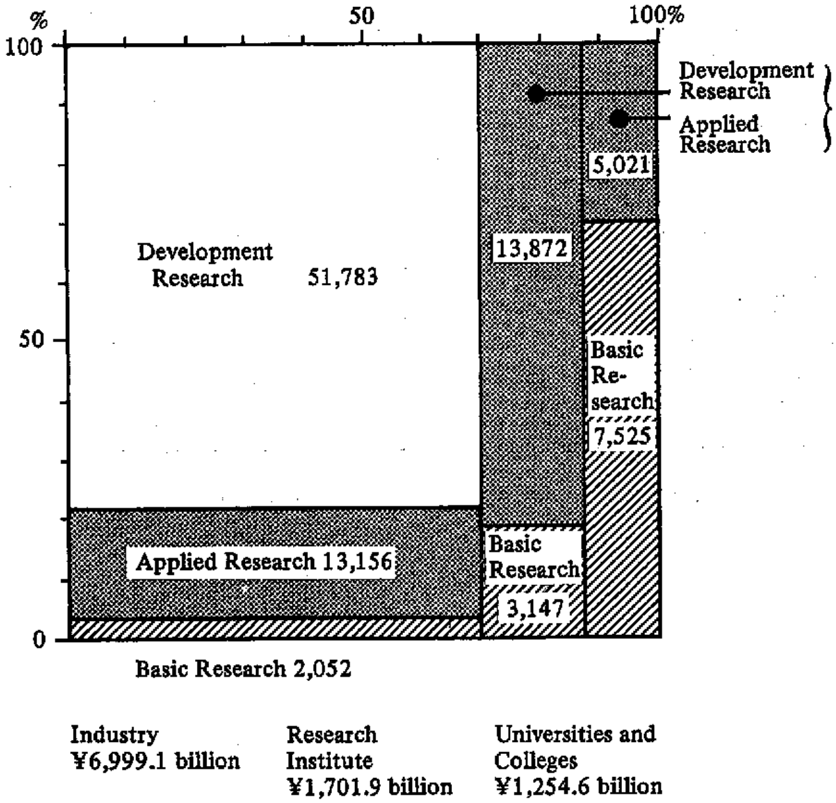
Figure 29: Share of R & D Expenditures by Sector and Type of Work in Japan



Sources: 'Report on the Survey of Research and Development'
'White Paper on Science and Technology in Japan'

Figure 30: Share of R & D Expenditures by Sector and Type of Work in the US

Total: ¥9,955.6 billion (FY 1978)



Source: NSF 'Science Indicators'
(Note: Conversion rate $1 = ¥300)

Figure 31: Basic R & D Expenditures per Researcher by Sector

Sector	(1) Basic R & D Expenditures in FY 1978 (Billion Yen)	(2) Number of Researchers in 1978	(1)/(2) (Thousand Yen)
Industry	98.8	307,347	320
Research Institutes	86.0	72,209	1,190
Universities and Colleges	367.6	205,434	1,790

Source: 'Report on the Survey of Research and Development'

Chapter Six

CONCLUSION

Chairman of the Session:
The Rt Hon Viscount Caldecote DSC FEng
President, The Fellowship of Engineering

Editor's Summary

The sixth session of the MANTECH Symposium was devoted to a general discussion and the formulation of conclusions. There were no further 'keynote addresses', but the session opened with a review by Sir Francis Tombs, Vice-President of the Fellowship of Engineering, of all the preceding papers and discussions. The review[82] provided a comprehensive basis for the closing work of the meeting.

Recalling that modern technology, besides offering new opportunities for improving the lot of mankind could also have bad effects if used incautiously, Sir Francis listed what some of these disadvantages might be: pollution (although nature herself was a great polluter and technology could alleviate some of these effects); social disruption and the weakening of traditional authority (of parents, tribal chiefs, parliaments or witch-doctors); aiding the growth of power and domination in the hands of small élitist groups (some believed this was possibly the most severe long-term danger); increasing social gaps between rich and poor (though there were many examples of the opposite effect); increasing societal vulnerability if large all-embracing systems should break down; and increasing unemployment (in the traditional sense of no paid work) leading if uncompensated to comparative poverty.

Some of these undesirable effects, said Sir Francis, could be minimized and possibly avoided by a greater general acceptance of change, change which was often resisted for no reason other than traditional conservatism. (Fear of the unknown is more powerful than suspicion of the known.) Rate of change was a most important factor here (although Professor Furukawa's paper had demonstrated how careful preparation and 'pre-training' could increase substantially the acceptable rate).

Like most other participants in the Symposium, Sir Francis had noticed a widespread and persistent feeling among scientists and technologists that non-technologists were illiterate, a criticism which provoked the non-technologist to retaliate by accusing his scientific critic of being incapable of a humane conceptual approach to his work. This was an underlying dilemma of modern society, and its resolution clearly needed each side in the controversy to increase its knowledge of the other's expertise. In the words of one of the participants in the 1977 DISCOVERIES Symposium in Rome (Professor Barrington Nevitt of Toronto University), 'Engineers should be encouraged to become poets, and poets to become engineers'. Or at least, concluded Sir Francis, engineers should learn to read poetry.[83]

The subsequent discussion began with comments from three of the principal earlier speakers: Professor Shuhei Aida, Dr Robert Frosch and Professor Gunnar Hambraeus. It had been hoped also to include in this 'panel' the former French Secretary of State for Scientific Research Pierre Aigrain, under whose 'high patronage' the third DISCOVERIES Symposium had been held in Paris in 1978, and HE Sheikh Yamani. Both were unfortunately prevented from attending by last-minute developments.

The first speaker was Professor Aida,[84] who formulated what might have been considered the practical interpretation of Professor Nevitt's appeal, namely how science and technology could best be developed and applied to the construction of a better world. The answer was through the development of eco-technology, the technology which linked man with the practical application of his scientific and engineering progress. Information and communications technologies were particularly able to contribute to this new branch of social development: the computer had already shown itself capable of contributing far more to society than society had devoted to its creation. Other comparatively recent developments, notably biotechnology, also clearly had important contributions to make, but as always could be used for the benefit or for the disadvantage—even the eradication—of mankind as now understood.

This oblique reference was the nearest the Symposium came to the subject of genetic engineering, a subject which had featured prominently in some of the previous DISCOVERIES meetings. The fact was noted by the next speaker Dr Frosch,[85] who had also been surprised to hear so little mention of the world's expanding population, an obvious and major factor in any equation concerned with world evolution.[86] From the viewpoint of mankind the world was a world of people, and Dr Frosch reminded the meeting that people could be extremely perverse: in particular by refusing to conform to the brilliant plans of brilliant super-intellects who from time to time come forward with 'package solutions' to all world problems.

Recalling that it was 200 years since the death of Adam Smith, 100 since the death of Karl Marx, and 30 since that of J M Keynes, Dr Frosch was convinced that there remained scope (perhaps even more than before) for new social experiment designed to encourage an educated public to ponder the questions of the future and declare their wishes as to how it should—if possible—evolve. Evidently he had great faith in encouraging 'users' to choose what they wanted, and a very few—at least in a society pretending to democracy—could disagree, though perhaps the more prudent would add the proviso that the users should be aware of the factors affecting, and the likely consequences of, their choices.

Professor Hambraeus,[87] agreeing with Dr Frosch, observed that the only real difficulty facing advanced technology was people. It would be ideal, he said, if there were none to deal with! Although a remark made with tongue in cheek, there is no doubt that this summarized, in a most penetrating manner, the entire question of what was mankind's destiny and how he could best fulfil it. Clearly many traditional ideas were no longer as valid as in the past, particularly concerning the 'dignity' of hard manual labour, even of manual work in any form. Professor Hambraeus hoped for a system 'where everyone would give what he could in time and effort, each according to his own abilities'. Thus would employment be separated from its present direct relationship with wages and salaries.[88]

But the professor went further: his concluding remark recalled 'a former teacher who maintained that biological life on this earth was only an intermediate stage on the road to a very superior race of electronic life'. That the human race, in fact, was only a means towards an end and in no sense an end in itself.

The discussion was then opened to the floor, and immediately produced more comment on the problem of finding sufficient employment in a world of overproduction and market saturation in many fields. Professor Ranger Curran (Youngstown State University) believed this was a problem that must eventually face every country, though for many reasons both the impact and its time scale would vary according to the characteristics of individual countries and their populations. The professor considered all countries as yet underdeveloped with respect to automation, which in all cases would begin (or had begun) as small isolated 'islands' with humans on the periphery, each island gradually expanding until virtually all production everywhere would take place in automatic factories. As the world moved towards this condition, said the professor, and the 'information society' spread to every land, the intellectual and cultural gaps (stratifications) of present-day society could be expected to narrow, and the question of employment would face virtually everyone.

Practically, there were two types of scenario: the optimistic in which, after temporary unemployment followed by retraining, new work would be found by those seeking it; and the pessimistic scenario where 'people will never go back to work in manufacturing', for it was entirely conceivable that employment in the manufacturing sector would shrink to the same degree as it had already done in the agricultural sector.

This led Professor Curran to advocate more and better advance planning, against which—at least in the United States—he said there was a 'national phobia'.[89] He hoped that his and other countries would set up planning councils to make social provision for all people displaced from employment—people who had hitherto comprised a major stabilizing force in society.

The professor ended on an optimistic note. The industrial society, he said, had separated the artisan from the artist. The information society could and should enable them to be reunited, leading to 'the greatest revival of art that man has ever known'. All participants in MANTECH should return home with this great challenge in mind: 'it is not a dismal future, but a future that we have to shape . . . both in our technology and in our social institutions'.

Professor de Sola Pool (MIT) was also optimistic, if perhaps for different underlying reasons. There was, he said, 'a certain stability in human wants and human needs and human interests' that had persisted throughout human history, while what had changed had been technology. Hence the crucial social analysis was not 'how men will change over the next decades, or centuries, because they will change very little in their wants and needs, but how they will adapt the changing environment that technology creates to their wants and needs'. Policy-makers could create new environments but, as Dr Frosch had pointed out, people learnt to turn these to their advantage. The same would happen with technological developments, and the societal changes to be expected would be those enabling people to incorporate into their lives, and adapt themselves to, the changing technologies so as to draw from them the greatest benefits.

From this viewpoint it was true that any new technology—at least in its early stages—was 'very determinative', for it had to be used in the way in which it was initially created. The technology was determinative because it was so fixed. But later, 'in the mature stage of a technology, we know how to do with it whatever we want to do: how to modify it, or to do it in a very different way if we want to'. This was the cause of much difficulty, for '. . . in the meantime, social institutions will have evolved around the technology that are hard to change'. Government institutions, industries, unions, all sorts of institutions would have been built around the technology in its original form, so making the social conditions determinative at later stages rather than the technology. 'What is frustrating,' concluded the professor, 'is how does one introduce the changes that are now technologically possible into something that has a social cocoon built around it.'

This prompted Mr Peter Davidson, a consultant in education technology, to insist that (despite Professor Hambraeus's concluding remarks in his review of the Symposium) MANTECH was about MAN, about man's society and man's culture. Representing himself as a 'member of the public', Mr Davidson believed he had detected 'a certain underlying smugness' in much of what other speakers had said. He would very much have liked to believe Professor Pool's assurance that man would in the end always profit from new technology, and it was the duty of the 'experts' to ensure that this happened. Nevertheless he foresaw immense societal changes in the coming decades, so much that man, who had held the 'centre of the stage' throughout his civilized history, might by the mid twenty-first century 'not be on the stage at all'. He would be author, producer, director and also prompter, but he would no longer be a player. Electronics in one form or another, technology in one form or another, would do all the things which man had had to do in the past using brute muscle.

That was the nub of the employment problem. Mr Davidson knew of a case where a computer aided design (CAD) system would shortly enable a design team of 40 to do work currently occupying 165 people. Already those who did not know when they would be going, he said, knew very well that they would be going. 'These,' he concluded, 'are the real problems of the social and cultural pressures of technology, and just how worrying they are.'

A clarion call to the engineer's conscience! Professor M W Thring was quick to respond. The engineer, he said, had a special responsibility for the future, because he was the only person who could tell what kind of machines could be invented. 'The politicians always plant the future with existing machines, but the engineer knows that one can do this and one can do that.'[90]

Professor Thring again stressed, as he had done earlier, that the pursuit of faster and bigger machines, or bigger output, could not continue exponentially for ever. The responsible engineer must look forward and foresee the problems likely to be created by over-production in face of resource limitation, unemployment in face of tasks needing urgent attention, poverty in some parts of the world in face of excess plenty in others. These imbalances could well sow the seeds of war.[91] The responsible engineer, concluded the professor, 'should be concerned with those problems and not merely with developing more of the same because he enjoys doing it'.

At this point Mr G G Scarrott, who had clearly been listening critically to the largely indiscriminate substitutive use of the words science, engineering and technology (and their derivatives scientist, engineer and technologist), felt impelled to call for some precise definitions, which he believed might usefully be included as part of the record of the Symposium.

Science, proposed Mr Scarrott, should be defined as follows. Science fills a deep human need to understand the (natural) world. Scientific understanding is often useful, but not necessarily so. Hence scientific effort is motivated by insatiable curiosity, not utility, and must be supported by patronage in its classic sense of investment without foreseeable return.

Engineering however meets recognized needs of society. The spectrum of emphasis on distinct needs such as food, shelter, entertainment, armaments is determined by society at large, and engineers contribute to this assessment only as informed citizens, but without special privileges as engineers.

A typical engineering product or service is a synthesis of ends and means. The engineer identifies the ends from consideration of social needs and conceives the means by selecting from the laws of nature, initially discovered by scientists, those that will serve his purpose at least cost in human effort. So an engineering product that is not used is a contradiction in terms. It follows that every engineering enterprise can eventually justify itself in commercial terms. Engineering enterprise needs bold, informed investment but not patronage, which is death to engineering.

Technology refers to the means which are used by the engineer to achieve his ends, so that technology is to engineering as bricklaying is to architecture. Much technology is based on science, but it is an essential aspect of engineering, not science, so that technology must be supported by investment, not patronage.

On the basis of these definitions, Mr Scarrott then developed criticisms of the commonly used combinations 'science and technology' and 'research and development'. The two components in each case being intrinsically distinct pursuits, he believed their conjunction must lead to '. . . an ineffective use of resources since, for example, any single person or agency charged with fostering science and technology either regards support as an investment, and so cripples science, or regards it as patronage and thereby sterilizes technology as a servant of engineering'.

The final stage in this 'critique of pure connotation' came with the introduction of humane judgment[92] into engineering projects. This was to be achieved by recognizing that 'since engineering is a synthesis of ends and means, the means seldom justify the ends, and the ends do not always justify the means'. Mr Scarrott believed that some form of engineering equivalent of the Hippocratic oath might be developed for this.

However, Dr Frosch did not agree. Although he thought Mr Scarrott's definitions extremely elegant, he counselled rejection of their use. Why? 'Because,' he said, 'having practised in a career, starting with an education and a practice as a scientist, and sliding into a practice as an engineer simultaneously with being a scientist, having done both research and development separately and together, and having from government sponsored both research and development separately and together, I think that it is extremely important to blur those subjects. I have a reason for doing so, and it is that there are very important and powerful feedback connections among them, and if we are too precise in separating them then we shall forget that they feed upon each other. It is not the case that science creates what technology does, nor is it the case that technology proceeds separately from science. They feed on each other, and I am concerned that too precise a set of definitions will separate the necessary organic connections.'

Dr Frosch proceeded immediately to demonstrate those organic connections by declaring that he believed science and technology to be a 'human art form', created by man in order to describe and analyse the universe. 'We ourselves are part of that universe,' he said, 'and I see no reason why we cannot turn this art form to our own purpose in dealing with ourselves and our own problems more broadly than just at that part of the universe that we describe as being outside ourselves.' Mr Scarrott would almost certainly have agreed, though probably in different terms.

Dr Frosch's championship of interdisciplinary symbiosis was strongly supported by Sir Alan Muir Wood, provided it were accepted that the methodologies of the physical and engineering sciences were not always or necessarily applicable to every problem of the social sciences.[93] But there was certainly a need for greater 'synthesis across many abilities and professions if we are to achieve anything that we have been discussing at this conference', and Sir Alan believed the engineer's expertise in practical pragmatism was particularly well suited to bring this about. 'In many aspects of our profession,' he said, 'we learn to work with other professions,' bringing together the contributions of many to produce a 'single output of all the contributions'.

However, formidable obstacles were frequently encountered. One was the tendency of economists to make 'top-down' studies before bringing in the engineers, who could then be faced with impossible requirements that would have been avoided had the first approach been 'from the bottom up', demonstrating immediately what could and what could not be done.

In a further criticism of economists (evidently based on difficult personal experience) Sir Alan maintained that usually they 'did not understand the difference between what the ancient Greeks understood as labour and work, words which have very different connotations'. As a result they (the economists) had failed to produce 'economics which have any validity for closed systems, and we are moving towards closed systems for which schemes of economics have to be produced'.[94]

Application of 'the scientific method' to social problems was also discussed by Professor Fred Margulies (IFAC, Austria), who declared himself always encouraged when scientists and engineers showed concern over what their achievements might mean for the public in general and the individual human being in particular.

Professor Margulies shared the view of others who had suggested that MANTECH had concentrated more on technology than on man and society.[95] There were, he believed, two main reasons for this: first, that whenever a new technological development was being planned or introduced, everybody (technologists, economists, organizers, sometimes even government or social scientists) was encouraged to participate with the sole exception of 'those really affected', whose role was rarely more than '*post factum* acceptance or refusal'. Second, and this was reflected in the MANTECH attendance, the 'technologists and scientists put themselves in the position of medical doctors consulting over the treatment of a patient, taking great care the patient should not overhear their deliberations'.

The professor (who, as representative of the Austrian Federation of Trades Unions of Salaried Clerical, Commercial and Technical Employees, has frequently drawn the attention of DISCOVERIES meetings to points of this nature) insisted once again that 'technical and societal change will only be satisfying if it is brought about not for the people, but with the people affected'. The public acceptance of new technology, in fact, required consultation before not after its arrival. Otherwise, he said, 'we might find ourselves confronted with patients who take their cure into their own hands, maybe by calling conferences to discuss the effects of anti-technology on technologists'.

A threat perhaps, or a carefully placed gauntlet designed to bring the discussion back to the challenge of the Symposium title? However intended, the remarks immediately stimulated further comment on the implementation of human ideas in a humane manner.

First to respond was one of the most stalwart veterans of the DISCOVERIES Project, Professor Eduardo Caianiello, Director of the Salerno University Post-

Graduate School of Cybernetics and Physics, and formerly Director of the Cybernetics Laboratory of the Italian National Research Council,[96] who quietly but authoritatively asserted that he was in complete sympathy with all who championed the 'man' in MANTECH. Second, he questioned the 'wholly deterministic attitude that we as a congregation of scientists have here in telling what the future will be or should be'. The well-known theorems of Kurt Gödel provided fundamental reasons why this attitude was unsustainable, and the professor proceeded to demonstrate, firstly how very much 'conventions of the day' could be based on tradition pretending to be laws of nature ('the old Latin and Greek historians never made a single suggestion that their worlds might exist without the institution of slavery'), and secondly how much the evolution of civilization had been affected by accident. (He cited some almost trivial chance events in the history of the Islamic World.) 'Accident,' he declared, 'has ever prevailed in deciding battles, and not only military battles, and all sorts of events.'

But convention did change with time, with or without the stimulus of further 'accidents' (which would occur in any case), and the professor found it easy to show that a great deal of modern societal structure was in fact obsolete, 'starting with nations and armies on the one hand, and on the other a cultural background for which we do not even question whether some concepts which have been valid since we can remember from the times of our ancestors are really valid for ever'.

So with modern attitudes to work. Recalling a meeting, during the Rome Symposium, with the Vice-Chancellor of a Nigerian university, Professor Caianiello said he had explained that most Western constitutions were based on the ethic of work, not as a necessity but as an ennobling activity. The Nigerian Chancellor was astonished! 'Work if you have to, of course, but why frame a constitution on it?'

By living in the past, where human labour was necessary for survival, we were denying ourselves the future, where it would not be so. Dr Frosch had called for experiment with social change, and our reconciliation with the future—the glittering future that our science and technology had made possible—clearly called for such experiment. However, said the professor, we must seek ways of viable experimentation without arousing emotions, which could delay advances in almost any field.[97] But the river of progress would never be held back more than momentarily: interdisciplinary analysis and debate could decide whether the flow would be used for mankind's betterment or allowed to destroy it.

Experiments with social change might be planned by technologists, but their implementation inevitably required administrative help. It was most valuable to have the comments of the top-ranking British civil servant Lord Croham, for whom theoretical propositions concerning the causes of, and cures for, the 'disbenefits' of advanced technology were less fundamental than the day-to-day actions needed to keep the societal machine in good running order.

Like others before him (although, apart from Dr Frosch, less forcibly in the present Symposium than in some other meetings), His Lordship saw the expanding world population as a major cause for concern, bringing more and more people into an already oversaturated labour market.[98] However, he saw unemployment, at least in the advanced countries, less as a problem of 'finding people something to do with their leisure' than as a requirement to provide these people with an 'acceptable status', linked with income. To some of those present this thesis was novel and not without comfort (in practical terms, status can be less costly than salary), but His Lordship was adamant that 'those who are displaced because the cost of labour is too high' were above all anxious to secure 'the right kind of income without either being regarded by those who go on working as parasites, or being regarded by themselves as pushed back . . . in a queue of relative responsibility and weight'.

In agreement with earlier remarks by Professor Pool, His Lordship believed many fundamentals of human relationships were 'largely immutable'. For that reason the new communications society was unlikely to lead to the immediate and total isolation of individuals and the destruction of the family, meaning that 'the problem of labour time and unemployment will also be a problem of families'. Here again was a straw of reassurance, albeit difficult to reconcile with the prognostications of Professor Hambraeus's former teacher!

At a more mundane level, Lord Croham had some gentle words of criticism for technologists who tended to ignore the problems of costs and prices when advocating what they described as essential programmes of research and/or development. Gentle words? Perhaps because of where he was and among whom. But those with experience of extracting funds from keepers of the people's purse may have caught a glimpse of long-practised strategies for justifying negative responses to what Sir Alan Muir Wood had termed 'bottom upwards' approaches.

Two more comments on the problems of unemployment (or re-employment) came from Professor W S Elliott—a computer expert almost since the birth of electronic computers—and Dr Harold Chestnut of the US General Electric Company.

Professor Elliott recalled a science-fiction story written long ago by the Swedish Nobel Laureate Hannes Alfven—incidentally one of the professors who had taught Professor Hambraeus. In his book Professor Alfven predicted several developments which MANTECH had discussed, including computer robots capable of building more computer robots (self-production) until, having taken over the world, they rendered the whole of mankind redundant. However, being of a humane nature they practised the humane use of artificial intelligence, and provided man with 'just enough work to keep him happy'.

In the real world, said Professor Elliott, it had long been known that automation would lead to a great deal of leisure, and that people would need to be educated in its use. Now the leisure was here, and was known as unemployment. Perhaps society, like Professor Alfven's robots, should be planning to provide its members with just enough work to keep them happy.

But what kind of work? Some people were less gifted than others, and for them the provision of a full and satisfying life, with dignity, presented perhaps the greatest problem. Not all factory workers disliked repetitive work, and many had declared they would prefer it to queuing for unemployment benefit.

Here, in a nutshell, was the challenge of modern technology.

Dr Harold Chestnut had similar thoughts, and called for a study of 'new ways of employing people', to balance the loss of old ways that automation was bringing about. He was also concerned with the continuous emphasis (which MANTECH had certainly maintained) on more research and development when 'we already have many ideas which could be technologically transferred'.

'We should,' he declared, 'try to capitalize on the fact that we do have many products and many applications that could be exploited.' Recalling the description, by Professor Yoshimura, of how Japan had built her industrial success on imported technology, Dr Chestnut's call seemed both humane and economically sound.

Several further interventions in this somewhat marathon discussion should be recorded.

Two concerned agriculture, the first a proposal from Mr Handel Davies who called for much greater use of aerial spraying in the pesticide treatment of crops thoughout the world. Although such spraying was extensively used in a few 'advanced countries' (East Germany, Japan and New Zealand), in the developed world as a whole only two per cent of the land was treated, which was even well below the world average of five per cent. 'It would be nice,' said Mr Davies, 'if it were 30 per cent.'[99]

Professor Brian May included aerial crop spraying in his own plea for more technological aid in 'the race between population growth and the need for more food'. (He also called for embryo transplants, cloning and other biological manipulations.) Furthermore, in this field, and referring to various remarks and suggestions that the Third World was not always ready for the transfer of the most advanced technologies, Professor May insisted that in the case of agriculture, this was never the case.

A thoughtful comment on education came from Professor Sir Norman Rowntree, who had been impressed by the papers of Professors Furukawa and Yoshimura describing the situation in Japan. There, he believed, a great deal of attention was given to learning to learn, with results that were clearly seen throughout the world, and not least in the present meeting. Sir Norman also allowed himself to speculate on the changing subjects of scientific and technological study. Since his own graduation as a civil engineer there had been 'five major changes of subject', and he wondered what new subjects would face 'the new generation of engineers today'. Learning how to use leisure, perhaps?

Professor Gunnar Hambraeus, having already thrown into the discussions a considerable number of stimulating comments and suggestions, now contributed a list of points which he believed merited the careful attention of all his colleagues. First, the new relationships developing between employment and technology, and the need to create a new pattern of work. Second, the stimulation of the desire in young people for an education that would encourage their curiosity and their creativity, so that they should equip themselves to contribute to the advance of society. Third, improved transfer of technology, and the avoidance of protectionism—both in commerce and in the diffusion of knowledge. Fourth, the improvement of understanding and intellectual exchange between scientists and technologists on the one hand, and politicians and decision-makers on the other. Fifth, the need to avoid the 'monoculture of Western technology being uncritically acquired by the developing nations, to the exclusion of indigenous basic contributions'.

Lastly, a particularly encouraging remark for any and all who might be apprehensive concerning *quo vadimus?* 'I should like to stress,' said the professor, 'that all the technology we have discussed over the last few days is indeed a very friendly technology. It should be developed to be more and more friendly. Computers should speak with nice friendly voices, and telecommunications should convey good feelings between human beings. That is a goal we have to work for very hard, each within his own reality.'

This provoked Sir Francis Tombs to make one final and most profound observation. During the Symposium he had noted on several occasions that a particularly important question had 'shown signs of surfacing but had always gone away'. It was the question of the fundamental relationship between technology and mankind. 'It has been suggested at times,' said Sir Francis, 'that it is the job of society to adapt to technology, and at other times that technology should look ahead and organize itself to meet the needs of man. This role of technology as determinative or responsive is a very important point that would bear closer examination on another occasion, for it lies at the very root of many of the problems we have in obtaining social acceptance for some technological advances.'

A fitting thought for each participant to carry away from MANTECH.

6.1 Symposium Review

Sir Francis Tombs, Vice-President,
Fellowship of Engineering

The rich variety of viewpoints presented during this conference makes a full summing up quite impracticable. Instead I intend to try to synthesize the discussion on the central theme of the meeting and to suggest some resulting topics for discussion here and elsewhere.

The central theme of the Symposium was that modern technology creates new opportunities for mankind, but it can also bring with it new social problems. So I propose to deal first with some effects of technological development, then the perception of it by policy-makers and the public, then some brief consideration of particular Third World problems and finally I shall try to envisage some constructive steps forward.

First, on the effects of technological development. The benefits are so obvious and so widely accepted that it is sometimes thought by supporters of technology that any disadvantages are automatically offset. Conversely, the opponents of technology often take the advantages for granted and concentrate instead on the disadvantages.

The advantages will bear some restatement. They are concerned with providing for the enrichment and easing of the lot of mankind, though the full potential is often not realized for cultural and economic reasons. Some examples might be the control and mitigation of natural disasters such as floods, famines and epidemics, and the provision of such needs as shelter, clean water, sewage, food, communications, education and wealth at large.

What are the disadvantages? First, all those effects commonly recognized as pollution, although we might note that nature is a great polluter in its own right, and that technology is capable of reducing pollution whether created by nature or created by technology.

Second, the disruption of social patterns. We heard a very vivid description during the conference of the social effects, the ethnic effects, of the Aswan Dam development, which resulted in the displacement of large colonies of Nubian fishermen and farmers.

Next, perhaps, the weakening of traditional authorities in society: parents, chiefs, parliaments, witch doctors (although this is somewhat balanced by a growing recognition of the interdependence of individuals); the growth of power and domination amongst nations and individuals; the increasing gap between rich and poor, both nations and people; the vulnerability of some of the high technology systems we produce–very large conglomerations of power or computer systems–to disruptive action by quite a small number of people; and finally, of great importance in this country and many Western countries, the recent growth of unemployment, with the resultant loss of dignity, growth of boredom and comparative poverty.

The balance of advantage surely lies with technology, but it needs to be seen and used (and seen to be used) with sensitivity to its effects on people and on established institutions. Resistance to change is based on love of the past, which might be called security or tradition, and fear of the future, a general feeling of insecurity.

Technology is essentially the agent of change in material things, but the ability of man to adapt his habit of life is limited. Hence the importance of the rate of change, as stressed by many speakers in our meeting. Rapid developments last century produced enormous social changes in the UK, but these occurred against a background of poverty, population explosion and a general acceptance of authority–conditions which today may be present in the Third World, or parts of it, but with much higher pressures even there, much higher resistance to change, stemming from culture and other considerations. And there are in the Third World enormous instabilities appearing, arising from the rate of change which they are experiencing, from comparisons made with richer nations, and from expectations which are naturally promoted by politicians and others.

In the West the conditions underlying acceptance of change in the nineteenth century are not present today. Readiness to accept change diminishes with material well-being–what the economists would call the propensity to consume. People can use only so many motor-cars, so many video recorders, and eat only a given quantity of food per day. But readiness for change is also affected by democracy and the right to express one's opinion, with the growth of literacy and the ability to question. The tensions are different from those of the last century, but they are clearly visible, for example in protest movements and their politicisation. Perhaps protesting against technology is a luxury specially reserved for the wealthier nations.

The gap of wealth and technology between the North and South, or the centre and periphery as we heard it alternatively described, will be bridged, but not quickly. The rate of change possible is crucial, but developments need to be appropriate to the needs of the evolving countries and to take account of cultural and political frameworks in those countries.

I should like to turn briefly to the perception of technology by others, aptly described by one speaker as a mixture of appreciation and resentment. There is, I think, a feeling among the general public of lack of control of technology, stemming basically from an ignorance of the complex technical issues and the remoteness of the decisions taken; a feeling of powerlessness. Yet paradoxically there is a desire for an 'instant fix' of problems–a belief that all disease is curable—and an inability to accept failure in performance, which we have seen for example in thalidomide, Three Mile Island, Seveso and the DC-10 crashes. I think it is necessary, in discussing the perception of technology by others, to distinguish policy-makers (who need to try to understand the issues) from the public, who are generally interested in other things, but whose consent is needed, at all events in a democracy.

First, then, the policy-makers. Technologists generally deplore what they call technical illiteracy. We heard a great deal of this from a number of developed countries. We heard it suggested that the UK is perhaps the leader in technical illiteracy because of its educational background, and there is some justice in this comment. But, I wonder, do we technologists rely too much on using the scientific method to deal with tangible issues, and assume they must also be paramount in dealing with intangible issues? Is enthusiasm for technology therefore a trap? Many social issues have proved intractable by the scientific method, because the factors (generally people) were not measurable and because controlled experiments were not practicable. The contra-view of the non-technologist is that technologists are imprisoned by their mechanisms and incapable of a conceptual, philosophical approach. Whilst we do not have to accept that view entirely, there is enough in it to give us cause for thought. We and they have to bridge the gap by mutual understanding, and it is fair to say in this rather privileged company that the relative certainty of technology can lead to lack of humility in approach to more general problems.

In the published account of the DISCOVERIES Symposium held in Rome in 1977, the final paragraph reads[100]: 'The conclusion, simple of expression but most complex and difficult of realization, was that engineers should be encouraged to become poets and poets to become engineers. . . .' Well, perhaps not become, but at least appreciate.

Now for the public and their perception of technology. I said earlier, and I am quite convinced, that most members of the public are not really concerned with technology. They are concerned with football, or weather, or gardening. But they are, of course, subject to the effects of technology in every aspect of life, and they are frequently required to adapt their way of life through unemployment and retraining, or change of living patterns, under the pressure of technology. They are required, too, to accept major decisions as on nuclear power, biotechnology, information technology, the details of which they do not understand but which they can at least appreciate will have a major effect on their lives and on their standard of living. The communication of complex technical issues through the media is generally selective and highly edited to simplify the issues. In general, in order to obtain impact, there is a concentration on failures, and this is not a one-sided criticism of the media, it is what the audience demands and it is what the competition for circulation and viewing numbers requires. I am bound to wonder whether the rapidly growing volume of information will mean increased selectivity and editing, increased concentration and simplification. If so it may well be damaging, and it may be that the increased volume of information about which we all tend to be so pleased may bring substantial disadvantages.

I want finally to suggest, in relation to the public, that the authority of technologists in the public mind depends not only on their technical competence but on their concern for society and their willingness to contribute to wider issues than technological ones.

Next, a few comments on the Third World where the problems of technology's impact on society are quite different. Material needs are much greater. One need only mention poverty and sanitation in general, quite apart from food supplies. But the human and technical resources, and the financial resources, are less. These pressures, combined with the rate of change I mentioned earlier, produce political instability and impatience, either of which helps the transfer of wealth and technology from the richer nations. The West should therefore avoid imposing political or technological systems evolved over 150 years on the developing nations, whether from conviction or from convenience. One example of this might be a two-party democratic system, which we find very suitable but which other nations do not necessarily find suitable at all. Another example might be a nation with an under-employed nuclear power industry seeking to sell nuclear power stations in wholly inappropriate circumstances. Yet another example, from my own background, is the not infrequent proposition of an interconnected grid system with large central power stations in countries where local, independent small units–long since passed by in the West–would be more appropriate. Again, why insist on large jetliners where small turboprop feeder aircraft might be better; and let us recognize that the agricultural systems which we tend to impose, occasionally, are not necessarily suited to evolving peasant culture. The problem essentially is that we in the West tend to pass on our latest developments, whereas the countries receiving them may be looking for things long outdated here. On the other hand, dramatic steps like hydro projects, where the beneficial use of natural resources may also reduce natural hazards, have had some dramatic effects.

The aid agencies have an important guidance role, about which we heard during our conference. But technologists need to be aware, more aware than they are, of the cultural, social and economic pressures, and accordingly to adapt their current thinking and aims in trade with the Third World. The imbalance of wealth and the needs of the Third World is largely a political/ethical matter on which technologists should have a view as thinking, responsible citizens, but have no special contribution to make except through their chosen field.

If my general approach is accepted it is necessary, first, to recognize the limited though vitally important contribution of technology to the advancing condition of mankind.

Second, we must develop sympathy and understanding among technologists for social conceptual issues.

Third, we should try by all available means to advance technical understanding among policy-makers and the public.

Fourth, we must try to restrain enthusiasm for technological development *per se* where substantial social problems may be caused.

Fifth, current Western technology must be adapted to the present needs of the Third World, not vice versa.

Finally, we must use the great communications revolution in a constructive way. Are we so sure of what we want to communicate and how to make use of the powerful new facilities becoming available?

That represents my tentative summary of the threads of the discussion. I should like to suggest, if I may be so bold, some questions which seem to me to be very open and on which contributions would, I am sure, be welcome. They all arise from the conference; none of them is due to me.

First, does the growing application of technology necessarily increase the gap between rich and poor nations?

Second, are technologists in danger of excessive enthusiasm for technology to the possible detriment of society? If so who will moderate it? The businessman? The politician? Or the man in the street?

Third, will the growing rate of technological change produce a greater division between the technologically educated and the rest, and would such a course damage society?

Fourth, will the great advances in information technology swamp the capabilities of the individual? Will the role of the editor and the interpreter grow, with the risk of selective and biased presentation of technical issues?

Fifth, can technologists come to accept the limitations of the scientific method in social and political aspects of technological proposals?[101]

Finally, how can technologists convince policy-makers and the public of the validity of highly technical risk/benefit arguments?

6.2 Closing Address

Professor Shuhei Aida

As a member of both the Honda Foundation and the MANTECH Organizing Committee, I believe I should try to explain a little of the purpose of this meeting.

The aim of the DISCOVERIES movement, sponsored by the Honda Foundation, is to realize the concept of eco-technology, and MANTECH was conceived on this basis. MANTECH is an abbreviation for Man and Technology, and ties between man and technology.

The problem of how to create ties between man and technology is today's important theme in preparation for the twenty-first century. Recent technological progress can be described as the 3Cs and I: Communication, Control, Command and Intelligence. The technological revolution in communications, information and computers has been producing not only more social benefits than expected but also many negative factors.

In conventional technology an objective or an intention is first determined. Then, by virtue of technical efforts, the desired result takes form as hardware such as bridges, infrastructures, etc. The final result of the work is in fact defined at the time the objective is set, as is the 'scenario' or plan for its achievement.

This kind of relationship between man and technology has begun to take on a slightly different look with the development of information technology. The actual result of achieving an objective may be substantially different from what was originally planned. In the case of hardware structures such as bridges, buildings, etc. there is of course still expectation that the result will include what was planned, even though unexpected results may also be produced. In the case of information technology, on the other hand, it is no exaggeration to say that, unlike the construction of conventional infrastructures, the construction of even hardware can produce a series of unexpected results in society. It is to be noted therefore that the development of computer technology produces innovation in the 3Cs (Communication, Control and Command) and changes I (Intelligence), so having considerable impact on international, technological and economic relationships.

Along with the development of information technology, research and development in biotechnology is making rapid progress in step with the technological innovations in electronics. Biotechnology is expected soon to become 'world topic of the day', as indeed it is already in some of the mass media. In addition compound plastics and 'ultimate materials' are expected to be gradually highlighted in the chemical industry.

It is clear that much of this technology has already passed the stage of research and development and is now at the stage of diffusion. What we must consider today is whether we should create positive ties with that technology or negative ties. Throughout man's history so far, science and technology have always been related to the qualitative improvement of man's life.

This can be said of the recent information technology in particular. Man's information capacity has expanded on a global scale and has improved in quality. In this particular field man has created close positive ties with technology. With respect to the future of these ties, it is only too natural that the problems involved should concern how to employ future technology in man's society. In this sense it may be said that the ties between man and technology should be closer in future than they are today.

In history man's contact with science began when he began closely to observe natural phenomena and to use them to improve his way of life. His knowledge and use of the laws of nature, accumulated over the years and converted into various kinds of technology, have brought about today's technological age. In other words, in the past technology has been developed largely on the basis of accidental discoveries and their combinations. Today however (and the development of space technology provides a striking example) the progress of modern systems engineering has made it possible to achieve a particular objective by intentionally combining knowledge and technology in a pre-planned manner.

But such pre-planning should not apply only to 'technological hardware'. Societal developments (including such matters as employment and unemployment) should be included, for they are cultural, social and interdisciplinary problems.

Industrial society must be helped more and more towards maturity, in which process we have to consider how to establish symbiosis with information technology. It should also be recognized that the more knowledge of nature man acquires, the more negative ties between man and technology appear. That is to say that, with the elucidation of the ecological system, the idea appears that man's more negative ties with technology are necessary. The acceptance of this idea may help to harmonize human society.

Modern technology is certainly one of the results of past efforts to make a perpetual-motion machine, or the efforts of the alchemists to find the 'philosopher's stone'. There is no doubt that modern technologies born in the West have made unexpected progress. Robotics have made their début as the result of functional and structural research and development. The dreams of perpetual motion and the hopes of the alchemists have been shattered, but robots have appeared as systems in the information society and as parts of a modern myth. In order to hand down this myth from generation to generation it is important for us to reconstruct man's spiritual activities. To put it concretely, it is necessary to pursue technologies based on traditional culture. It should not be forgotten that the more functional capabilities a machine has, the more contact with human feelings is required.

From the viewpoint of technological history, modern mechanical civilization represented by robots or automation began with mechanisms made up of mechanical parts, and robots are the products of mechatronics; that is, mechanics and electronics combined. An ancient oriental philosopher seems to have predicted the confusion of today's mechanical civilization. According to him a machine is based on an artificial mechanism, and if man thinks only of the use of a machine the thought of leaving everything to the machine will be cultivated and he will lose his primary object and human feelings.

In introducing robots in particular, this is a basic matter to which we have to direct attention at all times. It is very regrettable that many Japanese companies involved have ignored the cultural and commercial rules of international society, thereby causing cultural and economic frictions between Japan and the Western countries.

In the case of business activities, robots are introduced and work in the production process and, at least in Japan, human workers work together with robots in perfect harmony. Under the European and American cultural climates however this kind of thing cannot even be thought of. Japan has the greatest number of robots in the world, and human workers faithfully work together with robots according to a mechanical command. This may appear bad to Europeans and Americans, and may even be beyond their comprehension. They need, I believe, a greater consciousness.

They say they do not want even to imagine that their places of work may be taken by robots, even if this is intended to improve economic development. Because this sort of thing can cause cultural frictions with other countries, it is necessary for us in Japan to develop a strategy and tactics designed to avoid any such frictions which may be caused by international industrial competition—for cultural friction is capable of destroying all international co-operation and harmony.

I believe that Japan, having become rich by virtue of her industries, should now take the initiative in what I have just discussed, and should prepare 'scenarios' for the coexistence of man and robots on the basis of the cultural and human characteristics of the countries involved. It is also imperative that countries should be warned of the dangers which may result from gaining advantage over other countries. We should all develop, now, a concept of industrial policy through international co-operation, not only in hardware systems but also in the software in its widest connotation.

6.3 Closing Address

Dr Robert Frosch

I have been struck by a number of points during the meeting, one of them being that we discussed social and cultural issues far less than I thought we would have before I arrived, and told each other about technology far more than I expected. We somewhat shy away from those issues because as technologists we are not sure–and here I refer back to Sir Francis's summing up–we have the right to intervene in those subjects which we are supposed not to understand. I am not really sure that this is a sensible position, and I want to reiterate something I said earlier, which is that we are quite used to the idea of change in those areas we define as technology, and we are quite used to being told by the non-technologists that sensible change is not possible in those areas we define as not being technology. As far as I can tell, economic ideas today are totally dominated by Adam Smith, who has been dead for some 200 years, Karl Marx, dead for 100 years, and Lord Keynes, for 30. There has not been anything that corresponds to a really new watershed idea in economics as far as I can tell in 50 years. The idea of analysis, perhaps, but no new hypothesis underlying it.

The lawyers (in keeping with their profession) explain to us that new ideas are dangerous. We have not had any really new governmental ideas. Somehow there is a distinction between the idea of change in technology and the idea of change in social technology, and perhaps we have to begin to approach rather tentatively and rather carefully the idea that perhaps we ought really to think about social change as something serious, to be thought of in an experimental way. Here I do not agree with the views of a previous speaker. I think it is possible to do social experiments. I think it is possible to frame hypotheses, to do things, and to examine afterwards whether the hypotheses were correct. In fact I believe we already do that, but by saying we do not we do it maladroitly and ineffectively.

I have a great faith in a number of these issues in the perversity of people. I do not think we shall be able to concern (and confuse) our populations with communications technology as thoroughly as we have concerned ourselves in the past several days. I do not think there is any more garbage content in a unit communication capability in television than there was in radio, or than there has been in cinema, or than there was in the printed word. The bookstores are full of junk, they are full of nonsense, they are full of good and bad fiction, and people read what they choose. The newspapers are good, bad and indifferent, and people read what they choose. I do not believe they will do any differently with communication technology.

What is more, I have for years been puzzled by—and I will be charitable—the childlike nature of policy-makers (I think in fact it is childish) who believe that the public will accept the policy they have just hand-crafted, and behave in the way the policy-maker thinks they should behave in response to the policy. They must be aware, for example, that every tax policy that has ever been constructed was instantly treated by the public as a game to be played with the tax collector. In fact we have entire branches of the legal and accounting profession dedicated to playing this game on a professional basis.

There is no such thing as making a policy and having it followed by people in the way which the policy-maker chooses. That is one reason why it is in the end not possible to do technological forecasting and assessment, even though many aspects of human behaviour have regularity. If we understand the regularities we can predict them until the point at which the public understands them, after which they will behave perversely.

I believe I have produced a neat contradiction in my last two statements. First, I have said that science is possible with public issues, and then I have said that the public is perverse. We are quite used to a version of that in quantum mechanics. It was startling and difficult to find that the old rules about measurement were not followed by the new discoveries. We shall have to take the same attitude. The old rules of social experimentation cannot be followed by the new discoveries about the real behaviour of people. We have to create some new views and approaches for doing that.

Another related point I should like to make is that we have had almost no discussion of biology; a little bit of discussion of medicine; a reference to genetics. This is a subject which apparently we are not quite prepared to deal with, and perhaps that only means that it is not technologically ripe enough for us to know what to say about it. But even more startling, in all the discussions of the First World, the Second World, the Third World, whatever the current terminology is, there was only an occasional, very careful, reference to the question of population and numbers of people, which must somehow be a controlling variable in all of this subject of how one deals with communication—which after all is a combinatorial process among the people communicating—how one deals with technology, how one uses it to produce food, clothing and shelter. Somehow the number of people have to matter, and the ratio of people to land has to matter. That too we have not cared to approach, although it is clearly a problem with a technological basis and a social difficulty. We are willing to approach technological questions, but we are not willing to face the social difficulties as though they were technological problems. We insist upon creating a mystique out of those problems.

I remain with the feeling that more can be done with scientific and technological thinking in social and cultural areas than we have yet been willing to try, provided we remember that we are dealing with human problems. But the technologies, the scientific ideas and the ideas we use to deal with these problems are all human creations—they are our creations. They too are malleable, they are not an outside force, and we can use them to deal with ourselves. But we have to be willing to do so, and not prefer to rule out a whole area of discourse known as technology when it impinges upon social and cultural questions.

6.4 Closing Address

Professor Gunnar Hambraeus

I have been very pleasantly surprised by this and other DISCOVERIES Symposia. The subjects chosen for examination are rather difficult ones, and we bring together not only engineers and scientists but sociologists, humanists and economists—and they come from the four corners of the world. One would think that out of this would come considerable confusion, as in the building of the Tower of Babel. But rather, I think, a number of important questions have been crystallizing in our minds, as crystals settle out of a solution of a mixture of many potent chemicals. What I now put forward are thoughts that have come to me while I listened to the various lectures and discussions.

I shall start with a very simple conclusion that we have again emphasized, namely that technology and science can be used for good or for evil, and that it is up to the human being to use it wisely. It is really an enormous misfortune that we have not developed our human sociology and our humanistic thinking as we have developed the ability to handle the forces of nature and our materials.

Of course, as engineers we are rather impatient with all these human beings getting in the way of the ideal world that we could create if we had no people to deal with. This can be expressed in another way: that the most promising solutions to the problems of the world today are often politically impossible. It is important that we, who have been educated for and are used to trying to create the impossible out of clay and coal, do not give up our aims to use these vehicles in a way that we deem to be for the good of mankind.

But to be able to do so we have to learn to communicate, and this is our own failure. We have not been able to explain to non-scientists the logic, the foundations, the thinking, the principles that are built into this world of ours in the immutable laws of nature. Very often when we meet politicians and tell them that gravity is there they ask why, and whether they could not do away with gravity, and we have to explain it to them. Then they tell us that we scientists can change our views, and that in a year from now we may say that gravity can be abated. We have to tell them that there are some laws in this world of ours that we cannot reverse; that what we do in developing science is not working on the first term of an exponential equation, but rather on the second, third, fourth and subsequent terms of the evolution of the mathematical expression.

But not only that. There has to be not only an understanding of the inevitability of the basic laws of nature, there has to be an understanding of what potential there is and what use could be made of all this if we really had a concerted action. I have no hope that we can educate everybody to understand the workings of the auto engine, the vacuum tube or the transistor, but we can make them understand that the combination of a number of black boxes will give results. We have to make them understand that 'the systems', as such, could be used in many ways provided certain rules are followed.

There is now, against the background of this lack of understanding, a public fear of technology—a fear that has manifested itself over the last couple of decades as an animosity, almost a denial of the benefits of science and technology. I believe that fear is beginning to pass, but we are still a long way from achieving a positive attitude to our taking our scientific and technical tools to the politicians and the great public and putting them to real use.

Perhaps this is partly due to rapid transition: within our lifetimes we have moved from a very old age to a very new one. In my father's house firewood was still used for heating, and we had to carry water from a well to cook our food. That was not more than 50 or 60 years ago. So the pace of change has really been extremely rapid. But it is not only that. The young people can absorb changes very rapidly. They now take for granted things that we would have thought of as wonders in our youth. They take to the new computers and new audio-visual tools like ducks to water. Right now it is the young people who are teaching their parents how to handle the personal computer, and I take this as an encouraging sign. We shall have a young generation which has really been brought up to use the tools of science and technology.

Of course there are obstacles along the road. One is that the schooling system in many countries is not adaptable to the interests of the youngsters in this new technology. In fact we have a fear that schools may be destroying a very healthy interest, actually destroying the creativity that these youngsters have from the beginning. One of the difficult tasks in front of us all is the reformation of schools, and the retraining of teachers and vocation counsellors in many countries.

Now, too, a new form of literacy is developing. Today there are many people in the world who have no need to be able to read a written language. We have heard about a new type of written characters that are a return to the characters of the hieroglyphic type or the Chinese type—ideograms rather than phonetic letters. Most people are already familiar with internationally accepted road signs: these are a sign language. The newest computers on the market do not display written instructions on the VDU, but rather use signals of various types for the operations that they should perform. The new graphic language that we have put on computers also underlines that new types of international language are on the way. Perhaps these could be developed to take the place of the Latin of the learned societies of two or three hundred years ago.

But in this new age of technology there is the grave danger of increasing the gaps between the gifted and the skilled and those who are not so fortunate. I do not know how we can solve this very real problem. Perhaps our society will be so affluent that we can leave all these people to an idle life, perhaps fill it with other activities that are not really productive but nevertheless satisfying. That could be one way. We could also have, as I said in my own discourse, a new division of labour, a new system of employment, where everyone would give what he could in time and effort, each according to his own abilities. Whatever we do there is this gap between the gifted and the skilled and the others: it is a very real thing, and we have to take it into account.

I am not that worried about the other gap that we talked about, the gap between the industrial world and the developing world. I was very much encouraged by Dr Patel's talk of the progress being made in the new countries, even if the differences in this range of countries are much wider than he was prepared to admit.

Many of the things that have been said and discussed during these past three days are giving rise to new thinking and a new revision of ideas. During some of the lectures I was reminded of a former teacher of my own who always maintained that biological life on this earth was only an intermediate stage on the road to a very superior race of electronic life.

EDITOR'S NOTES

82 For the full text see page 270.

83 Those who have regularly done this throughout their lives can vouch for its remarkable inspiration, as for that of great music and visual art, although the scientific basis for such an effect remains for the present hidden in the clouds of speculation. Incidentally, it is rare for poets to be advised to study, for example, the infinitesimal calculus or the pure and beautiful rationality behind, say, the laws of thermodynamics.

84 For the full text see page 275.

85 For the full text see page 278.

86 Could this perhaps have been because engineers (the majority of the participants), having their feet traditionally and firmly on the ground, tend to confine themselves to their own particular compartments of engineering, and that there were no genetic or demographic engineers present?

87 For the full text see page 281.

88 See the professor's remarks in presenting his second session paper. To at least one observer, what he was advocating did not seem very different from the age-old tradition, within family units, whereby each member contributed what he or she could best provide

towards the well-being of the family as a whole. Larger groups living in 'communities', such as monasteries, have practised this from times immemorial.

89 Perhaps because of the perverseness of people as described by Dr Frosch?

90 . . . and one *cannot* do the other.

91 They often have!

92 Mr Scarrott attributed the phrase, or at least the adjective, to Honda inspiration.

93 The validity of this thesis must surely depend on definitions (*pace* Mr Scarrott).

94 It is perhaps the reflection that 'holistic economics' can hardly concern other than closed systems, and that other approaches must in the end yield false if not disastrous results.

95 This was in fact no more than a continuation of a tendency in most DISCOVERIES meetings, particularly those of Stockholm (1979) and Columbus (1982). It would seem to demonstrate the not surprising tendency of technical people to slip rather easily into discussing their own technical field—perhaps because they are frequently criticized for declarations outside those fields. The invalidity of the facile adage that a broader field necessarily leads to trivialization of understanding has yet to be generally recognized.

96 Professor Caianiello had been associated with all the Project's symposia since the series began in Tokyo in 1976. He was chairman of the organizing committee of the Rome (1977) meeting.

97 Professor Caianiello offered an example (by no means as trivial as it might first appear) of such viable experimentation. 'If all the British or all the Americans were told to start the working day an hour earlier, to start and end everything each day one hour in advance, the outcome would be social revolution, but in fact they invented daylight saving time.'

98 Though also constituting an augmentation on the demand side of the overall growth equation.

99 One can imagine the outraged cries of the anti-technology groups if such an increase were attempted!

100 *The Humane Use of Human Ideas:* the DISCOVERIES Project and Eco-Technology, page 38. (Pergamon Press, 1983)

101 Limitations depending on definition of 'the scientific method'.

6.5 Reflections

It was fitting that the MANTECH Symposium should end with some reflections from a senior representative of the Honda Foundation, an organization created in 1976 on the personal initiative of Dr Soichiro Honda to sponsor combined oriental-occidental interdisciplinary studies of world problems. The concluding address was delivered by the Vice-President of the Foundation, Mr Hiromori Kawashima.

His first words were of special thanks and appreciation to His Royal Highness the Prince Philip, Senior Fellow of the Fellowship of Engineering, for his presence, his kind words and his frank opinions. For the Honda Foundation this honour would always 'shine as a great light in the history of the DISCOVERIES Symposia'.

Secondly Mr Kawashima paid tribute to the host country Great Britain, cradle of so much scientific and technological research, development and application since before the foundation of the Royal Society in 1660 to the present day. To the great engineering Institutions also, whose rooms and services had enabled the Symposium to unfold in such auspicious circumstances and surroundings, and to the Fellowship of Engineering itself, which had borne the burden of organization so well and with such success.

The people of the twentieth century, said Mr Kawashima, benefited from a truly wonderful heritage, and they must consider what they could, should and would pass on to their successors in the twenty-first century. That was to be considered now, and that had been a major question addressed by the London Symposium.

'We live,' continued Mr Kawashima, 'in the age of the test-tube baby, of genetic engineering. It has become possible for us to tamper with human life itself. New life may be created or can be transformed. We are stepping into a terrifying age. Who can guarantee that science and technology will not conquer man? Man must stand before them in fear and trembling as he tries to ensure that he retains control. We have the sound spirit of man, nature's mysterious powers of recovery, but this sound spirit of man, his balanced sensitivity, is beginning to deteriorate. Nature's powers of purification are being stretched beyond the critical point, and the original function of adjustment is degenerating, as we all know.

'In our contemporary civilization, many people are being educated to a high standard of technical capability, but education itself is departing from its original purpose, forgetting the spirit of man to pay high regard to inorganic efficiency, and following the defects of technical science. More than a technical education, what is supremely important is human education in the environment in which man lives. Besides oneself there are other people. This is the first premise and one we must not forget.

'The human environment is not only on the material level. Over against me, you exist. If we have infinite interest and concern for each other invaluable relationships can be born. This is the human characteristic, so that that which I am and that which you are can be the communion of hearts, and there can be throbbing and a stirring of hearts in various forms. Perhaps we can call it love.

'A certain oriental philosopher said: "Grieve not that you are not understood by another, but grieve that you do not understand him." We are living with encounters of such solemn destiny. This will help us to recognize the dignity of society once again. This is more important than anything else today. No matter how excellent the science or technology or its origins, unless we are able to develop it correctly civilization cannot fulfil its function and human society itself must decline without such human spirit and the ability of nature to purify.

'To make the most of the ideas of man for humanitarian purposes is the philosophy underlined by the profound human experience of Mr Soichiro Honda. This is the Honda Foundation. Technology, human beings and nature must all co-exist. Through this symbiosis a new technological civilization may be built. This is the desire. In Tokyō, Rome, Paris, Stockholm and Columbus DISCOVERIES symposia have been held, and now we are in London. We have come to the fatherland of civilization, artistic culture and scientific technology.

'The seed has already started to sprout in the rich soil of DISCOVERIES '83. Let us hope that all participants will take this rich seed to each country, to each university, to each institution and to each company. I trust they will scatter and plant that seed. If so wonderful, beautiful flowers will bloom before long and fruits will ripen. I have no doubt that it will happen.'

Mr Kawashima was warmly thanked by Viscount Caldecote, who also thanked the Honda Foundation for making possible the arrangement and organization of the Symposium. Throughout the world, he said, there was growing recognition of the power of technology, and of the need to use that power constructively, and to ensure that it remained the servant of mankind and did not become its master.

'We need to ensure,' concluded His Lordship, 'that we understand each other better, those who are engineers and technologists, and those who follow other callings. We must use the great ability of communication that technology gives us to create better understanding, all in the interests of the community and with due regard for human feelings and culture.'

Finally in this short closing ceremony, Professor Gunnar Hambraeus spoke on behalf of all the visiting participants, congratulating in particular Lord Caldecote as President of the Fellowship, and the chairman of the organizing committee Sir Henry Chilver, on the great and evident success of the meeting.

Appendix I Symposium Programme

Tuesday 26 April

am **Opening** *at The Institution of Civil Engineers,*
Great George Street, London SW1

HRH The Prince Philip, Duke of Edinburgh
The Senior Fellow, The Fellowship of Engineering

Mr Takeso Shimoda
President, Honda Foundation

Chairman: The Rt Hon Viscount Caldecote DSC FEng
President, The Fellowship of Engineering

Session I *at The Institution of Civil Engineers*
Opening Session

Chairman: Sir Denis Rooke CBE FEng FRS
Senior Vice-President, The Fellowship of Engineering

Viscount Caldecote
Technology–Master or Servant?

Mr Moeen Qureshi
Senior Vice-President, Finance, The World Bank
Technology in a Developing World

pm **Session II** *at The Institution of Mechanical Engineers*
Modern Technology in the Context of Western Europe

Chairman: Professor Sir Hugh Ford FEng FRS
Vice-President, The Fellowship of Engineering

Mr Umberto Agnelli
Managing Technological Change in Western Europe—Challenges and Possibilities

Dr Günter Schuster
National and International Collaboration in the Development of Science and Technology: a European View

Discussion

Professor Gunnar Hambraeus
Modern Technology in Western Europe: Problems and Options

Sir Peter Gadsden GBE FEng
The Perspective of the Past: Indications from the History of the Industrial Revolution in Britain

Discussion

Wednesday
27 April am **Session III** *at The Institution of Mechanical Engineers*
Advanced Technology in North America

Chairman: Sir Robert Clayton CBE FEng
Former Vice-President, The Fellowship of Engineering

Professor Herman Feshbach
Social and Cultural Effects in the USA of Recent Technological Developments: A Physicist's Viewpoint

Dr Robert A Frosch
On Tap But Not on Top: Technology in a Pluralistic Society

Discussion

Professor Ithiel de Sola Pool
Changing Technology—Its Social Impact

Dr Roger E Levien
Interactive Information in the Office and Home—Technological Evolution, Societal Revolution

Professor Harold W Lawson Jr
Some Consequences of Tomorrow's Electronics CAD Systems

Discussion

pm Session IV *at The Institution of Mechanical Engineers*
Technology and Cultures in Developing Countries

Chairman: The Rt Hon The Lord Nelson of Stafford FEng

His Excellency Sheikh Yamani
The Potential for Industrial Technology in Developing Countries

Dr Surendra J Patel
Technological Distance between the North and the South

Discussion

Mr B M Grime FEng
The Potential for National Resources with Reference to International Trade

Professor Brian A May
Effective Use of Agricultural Technology in the Developing Countries

Discussion

Thursday
28 April am **Session V** *at The Institution of Mechanical Engineers*
Social Aspects of Technology in South-East Asia and Japan

Chairman: The Rt Hon the Lord Sherfield GCB GCMG

Dr Shinroku Saito
Technological Society and Cultural Friction

Professor Ungku A Aziz
The Impact of Changing Patterns of Employment on Culture and Society

Professor Shuhei Aida
Future Possibilities in Telecommunications and Their Impact on Society in Japan

Professor Kazuhiko Atsumi
Medical Co-operation Programmes for ASEAN Countries

Professor Toshiyuki Furukawa
Medical Progress and Social Development

Professor Reikichi Shirane
Viewing the 21st Century Advanced Communications Society

Professor Toru Yoshimura
Economic Growth and Technological Revolution

Discussion

pm **Session VI** *at The Institution of Civil Engineers*
General Discussion and Formulation of Conclusions

Chairman: Viscount Caldecote

led by a panel of speakers including:

Professor S Aida
Dr R Frosch
Professor G Hambraeus

with a summing up by Sir Francis Tombs FEng
Vice-President, Fellowship of Engineering

Closing

Mr Hiromori Kawashima
Vice-President, Honda Foundation

Viscount Caldecote

Appendix II List of Participants

Professor Sixten ABRAHAMSSON
University of Gothenburg

Professor R T ACKROYD

Mr Bruce ADKINS
Chief Rapporteur

Mr Umberto AGNELLI
Fiat

Professor Shuhei AIDA
University of Electro-Communications, Tokyo

Sir Ove ARUP
The Fellowship of Engineering

Mr Eric ASH
The Fellowship of Engineering

Professor Kazuhiko ATSUMI
University of Tokyo

Professor Ungku A AZIZ
University of Malaya

Sir Peter BALDWIN
The Fellowship of Engineering

Mr C BAM
World Bank

Mr Harold M BARLOW
The Fellowship of Engineering

Mr J V BARTLETT
The Fellowship of Engineering

Dr J C BASS
The Fellowship of Engineering

Dr R BELL
National Institute of Agricultural Engineering

The Rt Hon the Earl of BESSBOROUGH
House of Lords

Professor R E D BISHOP
The Fellowship of Engineering

Professor J BLACK
The Fellowship of Engineering

Mr Basil D BLACKWELL
The Fellowship of Engineering

Dr John BOWMAN
National Environmental Research Council

Mr E U BROADBENT
The Fellowship of Engineering

Mr C D BROWN
The Fellowship of Engineering

Vice-Admiral Sir Lindsay BRYSON
The Fellowship of Engineering

Mr T W BUNYAN
The Fellowship of Engineering

Dr J H BURGOYNE
The Fellowship of Engineering

Mr M H CAHALAN
The Fellowship of Engineering

Professor Eduardo R CAIANIELLO
Post-graduate School in Cybernetics and Physics, Naples

Dr J C CAIN
British Technology Group

Viscount CALDECOTE
The Fellowship of Engineering

Sir Jack CALLARD
The Fellowship of Engineering

Sir Richard CAVE
Thorn-EMI

Dr A A L CHALLIS
Department of Energy

Dr J C CHAPMAN
The Fellowship of Engineering

Mr Philip CHAPPELL
Morgan Grenfell Holdings Limited

Dr Harold CHESTNUT
General Electric Company, Schenectady

Sir Henry CHILVER
The Fellowship of Engineering

Dr Annalisa CICERCHIA
Centro di Ricerco e Documentazione, Rome

Sir Robert CLAYTON
The Fellowship of Engineering

Mr Roy CLOSE
British Institute of Management

Professor J COALES
The Fellowship of Engineering

Dr John COLLINGWOOD
The Fellowship of Engineering

Mr H E COLLINS
The Fellowship of Engineering

Mr E H COOKE-YARBOROUGH
The Fellowship of Engineering

Mr John F COPLIN
The Fellowship of Engineering

Dr Jose Maria CORONADO VALCARCEL
Fédération Européenne d'Associations Nationales d'Ingénieurs

Professor F W CRAWFORD
The University of Aston in Birmingham

Lord CROHAM

Professor Charles A CSURI
The Ohio State University

Professor Ranger CURRAN
Youngstown State University

Mr Handel DAVIES
The Fellowship of Engineering

Mr John DERRINGTON
The Fellowship of Engineering

Miss Hilary DOLING
The *Sunday Express*

Professor P J DOWLING
The Fellowship of Engineering

Mr Diarmuid DOWNS
The Fellowship of Engineering

Mr G A DUMMETT
The Fellowship of Engineering

Sir George EDWARDS
The Fellowship of Engineering

Professor W S ELLIOTT
The Fellowship of Engineering

Sir St John ELSTUB
The Fellowship of Engineering

Mr Glyn ENGLAND
The Fellowship of Engineering

Lord EZRA

Dr G B R FEILDEN
The Fellowship of Engineering

Professor Herman FESHBACH
American Academy of Arts and Sciences, Cambridge, USA

Sir Monty FINNISTON
GKN Group of Companies

Mr C H FLURSCHEIM
The Fellowship of Engineering

Professor Sir Hugh FORD
The Fellowship of Engineering

Mr W FORREST
The Fellowship of Engineering

Dr A FRANKEL
The Fellowship of Engineering

Dr Robert A FROSCH
General Motors Corporation, USA

Mr D H FROST
Intermediate Technology Development Group

Professor Toshiyuki FURUKAWA
Institute of Medical Electronics, University of Tokyo

Sir Peter GADSDEN
The Fellowship of Engineering

Mr James Anthony GAFFNEY
The Fellowship of Engineering

Mr I D GARDINER
The Fellowship of Engineering

Mr R T GERRARD
The Fellowship of Engineering

Mr S A GHALIB
The Fellowship of Engineering

Mr J GILL
Department of Industry

Mr D W GINNS
The Fellowship of Engineering

Mr Donald GLOWER
The Ohio State University

Dr Y GOUSTY
IPOSI, Marseilles

Lord GREGSON
Fairey Holdings Limited

Professor Brian GRIFFITHS
The City University, London

Mr B M GRIME
English Clays Lovering Pochin & Co Limited

Mr Henry James GROUT
The Fellowship of Engineering

Mr G R HALL
The Fellowship of Engineering

Professor Gunnar HAMBRAEUS
Royal Swedish Academy of Engineering Sciences

Professor C HANDY

Dr R HAWLEY
The Fellowship of Engineering

Mr Lionel HAWORTH
The Fellowship of Engineering

Sir William HAWTHORNE
Churchill College, Cambridge

Mr H R HEWITT
The Fellowship of Engineering

Sir John HILL
The Fellowship of Engineering

Professor C HILSUM
The Fellowship of Engineering

Lord HINTON OF BANKSIDE
The Fellowship of Engineering

Dr G S HISLOP
The Fellowship of Engineering

Dr M W HOLDGATE
Department of the Environment

Dr J H HORLOCK
The Fellowship of Engineering

Sir Robert HUNT
The Fellowship of Engineering

Sir Andrew HUXLEY
The Royal Society

Mr R IREDALE
The *Engineer*

Mr F E IRELAND
The Fellowship of Engineering

Mr A W JACOMB
The Fellowship of Engineering

Mr C A H JAMES
Royal Commission for Exhibition of 1851

Mr A M JARVIS
The Fellowship of Engineering

Mr F P JENKIN
Central Electricity Generating Board

Dr David KALDERON
The Fellowship of Engineering

Mrs B KANU
Commonwealth Secretariat

Lord KEARTON

Dr R W J KEAY
The Royal Society

Dr A KELLY
The Fellowship of Engineering

Dr A J KENNEDY
The Fellowship of Engineering

Mr O A KERENSKY
The Fellowship of Engineering

The Hon Peter KERSHAW
The Fellowship of Engineering

Professor J F C KINGMAN
Science & Engineering Research Council

Dr B W KINGTON
Society of Education Officers

Mr B P LAIGHT
The Fellowship of Engineering

Sir Kirby LAING
The Fellowship of Engineering

Mr J LANGHAM THOMPSON
The Fellowship of Engineering

Professor Harold W LAWSON Jr
University of Linköping

Mr J LEE
The Fellowship of Engineering

Mr Michael LEONARD
The Fellowship of Engineering

Dr Roger E LEVIEN
Xerox Corporation, USA

Professor Olof LIDIN
University of Copenhagen

Professor M D LILLY
The Fellowship of Engineering

Professor Harold LINSTONE
Portland State University

Mr H A LONGDEN
The Fellowship of Engineering

Dr J S McFARLANE
Engineering Employers' Federation

Mr Peter McGREGOR
National Economic Development Office

Mr G McROBIE
International Technology Development Group

Sir Ieuan MADDOCK
The Fellowship of Engineering

Professor Fred MARGULIES
IFAC, Laxenburg

Mr P A MARSDEN
The Fellowship of Engineering

Sir Peter G MASEFIELD

Vice-Admiral Sir Frank MASON
The Fellowship of Engineering

Sir John MASON
Meteorological Office

Professor Brian MAY
Cranfield Institute of Technology

Dr J H H MERRIMAN
The Fellowship of Engineering

Dr A R MICHAELIS
Interdisciplinary Science Reviews

Dr K A G MILLER
The Fellowship of Engineering

Mr J R S MORRIS
The Fellowship of Engineering

Lady Sara MORRISON
The General Electric Company plc

Sir Alan MUIR WOOD
The Fellowship of Engineering

Mr M J NEALE
The Fellowship of Engineering

Lord NELSON OF STAFFORD
The Fellowship of Engineering

Mrs J P NORFOLK

Mr Denis G OSBORNE
Overseas Development Administration

Mr V John OSOLA
The Fellowship of Engineering

Sir Frederick PAGE
The Fellowship of Engineering

Dr Surendra J PATEL
UNCTAD

Mr N J PAYNE
British Airports Authority

Sir Denning PEARSON
The Fellowship of Engineering

Professor Umberto PELLEGRINI
TECNETRA, Milan

Sir David PHILLIPS
Laboratory of Molecular Bio-physics, Oxford

Sir Alastair PILKINGTON
Pilkington Brothers plc

The Baroness PLATT OF WRITTLE

Sir Charles PRINGLE
The Fellowship of Engineering

Mr Giancarlo QUARANTA
Centro di Ricerco e Documentazione, Rome

Mr Moeen QURESHI
World Bank

Vice-Admiral Sir George RAPER
The Fellowship of Engineering

Dame Diana READER HARRIS

Sir James REDMOND
The Fellowship of Engineering

Lord REILLY

Professor Bradley M RICHARDSON
The Ohio State University

Mr J F RICHARDSON
The Fellowship of Engineering

Dr W RIZK
The Fellowship of Engineering

Mr Geoffrey ROBINSON
Member of Parliament

Mr O ROITH
Department of Industry

Sir Denis ROOKE
The Fellowship of Engineering

Professor Sir Norman ROWNTREE
The Fellowship of Engineering

Mr M RUHEMANN
The Fellowship of Engineering

Mr L J RYDILL
The Fellowship of Engineering

Mr C F SAGE
Honda Automobiles (Suisse) SA

Dr Shinroku SAITO
Tokyo Institute of Technology

Professor R W H SARGENT
The Fellowship of Engineering

Mr G G SCARROTT
The Fellowship of Engineering

Dr Günter SCHUSTER

Dr Alwyn SCOTT
Technical University of Denmark

Lord SEEBOHM

The Rt Hon The Lord SHERFIELD
House of Lords Select Committee
on Science and Technology

Professor Thomas E SHERIDAN
Massachusetts Institute of Technology
Technology

Professor Reikichi SHIRANE
NTT Telecommunications Science
Foundation

Mr A SILVERLEAF
The Fellowship of Engineering

Mr Frank Alexander SIMS
The Fellowship of Engineering

Professor Ithiel de SOLA POOL
Massachusetts Institute of
Technology

Mr J M SOLBETT
The Fellowship of Engineering

Mr D G SPICKERNELL
British Standards Institution

Mr P F STOTT
The Fellowship of Engineering

Sir Maurice SUGDEN
Trinity College, Cambridge

Professor John SUTTON
Imperial College

Dr Haryono SUYONO
National Family Planning Board,
Jakarta

Professor J SWITHENBANK
The Fellowship of Engineering

Professor M W THRING
The Fellowship of Engineering

Sir Francis TOMBS
The Fellowship of Engineering

Vice-Admiral Sir Allan TREWBY
The Fellowship of Engineering

Dr P E TRIER
The Fellowship of Engineering

Professor Achiel VAN CAUWENBERGHE
University of Ghent

Mr C R WALKER
Department of Education and Science

Mr George WALKER
Training Consultant and Editor

Mr K H WALLEY
The Fellowship of Engineering

Mr Kenneth WARREN
Member of Parliament

Sir Richard WAY
Royal Commission for Exhibition of 1851

Professor J H WESTCOTT
The Fellowship of Engineering

Air Vice Marshal T P WHITE
Royal Air Force

Mr J S WHYTE
The Fellowship of Engineering

Mr G M J WILLIAMS
The Fellowship of Engineering

Mrs Shirley WILLIAMS
Member of Parliament

Professor P O WOLF
The Fellowship of Engineering

Professor Gordon R WRAY
The Fellowship of Engineering

Sheikh YAMANI
Minister of Petroleum and Mineral Resources, Saudi Arabia

Sir Eric YARROW
Yarrow plc

Professor Toru YOSHIMURA
Saitama University

Organizing Committee

Sir Henry Chilver FEng FRS *Chairman*
Vice-Chancellor, Cranfield Institute of Technology

Professor Shuhei Aida *Vice-Chairman*
University of Electro-Communications, Tokyo

Professor John Coales CBE FRS FEng *Vice-Chairman*
The Fellowship of Engineering

Bruce Adkins *Chief Rapporteur*

Philip Fellows OBE DSC *Symposium Organizer*
The Fellowship of Engineering

Professor Gunnar Hambraeus
The Royal Swedish Academy of Engineering Science

Michael Leonard FEng
Secretary, The Fellowship of Engineering

John Lyons
General Secretary, Engineers' & Managers' Association

Sir Francis Tombs FEng
Director, N M Rothschild & Sons Ltd

Dr Peter Trier CBE FEng
Director, Philips Industries UK

Taizo T Ueda
Managing Director, Honda Foundation
ex officio

Press Officer
Mr Michael Bradbeer

Symposium Staff
Miss Diana Kurzman
Miss Mary Mullin
Mr Sam Tulip

Honda Foundation Secretariat
Mr Taizo Ueda
Mr Yasuro Nakano
Mr Kahachiro Suzuki
Mr Youzo Yoshida
Mr Masaru Unno

Cambridge Information and Research Services Limited