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## Technology Foresight

### Summary

Technology Foresight (TF) is a major activity aimed at focusing the UK's science, engineering and technology (SET) resources to improving national wealth and quality of life. It involved a very large number of people and organisations and its first phase has just been extensively reported. This paper represents the views of the Council of the Royal Society on progress to date. Council welcomes the programme and the output of the past year's work.

The major benefit of the TF Programme so far is the expanded networking within and between academia, industry, commerce and Government departments. Top priority for the next phase should be to develop this much further and to develop greater awareness of SET at all levels, particularly in boardrooms and in the City.

Technology foresight is about markets and about technologies. It is not science foresight, i.e. it does not attempt to predict how scientific knowledge will develop. Nor could it. The identification of strategically important areas of technology raises, but does not answer, questions about the science needed to underpin these areas of technology. Many panels rightly emphasized the vital importance of maintaining a broad science base.

The overwhelming demand from panels and the Steering Group for continued excellence in SET and for an undiminished, broad-based basic science portfolio is welcomed. The linear model of innovation is not generally valid and must not be used to justify reducing support for basic science in areas that are not TF priorities.

The exciting opportunities noted by the panels justify more investment in SET by industry, Government and the financial community. The next phase of TF will clearly be to spread this message and the Society will play its part.

Panels call for much more interdisciplinary research, especially in universities. This will require cultural and infrastructural changes to be made. We support the recommendations to revise criteria for the Research Assessment exercise in order to encourage collaboration. We note that new mechanisms for reviewing cross-discipline research proposals need to be established.

Implementation of specific TF recommendations should proceed with caution. The Society's greatest concern is that the pressures for implementation of TF will be unevenly felt across funding agencies, Government Departments and industry. We believe that disproportionate pressure on OST-funded agencies, or inadequate responses from other Government Departments, will seriously reduce the benefits of TF, distort Research Council programmes and lead to a divergence between OST-funded science and that supported from other sources. We encourage Government

to ensure that the Departmental system is responsive both to Foresight priorities and to recommendations for interdepartmental funding of key programmes.

We believe that TF should provide impartial broad guidance on priority areas in SET. We support its continuation in this role and suggest that, by extending the TF structure in time, incomplete tasks (such as scenario building and analysis) will be finished, networks reinforced and a more authoritative set of priorities established. However, we recommend that, before the TF Programme as a whole is repeated, an independent appraisal and cost-benefit analysis of the present exercise are undertaken in order to ensure that the next round is done with greater efficiency and focus.

The Royal Society will monitor the continuation of TF and will provide appropriate support to aid successful implementation of the Programme.

The Technology Foresight (TF) Programme is an important innovation in UK science and technology policy and its recommendations deserve careful consideration by all concerned with science and technology (S&T). The Royal Society has taken a close interest in the exercise. In this report, the Council of the Society comments on the main issues arising from TF for national S&T policy and for education and training in science, engineering and technology (SET): in view of the Society's long-standing commitment to excellence in research, we have paid particular attention to recommendations relating to these issues.

The 1993 White Paper, *Realising our potential*, established the twin principles that public expenditure on S&T should be considered in its totality (not just as the sum of individual departmental spends), and that its purpose should be wealth creation and enhancement of the quality of life. TF is germane to both these principles and has been developed as an instrument for their implementation.

The TF Programme, consisting of a Steering Group and 15 Sector Panels, was initiated and managed by OST. However, the Sectoral and Steering Group reports do not formally constitute Government policy, though the Prime Minister has encouraged vigorous implementation of their recommendations. OST will produce a progress report by the end of 1995. We hope that this will respond formally to the many recommendations and resource implications of the reports. So, we are commenting here on a set of ideas, not a set of Government policies. The TF Programme has, so far, engendered much interest by all relevant parties and promises to yield major benefits. We trust that Foresight is here to stay, that major iterations will occur periodically (e.g. every 5 years) and that this important mechanism for bringing together all who are concerned with creating wealth from SET will be impartial and exempt from political pressures.

### **Conduct of the Exercise**

It was very encouraging to see, during the execution of the first phase, the great enthusiasm of the participants - not only the panel members, but also the very large number (c.10,000) of people who completed questionnaires, attended workshops and responded to personal enquiries - and the support from a wide range of professional organisations. There was clearly a widespread feeling that a national S&T policy is long overdue and this raised a commitment to help orchestrate UK resources to achieve improved national wealth and quality of life.

*The TF Programme was conducted at high speed, with less than 12 months between the establishment of the 15 sector panels and the completion of their reports. This had some advantages in terms of sustaining momentum and demonstrating the importance that OST attached to the exercise. But it also had disadvantages, which we discuss below. The exercise was conducted in a way that threw together people who would not normally meet, people with different views and from different backgrounds, in order to solve problems. The benefits of this networking are clear in the panel reports and we trust that Government will offer encouragement and incentives for this to continue.*

*Because of the frequency of panel meetings and the seniority of the members, it proved difficult to maintain a consistent group of people at successive meetings; this reduced the efficiency of the meetings. Exceptionally tight timetables, coupled with insufficient secretarial support, resulted in pressures to formulate conclusions before data had been fully analysed. The speed of the exercise led to inadequate briefing about panel objectives, inconsistencies in the ways workshops were undertaken and too little work on the important activity of generating alternative future scenarios. **We recommend a longer and more flexible timetable for the next Foresight exercise.***

The TF Programme was characterized by a welcome degree of openness, especially in the co-nomination procedure, the Delphi exercise and the workshops. Some key aspects, however, were not subjected to public debate. In particular, the definition of the 15 panels appeared arbitrary and caused considerable problems in certain cases. We note that the Steering Group recognised some of the inadequacies in panel scope in its Report. We suggest that before the TF exercise is repeated, an open and rigorous debate is held to define more useful panels. Furthermore, we are concerned that numerous topics spanning panel boundaries were not given adequate consideration. Major opportunities could be lost and expertise bases diminished if these boundary areas are not dealt with in the same depth as topics central to individual panels.

***Topics falling outside the mainstream interests of the 15 panels, or outside the panels altogether, need to be considered carefully: it must not be inferred that they are necessarily less significant than the mainstream topics.***

***In any future TF exercise, more attention needs to be paid to building a consensus about the definition of the panels.***

The postal Delphi survey, a major feature of the TF exercise, has proved largely worthless to date and was held in low esteem by many panellists. The costs in terms of time and money were out of proportion to what it contributed to panels' thinking. By contrast, the seminars and workshops held around the country by each panel proved highly worthwhile, both in terms of the ideas generated and in terms of the networking they engendered.

***In any future TF exercise, we strongly support the use of structured workshops and similar forms of consultation but recommend that the Delphi technique, as used this time, be abandoned. We would be pleased to see OST tendering for proposals to devise an efficient and effective mechanism for generating a consensus view of the country's SET priorities from a wide audience.***

TF, done properly, is expensive. OST spent £1.6M; respondents and panel members (or, rather, their employers) spent a great deal more in terms of time and opportunity cost. From the experience gained in this first exercise, it is apparent that insufficient resources (secretariat support etc) were provided to underpin the work of the panels, in contrast to the considerable sums spent on publicity aimed at stimulating interest and participation in the Programme.

Membership of each panel must represent a balance between all relevant interests (within the limits of practicality); we have no reason to suggest that this criterion was not met. The outputs from TF need to be impartial conclusions about future markets, technical advances, social and regulatory developments etc. drawn by the panellists from unbiased input data and opinion. There must be no attempt to align panel findings to the interests of one organization (company, Government department, political party etc); we have sufficient anecdotal evidence to suggest this has not always been the case this time. ***In any future exercise, the conditions for demonstrable independence must be guaranteed.***

### **Objectives and outputs of technology**

TF has three objectives:

- (i) to encourage closer interaction and net-working between the science, engineering, academic, business and Government communities;
- (ii) to build a common understanding between these communities of the challenges, concerns and emerging opportunities in markets and technologies;
- (iii) to provide broad guidance on priority areas of SET which have emerged from the consultative process so that these may be taken into account by the Government as a whole, individual Departments of Government, Research Councils, Higher Education Funding Councils, and industry.

The processes of TF are intended to achieve the first two of these, the findings to achieve the third.

There is no doubt that TF has been a real success in terms of its networking objectives. All panel reports emphasized this, and all called for initiatives to sustain the progress made in this direction during the Programme ***which we strongly support.*** This applies to networking not only between academics, Government departments and industrialists but also between different disciplines and between different companies. The TF Programme has made a real contribution to the White Paper objective of strengthening linkages between the science base and industry. ***However, much more needs to be done by all concerned, including the panels in their continuing work on TF, to perceive and eliminate the cultural barriers between academe, industry and Government.***

The objective of providing broad guidance to funding agencies on SET priority areas has been achieved at two levels. The Sectoral panels made 360 recommendations in all, although no panel ranked its priorities. From these, the Steering Group identified important areas of generic science at a holistic level which will provide a useful tool for future strategic thinking. However, the Steering Committee has extended this by clearly ranking their selected topics even though every Sectoral panel of experts refused to rank final lists of priorities. ***We commend panels for their wisdom in providing only broad guidance on SET priorities and would be concerned if***

**funding agencies disregarded the panel conclusions and focused instead solely on the more limited range of best bets from the Steering Committee. Given the natural difficulties in carrying out this major experiment for the first time, it would be wholly inappropriate to regard the Steering Group's rankings as definitive.** We stress that TF findings provide an important input into the priority-setting mechanisms of each funding agency but recommend that TF should not be used in a simplistic manner to determine priorities. **It would be a particular concern to the Society if areas not highlighted in panel reports were automatically given low priority or further if support for basic research was determined by any other criterion than scientific excellence.**

The Steering Group noted that progress on implementing TF recommendations would depend as much on management and human resources and on social, policy and regulatory factors as on scientific or technological matters. It pointed out, too, that financial institutions and Government need continuously to review their policies on long-term finance for small, innovative enterprises and the impact of the financial environment on industry's willingness to innovate. **We are in full agreement with this view: certain infrastructural issues could be critical to the successful implementation of TF recommendations.** Individual panels certainly recognised the complexity of these issues. The Communications panel, for example, drew attention to the importance of assessing customer demands and the content of communication services, not just the technology. Other panels made analogous comments.

The future development of the sector is determined as much by economic, social, political and environmental factors as it is by the availability of technology. [Transport panel]

"The psychology of consumer choice, and risk perception associated with the acceptance of new technologies, require further research. [Food and Drink panel]

"Cultural change is another major variable: public understanding of science and medicine, and attitudes to individual responsibility, determine, to a large extent, the effectiveness of preventive medicine. [Health and Life Sciences panel]

The TF Programme was focused on UK needs and opportunities. However, in some, if not most, panel sectors it may not be ideal to use a mainly national approach. This is particularly true in sectors where the market is dominated by international or global players; but it also arises from the fact that technological advance can come from almost anywhere in the world. The Food & Drink and Agriculture, Natural Resources & Environment panels each commented that their recommendations were consistent with the areas identified for further work in the Fourth Framework Programme. The Steering Group suggests that the UK's position in respect of the Fifth Framework Programme for 1998 onwards will need to take account of the results of Foresight. It would be useful to compare the findings of the UK and other TF Programmes, to see if the former has a distinct character attributable to UK circumstances.

## **Findings**

The main achievement of the TF exercise has been a raising of awareness of the scope and potential benefits of closer linkages between the science base, industry and Government. **This is an important achievement.** As the Steering Group states, Frequent interaction between science and business about market and

technology trends is no longer an optional extra; it is an essential component of long-term competitiveness. **We fully agree with this statement.**

We shall not comment on the detailed findings of individual panels. We note, though, that generic areas, as defined by the Steering Group, were each addressed by several panels, generally acting independently of each other. During the implementation phase, it will be important to review the diverse perspectives on these generic areas to ensure that the emphasis is placed on aspects which will maximise wealth creation or quality of life. The end of year OST report should make recommendations on how to handle generic areas, before firm decisions are made to commit resources.

Technology foresight is about markets and about technologies. It is not science foresight, i.e. it does not attempt to predict how scientific knowledge will develop. Nor could it. The identification of strategically important areas of technology raises, but does not answer, questions about the science needed to underpin these areas of technology. **Many panels rightly emphasised the vital importance of maintaining a broad science base.**

"Without adequate fundamental research, we risk not having the results or the intellectual skills on which to base future wealth creation. [Communications panel]

"The Panel fully supports the continuation of an adequate presence in the wider range of contributory scientific and technological disciplines in order to allow the continued generation of serendipitous ideas and opportunities. [Chemicals panel]

"We have assumed that the initiatives and programmes that will stem from the foresight programme will be superimposed upon a publicly funded science base in which a reasonable research presence is maintained across a diversity of academic disciplines. [Health and Life Sciences panel]

"The Panel recommend that basic research must be retained at a sufficient level across the widest field (irrespective of national priority areas) to allow the UK to be fully aware of emerging and potentially influential work elsewhere. The science and technology base must then assist industry become an intelligent customer in cases where it needs to source technology externally. [Manufacturing, Production and Business Processes panel]

This points up the nature of the role of the science base in wealth creation. The linear model, with scientific research leading to technological advance leading to industrial opportunities, is recognised as an inadequate description of a complex process. **Technology foresight must not be used to determine priorities for the science base in a simplistic manner that re-imports the linear model into science policy.**

The Steering Group recognised that it would be vital to maintain support for truly excellent basic research (whether in a Foresight priority area or not) on a selective basis; **we fully support this statement and look forward to its implementation.** We are especially pleased to see the Steering Group's conclusion, which reflects Royal Society strategy:

"Many panels insisted on the need to retain a broad range in the UK's support for excellent basic research, particularly by selectively targeting the best people, as judged by their peers.

It is not self-evident that current levels of funding for basic research are adequate to the needs identified by the panels; certainly, any reduction would be detrimental to national interests. It is disappointing that neither the Steering Group report nor the 1995 Forward Look address this extremely important issue. We recognise that time is needed to evaluate fully the funding implications of the TF recommendations but suggest that all interested parties are looking to Government to lead the discussion on this key issue of TF implementation.

A recurrent theme in the panel reports is the importance of multidisciplinary and inter-disciplinary work. For example, bio-technology, highlighted by several panels, demands a range of scientific and engineering skills. We welcome this recognition of the need to think and plan beyond the confines of individual disciplines. It forces comprehension of the whole problem, not just a small part of it. However, multi- and inter- disciplinaryity should be **encouraged** rather than artificially forced and will require separate structures for peer review assessment and monitoring. Recommendations such as that of the Materials panel that 30% of EPSRC funding should be reserved for grant proposals involving two or more different university departments, while laudable in intent, are not the way forward.

Many panels call, also, for broader education. Two types of broadening are noted: management enriched topics (such as financial, problem solving and communication techniques) and science or engineering enriched subjects. A significant degree of progress has already been made on introducing the former topics in many university departments. More progress is needed but we believe that greater emphasis now needs to be placed also on providing greater awareness of related areas of science and engineering in both undergraduate and post-graduate education.

Several panels suggested that the current structure of the Research Assessment exercise discourages collaborative research; this will need corrective action by the Funding Councils and ***we welcome the recommendations made by the Steering Group on this topic.***

We welcome, too, the recognition that the high reputation of basic research in the UK is a potent factor in attracting a high level of inward investment into the UK science base, with all the benefits that accrue to the UK. An important corollary is that we should pay more attention to the location of industrially-supported R&D and less to the formal nationality of the company concerned. This has implications for, e.g., the associated fiscal regimes. Additionally, other panels point to the need for the UK to access emerging science and technology in other countries. The Agriculture, Natural Resources and Environment panel emphasises the value of improving technology transfer to other countries, particularly the developing world. In short, the exercise has emphasised the international nature of business and has tried to define the UK niches.

A further significant set of findings concerns the importance of the public understanding of science. One aspect of this is the influence of public attitudes on the speed and direction of technological advance, mentioned above. Another aspect is understanding within industry:

"Government needs to target individuals in industry, from the board room downwards, to change attitudes where necessary to research and development and innovations, where appropriate, and to take forward the results of Foresight. [Materials panel]

"The biggest barrier to innovation and commercialisation of technology is frequently within companies themselves. [Chemicals panel]

Although TF has been successful in improving the interfaces between the science base, industry, commerce and Government, we stress the need to inject greater awareness of SET in company boardrooms and in the City.

Several panels pointed to the need to improve communication of scientific and technical advances from the science base to industry - especially to small companies; an expansion of the networking put in place during the past year will greatly facilitate this need.

## Findings

There is no clear indication of what implementing Foresight entails, nor is it clear who will be doing it. This being the case, we can comment on implementation only in general terms. The Steering Group report has made some pertinent recommendations but with no timescales attached, apart from that of continuing panel activity for another year, principally to preach the Foresight messages. Industrial leaders have a key part to play in ensuring that these messages are heeded, especially at boardroom level. We welcome the intention to maintain the panels (appropriately modified), and the Steering Group, in order to foster implementation. One important role will be to address cross-sectoral issues, recognised by the Steering Group, and issues at panel boundaries - especially those common to Food, Health and Agriculture, Aerospace and Transport, and marine and offshore technology, space science and forensic science. Another role should be to complete the unfinished future scenarios exercise, an essential part of Foresight, and to review their recommendations in the light of the predictions.

The 360 panel recommendations are addressed to every possible agency and combination of agencies (we include industry, commerce and charitable organisations here). All concerned are keen to see a vigorous implementation phase as a matter of high priority. The Government is putting £40M into a Foresight Challenge Fund, to be matched by an equal sum from the private sector. This is a promising start. The activities in the following months will be followed closely and we trust that there will continue to be a wide-ranging debate, including all of the communities involved so far, so that all have a sense of ownership in the results.

It is not essential to the success of TF that all 360 panel recommendations be implemented. Indeed, it is logistically impossible that they should be. ***The Society's greatest concern is that the funding agencies under OST control will feel pressurized into implementing the largest possible number of recommendations, while other Government Departments, and industry, do proportionately much less to respond to TF. The outcome would then be a major distortion of Research Council programmes and the loss of a rare opportunity to create, review and implement a national science policy..***

All those to whom recommendations are addressed must be allowed to assess them on their merits alongside their current programmes and objectives, and respond accordingly; none should simply ignore them or, conversely, be obliged to implement them without further ado. Particular interest will attach to the response of those Government Departments other than OST that have substantial, but mostly not peer-reviewed, budgets for R&D. As the Steering Group remarks:

"The fact that Foresight is endorsed by Government means a clear remit for each Department to take account of the findings. ...Government must ensure that Foresight messages are received loudly and clearly by appropriate programme managers in the Departmental system.

The Steering Group believes that it is necessary to strengthen OST's role in coordinating SET policy across Government. This should include ensuring that common standards of peer review of proposals, final reports and dissemination are applied across all Departments, and that unnecessary duplication of effort is avoided.

The Steering Group rightly stresses that the central aim of university-based researchers must be to sustain international excellence. It adds that other aims related more closely to wealth creation are also important, and recommends that various initiatives be taken to embed Foresight findings in university work. This implies a significant cultural change which will require some incentives, especially in terms of career structure and of smoothing the transitions of outstanding scientists who change their specialism. Moreover, care will be needed to implement any changes in a way that does not drive a destructive wedge between natural science, engineering, social science and humanities: a strong presence in all four is essential for a balanced contribution to national life.

We note the Steering Group recommendations in respect of Research Council priorities. ***It is essential that the same quality criteria are applied to all Research Council funding irrespective of whether the funding is in an area of earmarked priority. There is nothing to be gained by funding mediocre work, even if it is in a high priority area.***

We strongly endorse the Steering Group recommendation that indigenous and inwardly investing companies in the UK be treated equally with respect to Foresight involvement, diffusion and implementation. The suggestion that leading industrialists be enrolled as Foresight Champions may require incentives to compensate for the opportunity cost, such as action by Government on the various infrastructural barriers to investment in R&D and easier access to venture capital. Indeed, it is now timely for venture capitalists and fund managers to be brought more fully into Technology Foresight.

***We warmly welcome the Steering Group's statement that it attaches great importance to the UK's full involvement as a proactive partner in shaping EU policy and regulation. We must not stand on the sidelines and complain when we have the opportunity to influence.***

The first phase of the first TF Programme is now complete, and the second, implementation, phase is under way. The OST has widely stated that TF is an ongoing process, not a single event. We believe that there would be value in repeating the exercise in about five years. Before embarking on it, however, there should be a cost/benefit analysis of the outcomes of this exercise, and an attempt to identify ways of improving efficiency by focusing on areas where the greatest change is likely to have occurred during the intervening period. More attention needs to be placed on market foresight - identifying not only market opportunities but also how best to get new technology to the marketplace. The definition of panel remits should be reconsidered. Greater care may be needed to encourage industrial participants to be open: this was evidently a difficulty this time, especially for the Retail and Distribution panel. Further analysis of the conduct and consequences of TF exercises in other countries would be a valuable input to the design of a second UK exercise.

We note that few of the TF recommendations have a timescale attached to them. While this may not be too problematical with respect to many of the scientific and technical issues, an open-ended approach to dealing with important infrastructural issues could be disadvantageous to the efficient implementation of TF and to retaining the commitment of industry. This is something to be addressed as a matter of urgency during the initial implementation phase.

Although we are still a long way from having a coherent national policy for science and technology, the encouraging results of Technology Foresight so far lead us to expect that, with maturity, it will make an invaluable contribution to such a policy. This first exercise - necessarily experimental in nature - has pointed to the benefits that can come from all parties pulling towards the same goals. The Royal Society welcomes this exercise, which has given a high profile to science and technology, to their vital role in innovation and wealth creation and to the benefits of taking a holistic approach to strengths, weaknesses, threats and opportunities. We hope that Foresight is here to stay.

*This report has been prepared by a group chaired by Dr Mike Stowell. The members were Professor John Ffowcs Williams, Professor Brian Heap, Professor Mike Kelly, Professor Kevin Kendall, Dr Bob Moor, Professor Roger Needham, Dr Andrew Palmer, Dr Bill Wilkinson and Dr Peter Collins (secretary).*