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The Collyear Report on New Materials Technology

SCIENCE & TECHNOLOGY

S 3000

August 1984

Referred to	Date	Referred to	Date	Referred to	Date	Referred to	Date
~~15.8.84~~							
~~30/8/84~~ 31/8/84							
~~4.9.84~~							
~~11.9.84~~							
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PREM 19/1937

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10 DOWNING STREET

From the Private Secretary

9 January 1986

Thank you for your letter of 24 December. The Prime Minister agrees that the Department should now set out its policy by way of an arranged PQ, and she has approved the text of the reply attached to your letter.

I am copying this to Sir Robin Nicholson.

Mark Addison

Miss Catherine Bradley
Department of Trade and Industry

PRIME MINISTER

MATERIALS TECHNOLOGY: COLLYEAR REPORT

You took a good deal of interest in this Report, which was produced in 1984. You had considerable reservations about some of its conclusions, in particular that a further contribution from the taxpayer was called for, and that the DTI should co-ordinate the collaboration between companies. Your reservations are now shared by DTI, and the line they propose to take reflects this.

Agree that DTI should now set out their policy by way of the arranged PQ reply, as drafted (Flag A)? Sir Robin Nicholson is content (Flag B).

Yes

MEA

MARK ADDISON

8 January 1986

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MR ADDISON
10 Downing Street

7 January 1986

MATERIALS TECHNOLOGY

There was considerable industrial interest in the Report (A Programme for the Wider Application of New and Improved Materials and Processes) prepared by the Materials Advisory Group under John Collyear. Mr Pattie invited comments on the report, it would therefore be appropriate to announce the actions which DTI propose to take.

While little additional DTI expenditure is planned, materials technology will be a priority area, with DTI acting to encourage early commercial exploitation of new materials.

A low key announcement would be appropriate and the proposed PQ is, WITH MGA in my view, a sensible way to proceed. I think that the draft sent to you on 24 December is sufficiently positively phrased to indicate that DTI have given priority to this area of industrial opportunity.

There is likely to be some backlash from industrialists who anticipated a major new R & D programme on the scale proposed in the Collyear report (ie £60M from Government over 5 years).

RBN.

SIR ROBIN NICHOLSON
Chief Scientific Adviser

SCIENCE + TECH 8/81

MATERIALS TECHNOLOGY

- cc BG

DEPARTMENT OF TRADE AND INDUSTRY
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Secretary of State for Trade and Industry

PS/

24 December 1985

Mark Addison Esq
Private Secretary to the
Prime Minister
10 Downing Street
LONDON
SW1

Dear Mr Addison,

MATERIALS TECHNOLOGY

The Department has been reviewing its policy towards the exploitation of new materials and processes. It has done so in the light of our review of the Support for Innovation Scheme, and against the background of the proposals in the Materials Advisory Group Report which were the subject of correspondence between the Prime Minister and Mr Tebbit. The most recent correspondence on this was 15 and 16 January 1985.

As you will recall, Mr Pattie set out clearly the Government's reservations over public finance in this area in his preface to the report on publication. This initiated consultation with industry. There was a strong response, mostly favourable to the Report's proposals. However, the case against additional public expenditure on the scale recommended by the Materials Advisory Group remains strong and my Secretary of State is also unconvinced of the need for a steering or co-ordinating committee. Rather there is scope for the redirection and more efficient use of existing resources so as to increase the already substantial amount of work in this important field at little extra cost. Such redirection should take full of international initiatives such as the Versailles Work Group : Advanced Materials and Standards project (VAMAS) and EUREKA, as well as of the EC materials programme on which Mr Pattie reached a satisfactory agreement at the recent EC Research Council devoted to advanced materials technology. Participation in such international activities can help to ensure that limited resources are used more effectively.

Although Ministers are not formally committed to a public response to the Materials Advisory Group Report, this Department continues to receive enquiries about it. There may well be parliamentary interest and my Secretary of State considers that it would be better to take the initiative now by setting out the Department's policy through an arranged PQ (copy attached). The policy will not satisfy those seeking major additional expenditure but it does represent a significant deployment of effort within existing

DW3AFQ

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resources.

The elements of the approach are:

i. Re-orientation of existing resources towards materials work

ii. Improvement of the awareness of new materials and development of collaborative projects which will accelerate commercial application

iii. Closer collaboration between this Department and the Science and Engineering Research Council to guide university research and promote technology transfer.

iv. Better liaison between this Department and the Ministry of Defence with a view to commercial exploitation of materials developments.

v. Participation in European Community and other international collaborative programmes, such as EUREKA, wherever this is appropriate

vi. Exploitation of the opportunities for the increased use of new materials through improved specification standards.

This approach is consistent with the firm line which this Department took on the Collyear Committee Report at the time of its publication. It is also fully consistent with the Department's general policies on support for research and development arising from the recent review.

Implementation will result in funds being diverted to new and improved materials but within existing budgets. An informal group of officials will maintain an overview of policy and co-ordinate activities as necessary.

I am copying this to Sir Robin Nicholson.

Yours sincerely,

C Bradley

CATHERINE BRADLEY
Private Secretary

DW3AFQ

ANNEX 1

DRAFT PQ

To ask the Secretary of State for Trade and Industry what his Department's policy is on the wider application of new and improved materials and processes in the light of the Department's review of its Support for Innovation Scheme and the publication of the Materials Advisory Group Report.

DRAFT ANSWER (Mr Pattie)

The Materials Advisory Group drew attention to the very important field of materials technology and identified within it areas of particular opportunity to a wide range of UK industries. This has made a major contribution to my Department's continuing assessment of research priorities. While I am unable to accept that progress in this field can only be made by the provision of additional Government funding on the scale suggested by the Group, I consider that there is considerable scope for obtaining greater benefit from the already substantial amount of work in the materials field by the redirection and more efficient use of Government resources.

The Department will therefore be : re-orientating its existing resources towards materials work; seeking to improve awareness of new materials and to develop collaborative projects which will accelerate commercial application; collaborating more closely with the Science and Engineering Research Council to guide university research and promote technology transfer; working with the Ministry of Defence with a view to commercial exploitation of military materials developments; seeking the fullest UK participation in European Community and other international collaborative programmes; and working for improved specification standards where these offer opportunities for exploitation of new materials.

In the discussion which has been concluded in the European Community's Research Council on an extension of the Community's Primary Raw Materials Programme I particularly emphasised the importance which the UK attaches to the new section on advanced materials. In the four year Research Action Programme on Materials which we agreed, over 40% of the total budget of £40 million will be devoted to this section, thus providing a useful further stimulus to advanced materials work.

SCIENCE + TECH

NEW MATERIALS

TECHNOLOGY

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File

10 DOWNING STREET

From the Private Secretary 16 January 1985

Materials Technology

Thank you for your letter of 15 January about the handling of the publication of the Collyear Report.

The Prime Minister has seen your letter, and is content with the line which your Secretary of State proposes to take. She has noted, in particular, that he intends to express reservations about the need for a separate scheme of support, or for public expenditure on the scale which Collyear recommended.

I am sending copies of this correspondence for information to Sir Robin Nicholson.

(David Barclay)

Miss Maureen Dodsworth
Department of Trade and Industry

E B+

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PS/
Secretary of State for Trade and Industry

15 January 1985

David Barclay Esq
Private Secretary to the
Prime Minister
10 Downing Street
London SW1

Prime Minister (1)

The presentation now proposed by DTI (see para 5) better reflects your own doubts about the merits of Collyear's recommendation for Government funded research. Content?

DWB 15/1

Dear David

MATERIALS TECHNOLOGY

Thank you for your letter of 20 November to Neil McMillan. You asked for proposals on handling the publication of the Collyear Report, and the Government's response to it. My Secretary of State discussed it with Mr Pattie before the latter's departure to the US.

2 They both believe that materials technology is likely to be fundamental to the future success of British industry. The Collyear Report draws attention to key sectors and outlines a possible framework for action. Publication will raise awareness of this technology and enable us to consult industry on specific points on a wider basis than was possible by the Materials Advisory Group. As you say the issues of principle raised by Collyear are similar to those raised by the review of support for industrial research and development announced by Mr Pattie.

3 Ministers have considered either editing the report before publication to remove the detailed costing and the internal organisation for a co-ordinating unit, or alternatively issuing a consultative document based on some of the Collyear recommendations. They have, however, concluded that either action would draw attention to the deletions and would attract the charge that the Materials Advisory Group had failed to address fully its terms of reference. Such criticism would also be likely to lead to pressure on Mr Collyear and other non-official members of the Group to comment on deleted sections.

4 Since the establishment of the Materials Advisory Group and the completion of its work were announced by Mr Baker in written Parliamentary Questions, it would be appropriate to announce publication in the same way with an accompanying press notice.

JH4AQZ

5 My Secretary of State would like the announcement to endorse the report's emphasis on the importance of new materials and processes and to invite comments on the "key technologies of opportunity". It will, however, express reservations about the need for a separate scheme of support or for public expenditure on the scale proposed. In the long term, work in this area will benefit industry and we will look to industry to provide finance for it. The announcement will invite comments on the report in terms which will ask industry how they can best co-ordinate projects which they see as important. It will also question whether there were not more effective arrangements, closer to industry, than those proposed by Collyear. The announcement will invite early comment so they can be taken into account within the review of SFI which Mr Pattie announced on 12 November.

Yours sincerely,

Maureen Dodsworth.

MAUREEN DODSWORTH
Private Secretary

JH4AQZ

Science & Technology : Collyear Report : Aug '84

15 JAN 1985

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10 DOWNING STREET

From the Private Secretary

20 November 1984

MATERIALS TECHNOLOGY

In my letter of 11 September to Callum McCarthy about the Collyear Report, I said that the Prime Minister was minded to hold a Seminar on Materials Technology at Chequers later this year.

Provisional arrangements had been made to hold such a Seminar on 9 December. I understand, however, that your Secretary of State is unlikely to feel ready to take part in the meeting by that date, and in view of this, and the extreme pressure on her diary from other directions, the Prime Minister has reluctantly decided not to proceed as originally planned. She would be grateful if your Minister could instead put forward proposals in correspondence on handling publication of the Collyear Report, and the Government's response to it.

BF /

The issues of principle raised by Collyear can be expected to arise also from the review of Support for Innovation that your Department is conducting. The Prime Minister looks forward to considering them in that context.

I am sending copies of this letter to Robin Nicholson and Richard Hatfield (Cabinet Office).

David Barclay

Neil McMillan Esq
Department of Trade and Industry

Cf ppsor the seminar please.

DMB 19/11

Cancel the 9th Dec at Chequers - we already have more than enough between now & Christmas. Space-station meeting in London not

PRIME MINISTER

CHEQUERS SEMINAR: 9 DECEMBER

We are planning a seminar on materials technology, and in particular the Collyear Report, at Chequers on 9 December. Part of the object, however, is to use the Collyear Report as a case study for a wider discussion of Government support for industrial research and development.

Mr. Pattie has now taken over responsibility for this subject at DTI. But he does not seem to share Mr. Baker's enthusiasm for it, and he has suggested instead that the time should be used for a Ministerial meeting at Chquers on the US space station (his minute at Flag A).

I understand from his Private Secretary that Mr. Tebbit still tires easily, and is unlikely to be able to take part in person in the seminar on 9 December, on either subject.

In my view, and I believe in Robin Nicholson's, it would be a pity to forego the materials technology discussion. Besides, the US space station is an intra-governmental issue at this stage, and could - I should have thought - be dealt with just as effectively at No. 10.

Agree:

(i) To proceed with the materials seminar at Chequers?

(ii) To invite those whose names are highlighted in yellow on the list at Flag B?

(iii) ✓ To hold a meeting on the US space station in London in December?

DMB

16 November 1984

VSCAEJ

Await DTI

PRIME MINISTER

US SPACE STATION

As you know decisions will soon have to be taken on British participation in the European contribution to the US Space Station. The topic has wide ramifications for relations with our partners in Europe and with the US, for the funding and future viability of our space programme, and for the image of our overall technological capabilities which we present to the world. With a Ministerial meeting of the European Space Agency due to take place in Rome 29-31 January, the decision to join the ESA space station definition studies will need to be taken before Christmas.

I was, as you know, hopeful that the Materials Initiative might be discussed with colleagues at Chequers in the next few weeks but as this is not time-critical I would be content for this to be put on the back burner for the moment and discuss the Space Station instead. If it is at all possible I should like to urge as early a Chequers meeting as can be arranged.

GEOFFREY PATTIE

8 November 1984

NO2/NO2AAJ

Recommendations for attendance at a presentation to the Prime Minister on new materials technology.

<u>Producers of "traditional" materials</u>

Dr David Atterton, Chairman Foseco Minsep
Director of the Bank of England
Member of ACARD.

Viscount Caldecote, Former Chairman of Delta Metals
now Chairman of Investors in Industry.

<u>Producers of "new" materials</u>

Mr John Harvey Jones, Chairman ICI

Mr John Thompson, Chairman of HIP (Powder Metals) Ltd (a small company producing novel materials)

<u>"High tech" users of new materials</u>

Mr Ralph Robins, Chief Executive (elect), Rolls Royce

Admiral Sir Raymond Lygo, Chief Executive, British Aerospace

Sir Kenneth Corfield, Chairman and Chief Executive, Standard Telephones & Cables.

<u>"Medium tech" users of new materials</u>

Mr John Collyear, Chairman of AE, Author of the Collyear report

Mr Roy Roberts, Managing Director GKN

<u>or</u> Mr Anthony Gill, Chief Executive, Lucas

Manufacturers of processing equipment

Mr Mike Hoffman, Group Managing Director, Babcock International (formerly with Massey/Perkins)

Academics/Independents

Professor John Kingman, Chairman, Science and Engineering Research Council

Professor Sir Hugh Ford, Emeritus Professor, Imperial College of Science and Technology.

or Dr A Kelly, Vice Chancellor, University of Surrey

Ministers with particular interest in the new materials technology report

[Secretary of State for Trade and Industry]
Minister of State for Information Technology

Minister of State (Defence Procurement)
Parliamentary Under Secretary of State for Science (Mr Brooke)

Others

Dr R B Nicholson, Chief Scientific Adviser, Cabinet Office

Mr Oscar Roith, Chief Engineer and Scientist, Dept of Trade and Industry.

Collyear Report: Science & Tech.
Aug 84.

10 NOV 1984

W0829

MR BARCLAY - No. 10 9 November 1984

COLLYEAR REPORT ON NEW MATERIALS TECHNOLOGY.

In your minute of 22 October you said that the Prime Minister had agreed to proceed with a presentation on the Collyear Report, at Chequers on Sunday 9 December.

I have recently discussed plans for a presentation with Mr John Collyear and with the Department of Trade and Industry. I attach a list of industrialists from whom the final choice would be made depending on availability etc.

I would be grateful if you could confirm that the presentation will go ahead on Sunday 9 December at Chequers in order that the DTI can assemble the items for the exhibition which we propose to use to enhance the discussion.

Perhaps you could put the list of recommendations for attendance to the Prime Minister. I have also listed those Ministers who have the most direct interest in this topic. I think it would be appropriate to include the Chairman of the Science and Engineering Research Council, in view of the Prime Minister's earlier comments about the coordination of collaborative research in this field; if so, then a Minister from the Department of Education and Science should be included.

When I receive comments on the invitation list, I will send invitees copies of the Collyear Report and talk to them about the presentation.

RBN

Robin B NICHOLSON
Chief Scientific Adviser.

FILE
da

10 DOWNING STREET

From the Private Secretary

DR. NICHOLSON
CABINET OFFICE

Collyear Report on Materials Technology

Thank you for your minute of 16 October, which I saw on my return from leave.

I have consulted the Prime Minister, who agrees to proceed with the proposed presentation on the Collyear Report, to take place at Chequers on Sunday 9 December. We aim to set aside about three hours for discussion, and to follow the meeting with a buffet supper.

I have not troubled the Prime Minister with your suggested guest list at this stage. There is no-one on it who strikes me as unsuitable - so perhaps you could develop the plans a little further with the Department of Trade and Industry, and let the Prime Minister have some firm recommendations for attendance in due course. I should prefer, if you agree, to leave over the question of Ministerial attendance for consideration at that time.

I do not think that the Prime Minister would have any objection to your providing copies of the Collyear Report for those attending, as long as the Department of Trade and Industry are also content.

David Barclay

22 October 1984

ECA

PRIME MINISTER

You suggested a meeting at Chequers on the Collyear Report. I attach proposals from Dr. Nicholson.

Would you like to proceed with this, on Sunday 9 December - say from 1600 to 1900 hours, followed by a light supper? If so, could you please indicate any names that particularly appeal in the Annex to Dr. Nicholson's note (plus any that you would not want invited)? Robin suggests that we should aim at about half a dozen industrialists, plus one academic.

I rather think that weekend will be very full. Isn't it about the time that Gorbachev comes?

DWB

Will consult with Caroline

David Barclay
19 October 1984

RESTRICTED

W.0752 16 October 1984

MR BARCLAY, NO 10

COLLYEAR REPORT ON MATERIALS TECHNOLOGY

In discussion, following your minute of 11 September to Callum McCarthy, we agreed that the first step in providing an opportunity for the Prime Minister to discuss the issues raised should be to arrange a presentation for her at which a small number of leading industrialists and researchers would set out their views on the opportunities offered by new materials technology, and they could also discuss with her how the UK might exploit the new developments most effectively. We agreed that some aspects of the financing of materials projects within industry might be discussed, but that issues relating to the fundamental role of the Department of Trade and Industry would probably not be appropriate for detailed discussion with industrialists present.*

*though they could and should be considered by Ministers separately. DMB 19/10

I have asked the Department of Trade and Industry to reassemble the exhibition which was shown by the Collyear group to Ministers earlier this year, and I would propose that the presentation to the Prime Minister be based on informal presentations by the industrialists relating to the exhibition.

I have considered, with help from DTI, some industrialists who might be invited. The list attached includes the type of people I think would be appropriate and I would be grateful if you could give me some guidance on preference (either positive or negative). I have deliberately chosen names from the top level of industry since it is only those people who can speak authoritatively about the financial commitments their companies are prepared to make in the exploitation of materials technology.

If these proposals are broadly in the right direction, I would propose to meet with John Collyear and also get his input on the best selection from the nominees. I would aim to end up with about half a dozen industrialists and perhaps one academic.

RESTRICTED

Your minute of 11 September mentioned the possible role of the Science and Engineering Research Council, and if this is to be discussed, I would add Professor John Kingman to the list.

As far as Ministerial attendance is concerned, I would suggest the Secretary of State for Trade and Industry, the Minister of State for Information Technology, the Minister of State for Defence Procurement and, if SERC is to be represented, the Parliamentary Under Secretary of State for Science.

I have had a word with Caroline Ryder and I believe that 9 December is pencilled into the diary. This date was checked with Mr Tebbit's office pre-Brighton.

In order to prepare for the discussion it would be necessary to provide those attending with copies of the Collyear Report and I would be grateful if you could seek the Prime Minister's agreement that the Report be provided, in confidence, to them.

RBN

ROBIN B NICHOLSON
Chief Scientific Adviser

LIST OF NOMINEES

RESTRICTED

Producers of "traditional" materials

Dr David Atterton, Chairman of Foseco Minsep, Director of the Bank of England, Member of ACARD

Sir Alastair Pilkington, Chairman of Pilkington Bros.

Mr David Balchin, Chairman of Inco Alloy Products

Viscount Caldecote, Former Chairman of Delta Metals, now Chairman of Investors in Industry.

Producers of "new" materials

Mr John Harvey Jones, Chairman of ICI

Mr Robert Malpas, Director of BP, Member of ACARD

Mr John Thompson, Chairman of HIP (a small company producing novel materials)

"High tech" users of new materials

Sir William Duncan, Chairman of Rolls Royce

Admiral Sir Raymond Lygo, Chief Executive of British Aerospace

"Medium tech" users of new materials

Mr John Collyear, Chairman of AE, author of the Collyear Report

Mr Anthony Gill, Managing Director of Lucas

Lord Gregson, Director, Fairey Holdings

Mr Harry Sheron, Director of BL Holdings

Academics and independents

Professor Sir Hugh Ford, Emeritus Professor, Imperial College of Science and Technology

Dr Diarmuid Downs, Chairman, Ricardo Consulting Engineers

Dr Anthony Kelly, Vice Chancellor, University of Surrey

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10 DOWNING STREET

From the Private Secretary

PERSONAL

11 September 1984

The Prime Minister was grateful for your Secretary of State's personal minute of 8 August, in which he sought her initial reaction to Mr. Collyear's report on materials technology.

The Prime Minister would not dispute the proposition that materials technology is likely to be fundamental to the success of British industry over the coming decades. Nor would she disagree that there are many exciting developments and opportunities in this field at the present time. The Prime Minister has, however, noted that your Secretary of State is sceptical about some of the judgements and proposals in the report. She herself has considerable reservations about the conclusions which Mr. Collyear and his colleagues draw from their analysis.

In the first place, the Prime Minister considers that the case for a financial contribution from the taxpayer to the proposed programme requires further, critical, examination. She has noted the assertion in paragraph 3.1 of the report that "The private sector of manufacturing industry will be reluctant on its own to provide the enhanced level of effort and funding because the UK financial climate for public companies, dominated by institutional investors, does not encourage investment of this type". She wonders however what is the evidence for this claim and how rigorously it has been tested.

Secondly, the Prime Minister would not necessarily accept that inter-company collaboration in this field - if indeed it is required - needs to be co-ordinated by the Department of Trade and Industry. She wonders what consideration has been given to alternative arrangements, for example asking a private sector institution to manage the programme on the Government's behalf; or inviting an existing public sector institution, such as the Science and Engineering Research Council, to adopt a more positive role in materials development.

DCAAFZ

The Prime Minister would like the opportunity to discuss these issues, which she considers are quite fundamental, with your Secretary of State, and with leading figures from research and from industry (including of course Mr. Collyear), before the report is published. She has asked Dr. Nicholson, in consultation with your Department, to suggest the names of those who might be invited to take part in such a discussion, which we would hope to arrange at Chequers in the near future.

I am sending a copy of this letter to Dr. Nicholson (Cabinet Office).

David Barclay

Callum McCarthy, Esq.,
Department of Trade and Industry.

MFJ ADF

DRAFT PRIVATE SECRETARY LETTER TO DTI

COLLYEAR REPORT

The Prime Minister was grateful for your Secretary of State's minute of 8 August, in which he sought her initial reaction to Mr. Collyear's report on materials technology.

The Prime Minister recognises that the scientific and technical issues raised in the report are timely and important. Many new products owe their competitiveness to the effective ~~utilisation~~ use of new materials; and, as the report makes clear, significant future developments are on the horizon. The availability of new materials will change designers' traditional expectations of the relationships between strength, weight and temperature resistance; and the Prime Minister believes that British industry must exploit these developments energetically if its products are to be competitive in world markets.

The central question raised by Mr. Collyear's report is whether the Government has a role - and if so, what sort of role - in ensuring that this commercial exploitation occurs. The Prime Minister sees the force of the argument that the time scale of materials development, and the need for collaboration between many companies, make a degree of Government co-ordination desirable. But before reaching a conclusion on this point, the Prime Minister believes that it will be essential to have the views of key people in industry, so that the Government can gauge their likely commitment to a materials R&D initiative, and the willingness of the private sector to invest in order to exploit the outcome. The Prime Minister therefore agrees that it would be sensible to publish the group's report as a consultative document as soon as possible.

The Prime Minister has asked me to make two further points. First, she has some reservations about the detailed arguments in Mr. Collyear's report. In particular, some of the proposed R&D projects seem sufficiently close to the marketplace for industry to pursue them without the need for any Government help. Secondly, the Prime Minister believes that some thought could usefully be given even at this early stage to possible ways to administer a materials R&D initiative. One possibility would be for the management of the programme to be contracted out to a private sector group with relevant expertise, with some civil servants seconded to it. An alternative would be to second industrialists to Whitehall to work alongside civil servants in an independent unit, as has been the case with the Alvey programme, and with biotechnology. In addition to these arrangements, there may also need to be a steering committee, to bring together the various Government participants with industry. The Prime Minister would see some advantage in this steering committee being chaired by senior industrialists.

The Prime Minister would be grateful to be kept in touch with the response which industry gives to the Collyear Report, and with the way your Secretary of State's thinking developes as a result.

Prime Minister (1)

Agree draft reply to DTI at Annex 3?

DWB 7/9

W.0604

4 September 1984

I am very unhappy about what is proposed

PRIME MINISTER

May I discuss with Robin Nicholson

REPORT FROM THE MATERIALS ADVISORY GROUP (CHAIRED BY JOHN COLLYEAR): "A PROGRAMME FOR THE WIDER APPLICATION OF NEW AND IMPROVED MATERIALS AND PROCESSES"

In his minute of 8 August, the Secretary of State for Trade and Industry draws your attention to the Collyear report on a proposed initiative on new materials technology, asks for your comments on the scientific and technical issues which the report raises and seeks your views on the apparent difficulty which industry finds in carrying through appropriate R&D programmes in this field without Government assistance and co-ordination. A summary of the report is attached (Annex 1).

2. Many countries (including USA, Japan and France) have identified materials technology as one of a small number of 'enabling technologies' like microelectronics and biotechnology where mastery of the relevant skills will be an essential component of a successful manufacturing industry in the future. There are two reasons for this:

(a) Many current products owe their competitive position to effective utilisation of advances in materials technology: light alloys and plastics in more economic cars, single crystal blades in fuel-efficient gas turbines, microprocessors with more closely packed components, stiff carbon fibres in sports goods, more readable display units with liquid crystals.

(b) There is an upsurge in R&D in materials science and technology leading to many novel materials: ductile cements, high temperature engineering ceramics, ceramic/metal and ceramic/plastic composites, laser treatment of materials surfaces etc.

3. Thus the Collyear report is very timely and must carry weight because the leading members of Collyear's group are industrialists who are users of new materials. John Collyear himself is Chairman of AE plc which has a good record of exploiting advances in materials technology through their automotive products. I have heard Collyear make a presentation of his report to Mr Tebbit and seen an excellent exhibition of new materials and their utilisation which his group has prepared. The UK has an excellent track record in R&D in materials science and technology: we have played a major part in developments such as liquid crystal displays, carbon fibres, glass reinforced cements and micro-alloyed steels. As usual our exploitation of these R&D advances has been less successful.

4. If the benefits of materials technology are so manifest, why is there any need for Government to be involved? Collyear believes that the need arises for three reasons:

(a) the long time-scale of materials developments;

(b) the necessary involvement of a wide range of organisations;

(c) the lack of awareness amongst users at the design stage for new products of the availability of new materials.

In materials technology, the results of R&D programmes have to travel from the laboratory to material producers, to those who design and build machines to form the material into a component, to designers and manufacturers of finished products - and all need to see a new or enlarged market to justify their involvement. Additionally, there is the need to test new materials and products involving new materials extensively before they can be sold. All this takes a long time if it is left to natural processes and too frequently new ideas fail to reach the places where they could be applied in time to catch the market. Some feel for typical materials development programmes can be gained from the attached copies (Annex 2) of two of 16 case histories included in a 1983 report by the Fellowship of Engineering to DTI on 'Modern Materials in Manufacturing Industry'.

5. I think the main conclusions from this group on the importance of materials technology and the need for Government involvement do stand up. We cannot afford to lose out on this important enabling technology and so miss opportunities to exploit new materials in more competitive products. The estimated cost (£120m over 5 years with industry expected to pay half the costs of the R&D component, ie £54m out of £108m) is not out of line with the possible returns to manufacturing industry which I believe could be considerable. The report estimates that £12m of the estimated £75m DTI spend on materials in the next 5 years is already in the right areas, and clearly at least some of the remaining finance can be found in re-directing parts of the existing materials programmes and replacing other DTI R&D programmes of lower priority.

6. Before you consider supporting the proposals, you will want to be certain that industry is behind them, will contribute appropriately to the costs of collaborative R&D programmes and will be in a position to exploit the results by suitable investment and marketing. You may therefore wish to suggest that the Secretary of State for Trade and Industry should publish the report as a consultative document, immediately, so that the views of a wider industrial group than has so far been consulted can be obtained before firm decisions are made.

7. It may not be too early to consider possible machinery to deal with the programme. If Whitehall were to co-ordinate it, it would be desirable to second industrialists to work with Civil Servants as has been done in the Alvey Directorate and for the biotechnology programmes of DTI. However, it might also be worth considering whether the management of the programme chould be contracted out to the private sector, with some Civil Servants seconded out for short periods. It might also be appropriate to consider setting up a steering committee

bringing together DTI, MOD, SERC, and DES as active participants with industry, under the chairmanship of an industrialist. I have included these points in the attached draft minute (Annex 3) for you to consider sending as a reply to Mr Tebbit.

8. I am copying this minute and the draft minute to Mr Tebbit to Sir Robert Armstrong.

RBN.

ROBIN B NICHOLSON
Chief Scientific Adviser

Cabinet Office
4 September 1984

SUMMARY OF THE REPORT FROM THE MATERIALS ADVISORY GROUP
(CHAIRED BY JOHN COLLYEAR) ENTITLED
"A PROGRAMME FOR THE WIDER APPLICATION OF NEW AND IMPROVED
MATERIALS AND PROCESSES"

The Advisory Group have concluded that if UK industry were to adopt new and improved materials and processes (NIMP) more effectively their products could have a competitive edge. However, the time scale for technical developments in materials is a long one involving many steps and high risk. They therefore propose a programme designed to increase the rate at which the many technological developments are exploited in industrial applications, and thus ensure that UK manufacturing industry does not miss opportunities which competitors overseas seem set to seize.

2. A Government-led programme is suggested for the following reasons:-

- the costs and long lead times of development programmes are greater than single companies can afford, and usually involve more than one type of firm (material supplier and machinery maker, for example)

- in order to take full advantage of the technological advances, revolutionary changes in engineering design and production technology will be needed which require awareness and stimulation from the Government as the largest purchaser of goods

- only Government can stimulate the necessary collaboration between companies, and between industry and research organisations (including Universities)

3. The Group identified the following materials and enabling technologies as those which offer opportunities to UK manufacturing industry: -

Composites: particularly reinforced thermoplastics
self reinforcing polymers
metal matrix composites
reinforced cements, ceramics

Engineering Ceramics (including hot isostatic pressing techniques)

Rapid Solidification technology

Electronic Materials: including multi-layer structures (super lattices)
gallium/indium compounds
organic semiconductors

Near net shaping methods of manufacture: powder metallurgy
precision casting
super plastic forming/
diffusion bonding

Joining technology

Coatings and surface treatment

Assurance of product performance: automation of materials processing
non destructive evaluation
product life evaluation

4. The report recommends the setting up of a Materials Co-ordinating Group (MCG), in the Department of Trade and Industry (DTI), with members from industry, Government and the research community in order to implement the propoals, administer the programme and monitor, review and update priorities.

5. For many technologies it is recommended that `clubs' are formed to undertake pre-competitive research and development. These would involve supplier and user companies and machinery manufacturers and work would be carried out in Government research establishments, Universities or industry. `Clubs' of this type already exist for some aspects of materials and have proved successful in effecting technology transfer. Other collaborative R & D programmes in industry are also put forward.

6. The Group recommend, that a programme of collaborative R & D, individual industrial research projects, demonstration projects and strategic research be carried out over the next 5 years at an estimated cost of £108 m, backed up by an awareness programme and education and training costing a further £12 m.

Out of the total cost of £120 m over 5 years, industry would be expected to contribute £54 m (half the R & D costs) with Government funding the remainder via DTI (£50 m), SERC (£6 m) and DES (£10 m). The group recommend that the programme should begin immediately.

CASE HISTORY NO 1

LIQUID CRYSTALS FOR OPTICAL DISPLAY DEVICES

Reasons for Change

The reason for interest in liquid crystals as optical display media was that flat panel displays were required for a range of civil and military applications. The cathode ray tube had been used for many years, but its large bulk and high voltage were incompatible with the new generation of electronics, integrated circuit chips, working from a few volts. The first step forward was to use light emitting diodes (LEDs), but these are unsuitable for complex displays and have a high power consumption. Nevertheless, they were used for the first digital watches and calculators, in the absence of any alternative. They have now been displaced by liquid crystals as the first choice for small display devices, because liquid crystals work with very little power. Liquid crystal displays (LCDs) are passive, relying for their visual effect on ambient light, which is locally modulated through a change in reflection, transmission or absorption, caused by a rearrangement of the molecules of the liquid crystal under the influence of an electric field.

This case history describes how an originally imperfect material with potential for use in electro-optical displays was developed into a commercial success.

History

By 1970 around 3000 different liquid crystals had been synthesised although few held any interest for designers of electro-optic display devices. Most had operative temperature ranges well above room temperature, and the few that did work at room temperature were degraded by water vapour or decomposed by UV radiation. This unreliability made them poor candidates for commercial use, and quite unsuitable for military applications. At this time the UK had no effective programme to develop liquid crystal materials and devices, though work was being conducted in Japan and the USA on this and rival passive display phenomena. The need for flat panel displays for military applications, plus concern over the import of electronic devices produced overseas, led to a reassessment of electro-optical display phenomena by Dr Cyril Hilsum of RSRE.

His decision to recommend support for a new and substantial development programme on liquid crystals, in preference to other potentially useful devices, was based on many factors, but two of the more important were (i) that the UK had an international expert in Dr (now Professor) Gray of Hull University and (ii) liquid crystals had been neglected in preference to other options by natural prejudice amongst electronic engineers in favour of solids as opposed to liquids.

Dr Hilsum established a collaborative programme between RSRE, Malvern and Hull University, with the University work funded by the Ministry of Defence Components Valves and Devices (CVD) agency. The success of this programme in developing suitable mixtures of liquid crystals for display devices relied on crucial inputs from both organisations in the collaborative programme.

The materials and mixtures were patented in 1972 and passed to BDH Chemicals Limited, a company experienced in the production of ultra-pure organic chemicals, but with no previous experience of liquid crystal technology. BDH devised methods of synthesis which were suitable for large scale production at acceptable costs. Samples were distributed to customers in Europe, the USA and Japan in 1973. The initial materials were suitable for four-digit wrist-watch cells, and began displacing watches using LEDs and unstable LCDs in 1975.

During the course of these developments it was necessary to prove that the materials were not carcinogenic and were superior to competitive materials produced in the USA and Japan. The selling price was in fact at least double that of competitive materials.

By 1977 BDH had 50% of the world market, worth over £1.25 million. Since then, further technical development has been necessary to evolve materials suitable for larger displays, eg eight-digit calculators, which employ a more complex form of electronic addressing; viz multiplexing. This has been successfully achieved through the same collaborative approach and BDH's sales of liquid crystal materials had doubled to £2.5 million by 1981. Despite the emergence of competitors in the field, the UK-designed and produced materials are still regarded as the best in the world.

Development work continues to evolve the materials required for future display systems. The inventors, through MOD, receive substantial royalties.

Unfortunately downstream manufacture of the higher added value display devices and host products, eg calculators or digital watches, has not developed in the UK to take advantage of an indigenous source of liquid crystal materials. However this should not be seen as a problem experienced by the UK alone. LCD device manufacture is now concentrated in the Far East and it would appear that, given the current state of electronic device production technology, cheap, reliable labour is still an important ingredient of commercial success.

Technical Description

Liquid crystals are organic substances, intermediate between the solid and liquid state, which have interesting electro-optical and thermo-optic properties. The essential features of the most common liquid crystal display device are shown in Figure 1. In the activated state the layer of liquid crystal, about 0.01mm thick, rotates the plane of polarisation of incident light by 90°. The layer is

CASE HISTORY 1

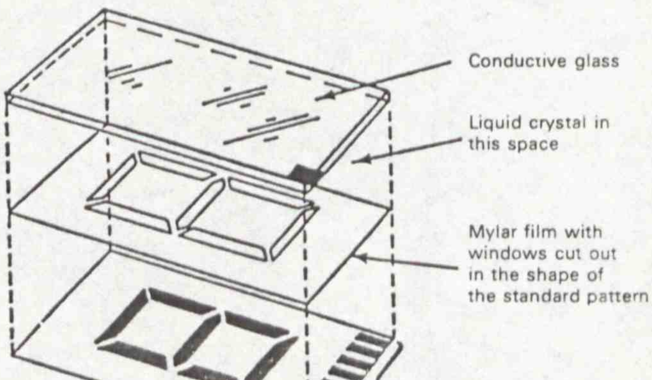

Fig. 1 Exploded view of a Liquid Crystal Numeral Tube (From Modern Electronics Made Simple — G H Olson Published by W H Allen (London) 1977)

sandwiched between conductive glass and two sheets of polariser, polarised parallel to each other. The display looks dark. Activation with a small voltage removes the 90° polarisation rotation, and the cell then looks bright. In practice the activation is localised by etching the conducting layers on the inner surfaces of the glass walls into segments. Each segment acts as a separate electrode, and a bright region of the display appears beneath any segment to which volts are applied. For number presentation there are seven segments, arranged as a figure eight, and by appropriate activation of the segments any number from 0 to 9 may be obtained. For letters, 35 dot segments in a 7 × 5 matrix are needed.

In 1970, although a number of liquid crystal materials would display the above described properties at room temperature, all types had unacceptable limitations of stability – reaction with moisture, UV light or the cell materials – or were discoloured or slow in response. Gray and his co-workers at Hull University identified the basic cause of instability and synthesised a new family of materials, cyanobiphenyls, which have the desired stability, response time, and low operating voltage. The problem remained that no one material would retain these properties over the required temperature range of −10°C to +60°C. The key was to make mixtures of near eutectic composition but the number of conceivable multi-component systems was much too great to embark on a random search.

It was here that Dr Raynes of RSRE made a crucial contribution by devising a method of predicting eutectic properties from the thermodynamic parameters of the individual components. Raynes' theoretical and experimental work clearly indicated that further developments of the individual components were necessary. This was successfully undertaken at Hull University, and so the first generation of liquid crystal materials, suitable for watch or calculator displays, was born.

The contribution of BDH was to devise and develop methods of synthesising materials to the required level of purity, economically, and on a commercial scale, and, with the technical assistance of Hilsam and his colleagues at RSRE, to market the materials on a worldwide basis.

The fundamental understanding of the requirements of liquid crystals, the innovative work at Hull University and RSRE, and the evolution of commercial chemical manufacturing methods have laid the foundations for further evolution of materials to match the changing demands of the end-users. The incorporation of dyes to produce multi-colour displays is an example of current developments.

Factors influencing change

The factors influencing the successful development of liquid crystal display materials are as follows:-

(i) A clearly defined need for a product coupled with the desire not to be dependent on imported materials.

(ii) Funding from the same source that had the need, ie the Ministry of Defence.

(iii) An individual (Dr Cyril Hilsum) with an awareness of the need, an understanding of potentially useful phenomena, and the ability to bring together complementary sources of expertise sufficient to undertake the necessary development *and* commercial exploitation of the materials.

(iv) The protection of a strong patent.

(v) The recognition of a need for continual evolution based on the original discoveries.

The factors working against the development and exploitation were as follows:-

(i) A number of alternative materials with apparently equal or better development possibilities.

(ii) The basic nature of the chosen material ie liquid, not solid.

(iii) The need to achieve collaboration between three geographically remote and structurally different organisations.

(iv) The relatively small absolute value of the material (currently the world market is probably worth around £10m/year but is growing fast).

(v) The small size (almost complete absence now) of a home market for the materials. (nearly all liquid crystal display devices are assembled in the Far East).

(vi) The relatively high price of the materials.

Lessons

(i) When the specific need and the finance to support the necessary development are within the same organisation the first link in the development chain is forged. Of course this does not mean that this particular development would necessarily have been funded in preference to others.

(ii) When one individual has the knowledge, understanding and ability not only to be aware of the need and of a potentially useful invention, but also to organise the necessary resources for innovation, evolution and commercial exploitation, then an enormous amount of time and effort must be saved on communication. It is probable that the role of the committed and sufficiently able individual is vital to the success of this and most other successful engineering developments, at least in Western countries. The Japanese may be better at getting groups to work together.

(iii) While the person in overall charge of the programme must have a breadth of abilities, each in fair depth, the other individual contributions come from people operating in a field in which they are recognised experts; eg Gray and Harrison on the fundamental organic chemistry of liquid crystals, Raynes on the thermodynamics of mixtures and physics of electro-optic devices, and BDH personnel on commercial production of ultra-pure chemicals. Each contributed vital pieces to the jig-saw but each was operating on familiar ground. This does not mean that imaginative or ingenious thought was not also required; but each would be considered to be evolving their skills on the basis of previous knowledge and in the light of new demands.

(iv) A high price of material, relative to the competition, is not a deterrent to successful sales if quality and performance are sufficiently superior.

SI-AL-O-N CERAMICS - THE LUCAS SYALON STORY

Reasons for Change

Many important engineering components are limited in their temperature of operation by the heat resistance of metals. Examples include gas turbine blades and vanes, combustion chambers, turbocharger rotors and tools for machining metals. Engineering ceramics possess better oxidation resistance than metals, and can be stronger at high temperatures.

The difficulties of using such materials are, principally, the difficulty of forming them and their low values of toughness. However, in many applications, the small values of toughness are not important. It was discovered, independently in Japan and in England at the same time in the early 1970's, that some of the difficulties of fabrication could be overcome if a form of ceramic "alloying" were used.

This case history relates how Lucas with an early involvement with engineering ceramics succeeded in commercialising one member of a new family of materials based on the alloys of Si-Al-O-N which has captured a sector of the machining tool tip market and has potential for application in other areas. The discovery of "sialons" and of ceramic "alloying„ is thus an example of a generic invention which *may* have wide application in many fields.

History

Lucas became involved with ceramics in the early 1960's with the development of crucible materials for silicon crystal growing and small and exceptionally heat resistant tooling. This initial work on silicon nitride led to involvement in the ceramic gas turbine programme, centred on the Ford Motor Co of America, with some small components made also for the Rover company, which subsequently became part of British Leyland. The problems of making turbine components from hot pressed silicon nitride, were and still are technically very difficult.

The sudden increase in oil prices in 1973 combined with the difficulty of producing an effective heat exchanger, made gas turbines for land transport uneconomic, in fuel economy terms, compared with internal combustion engines and this contributed to the abandonment of the ceramic gas turbine project.

At that time there was a real possibility that Lucas would abandon their involvement with engineering ceramics. However, a research contract placed with Professor K. H. Jack at Newcastle University in 1970 had yielded encouraging results for the small but dedicated ceramics team which Lucas retained. Jack had previously worked for the Admiralty Materials Laboratory on the role of magnesia in the densification of hot-pressed silicon nitride and Dr W J Arrol, Research Manager of Lucas, heard about this and took over some support.

John Lumby the product champion for ceramics for Lucas, in collaboration with Professor Jack developed a family of new ceramic materials. Some of these were later patented under the name of "SYALON" (a trade mark of Lucas Industries Ltd) which has been so far restricted to materials containing more than 90% of the ß -Si-Al-O-N solid solution isostructural with ß-silicon nitride. By appropriate adjustment of composition, different grades of sialons can be produced to match the requirements of particular applications.

The development of machining tool tips, especially designed for machining cast iron and difficult materials, such as nickel and titanium alloys, has been so successful that licences have been taken up by two of the world's leading suppliers of tungsten carbide materials, viz Sandvik and Kennametal.

The reasons why syalons are such good machining tool materials cannot be defined exactly, as the tribological phenomena associated with machining are not fully understood. However, it is clear that the inertness of syalon at the high temperatures generated at the tool tip and the absence of carbon, help prevent reactions between the tool and workpiece. The high thermal shock resistance is also very beneficial in avoiding cracking and chipping. Generally, with ceramic tools, it is necessary to machine at high speeds to obtain satisfactory performance and this in turn requires that the machine tools are capable of, and in sufficiently good condition to, attain these speeds. Syalons have been shown to work efficiently both at high and at low speeds.

Other applications for special grades of syalon include welding nozzles, shrouds and location pins, where thermal shock resistance, electrical insulation, and resistance to molten metal pick up are important; and rotating shaft seals in hostile environments, where chemical inertness, low friction and wear resistance are important. In addition syalons are currently being evaluated for roller, shell and ball bearings, diesel engine components, gas turbine components and many other applications requiring wear resistance, heat resistance, chemical inertness and thermal shock resistance.

Technical Description

Silicon nitride (Si_3N_4) and silicon carbide (SiC) are leading contenders for high temperature engineering application because of their high decomposition temperature, their high modulus, low specific gravity and low co-efficient of thermal expansion. This is combined in the case of silicon nitride with very good oxidation resistance coupled with high strength, good wear resistance and low co-efficient of friction as well as resistance to corrosive environments. However, a major difficulty arises in fabricating shapes with desirable properties. Silicon nitride is co-valently bonded and the self-diffusivity of silicon nitride is small. It cannot therefore be sintered to maximum density by firing – the same is true of silicon carbide, which also decomposes rather than melting. The highest strength Si_3N_4 (showing for example a modulus of rupture of $1GNm^{-2}$) can only be obtained by hot pressing and so is limited to fairly simple shapes and it is costly. On the other hand reaction-bonded material, in which the required shape is first made from compacted silicon powder which is then nitrided, could at that time be fabricated easily but was porous and much weaker.*

It was discovered apparently simultaneously in the years 1970-72, in Japan by Oyama and his colleagues at Toyota and by Tsuge at Toshiba, and in England by Jack in Newcastle-upon-Tyne, that a whole field of new materials can be made involving phases in the silicon-aluminium-oxygen-nitrogen system; Sialons – analagous to the aluminosilicate found in nature. This raises the possibility of improving properties and facilitating fabrication by the use of "ceramic alloys". Pressure-less sintering, to

*Recent developments indicate that such material, when sintered, has greatly improved properties and, most importantly, shows a Weibull modulus greater than that of Syalons.

theoretical density, can be achieved more easily with sialons than with silicon nitride, and improvements in strength, creep resistance, oxidation resistance as well as chemical compatibility can be brought about by specific chemical additions. It follows that materials can be designed for rather specific applications, particularly those in which chemical compatibility is not available from pure silicon nitride.

This alloying arises because of the possibility of the reversible replacement:

$$Si^{4+}N^{3-} \rightleftharpoons Al^{3+}O^{2-}$$

so that these sialons are essentially β'-Si_3N_4 in which one or more atoms of silicon are replaced by aluminium while simultaneously the same number of nitrogen atoms are replaced by oxygen.

It has since been discovered, again independently in Salt Lake City and in Newcastle in 1978, that silicon carbide can be incorporated into the system.

The family of ceramic alloys includes vitreous materials as well as crystalline phases. The inter-atomic bonding covers a wide spectrum from partly ionic to highly co-valent and since creep properties can be varied, there is the possibility of increasing ductility and hence reducing brittleness at elevated temperatures.

Pressureless sintering can be brought about by adding a metal oxide, yttria, say in the case of silicon nitride, which forms a liquid phase in order to assist sintering at low temperatures. When densification is complete this reacts with more silicon nitride to give a highly refactory phase.

The cutting tool material is a ß' sialon isostructural with ß silicon nitride. The Lucas patented method of preparation involves the heating together of silicon nitride powder which is mixed with aluminium oxide, with yttrium oxide as a sintering aid and with what is called a polytype material (based on aluminium nitride but also containing silicon and oxygen). The polytype avoids the difficulty of the ready hydrolysis of AlN. The formula of the cutting tool is $Si_{6-Z}Al_ZN_{8-Z}O_Z$ where Z is close to 1.

Factors influencing change

The factors working against this development were as follows:

1 Lucas are not a tool materials manfacturing company. Hence the return on investment in the development could come only from usage in their own factories or through licensing deals.

2 When the ceramic gas turbine project was abandoned there was a great temptation to stop all work on engineering ceramics.

3 Apart from tool tips, Lucas must rely on potential customers to test the performance of most other components which could be made of syalon.

The factors working in favour of the development were:

1 There was a product champion who was prepared to look outside the company to supplement his own and the company's expertise in ceramics.

2 It was possible to test and optimise the formulation of the tool tip material through in-house trials.

3 Licensing of the tool material grade of syalon will provide revenue to continue development of other syalon components with high added value.

Lessons

The lessons of this case history are as follows:

1 If the major application intended for a new material is not successful there should be an alternative outlet.

2 Successful development of new materials takes a long time – more than ten years in this instance. Since the development phase is so long, the research director of a company must be able to transmit his own technical confidence of success to his Board, which becomes nervous at every setback.

3 The recognition by experts inside a company that outside expertise can help, produced a crucial improvement in material performance; ie product champions, who are technical experts, must recognise the value of other experts in the same field.

TOP COPY RETURNED TO DR. NICHOLSON

Dr Nicholson

Thank you. We discussed with the PM this afternoon, and I am writing to DTI. Report returned herewith.

W.0603

4 September 1984

MR DAVID BARCLAY, NO 10

DRB 14/9

COLLYEAR REPORT

Attached is the information I have prepared to help the Prime Minister consider the Collyear report on materials and Mr Tebbit's covering letter of 8 August.

2. I do not recommend that the Prime Minister reads the Collyear report. It has some good material in it but it is long-winded and poorly drafted. Instead I have prepared a summary (Annex 1 of my minute to the Prime Minister attached).

3. If the Prime Minister wishes to see a little more detail on materials technology, the best information is contained in the 1983 report by the Fellowship of Engineering to DTI entitled 'Modern Materials in Manufacturing Industry', which is referred to in the Collyear report. I have copied two of the excellent case histories from this as Annex 2 to my minute to the Prime Minister. I am enclosing a copy of the source document for you but I would appreciate its return.

4. In preparing this information on Collyear, I am mindful that the Prime Minister felt that she had been under-informed on Alvey and made aware of his proposals too late in the day. Hence the last paragraph in my draft response to Mr Tebbit. Hence also the square-bracketed piece on paragraph 3 of that minute. The exhibition really is excellent and could readily be set up, in No 10 if necessary, for the Prime Minister to spend 20 minutes very efficiently in getting a good feel for what Collyear is all about.

RBN

ROBIN B NICHOLSON
Chief Scientific Adviser

W.0590

30 August 1984

DUTY CLERK, NO 10

COLLYEAR REPORT

Confirming my telephone conversation with you this afternoon we agreed to extend the date of our preparing a summary of the Collyear Report to Monday, 3 September instead of 31 August, owing to the press of work here on return from holidays.

We will submit a summary and advice on it next Monday.

Val Meadows

Secretary to Dr R B Nicholson,
Chief Scientific Adviser

MFJADF

DRAFT PRIVATE SECRETARY LETTER TO DTI

COLLYEAR REPORT

The Prime Minister was grateful for your Secretary of State's minute of 8 August, in which he sought her initial reaction to Mr. Collyear's report on materials technology.

The Prime Minister recognises that the scientific and technical issues raised in the report are timely and important. Many new products owe their competitiveness to the effective utilisation of new materials; and, as the report makes clear, significant future developments are on the horizon. The availability of new materials will change designers' traditional expectations of the relationships between strength, weight and temperature resistance; and the Prime Minister believes that British industry must exploit these developments energetically if its products are to be competitive in world markets.

The central question raised by Mr. Collyear's report is whether the Government has a role - and if so, what sort of role - in ensuring that this commercial exploitation occurs. The Prime Minister sees the force of the argument that the time scale of materials development, and the need for collaboration between many companies, make a degree of Government co-ordination desirable. But before reaching a conclusion on this point, the Prime Minister believes that it will be essential to have the views of key people in industry, so that the Government can gauge their likely commitment to a materials R&D initiative, and the willingness of the private sector to invest in order to exploit the outcome. The Prime Minister therefore agrees that it would be sensible to publish the group's report as a consultative document as soon as possible.

The Prime Minister has asked me to make two further points. First, she has some reservations about the detailed arguments in Mr. Collyear's report. In particular, some of the proposed R&D projects seem sufficiently close to the marketplace for industry to pursue them without the need for any Government help. Secondly, the Prime Minister believes that some thought could usefully be given even at this early stage to possible ways to administer a materials R&D initiative. One possibility would be for the management of the programme to be contracted out to a private sector group with relevant expertise, with some civil servants seconded to it. An alternative would be to second industrialists to Whitehall to work alongside civil servants in an independent unit, as has been the case with the Alvey programme, and with biotechnology. In addition to these arrangements, there may also need to be a steering committee, to bring together the various Government participants with industry. The Prime Minister would see some advantage in this steering committee being chaired by senior industrialists.

The Prime Minister would be grateful to be kept in touch with the response which industry gives to the Collyear Report, and with the way your Secretary of State's thinking developes as a result.

DRAFT LETTER FOR THE PRIME MINISTER TO SEND TO SECRETARY OF STATE FOR TRADE AND INDUSTRY

REPORT FROM MR JOHN COLLYEAR'S MATERIALS ADVISORY GROUP

¶ The PM was grateful for your SofS's minute of ~~I have now considered the comments made in your letter of~~ 8 August, in which he sought her initial reaction to ~~which you sent with a copy of~~ Mr Collyear's report on materials technology.

¶ The PM recognises that ~~2.~~ the scientific and technical issues raised in the report are timely and important. Many new products owe their competitiveness to the effective utilisation of new materials; ~~light alloys in lightweight car engines, liquid crystals in optical displays, single crystal alloy blades in fuel-efficient gas turbines, carbon fibres in sports goods.~~ and, as the report makes clear, significant

~~3.~~ ~~F~~further ~~new and exciting~~ developments ~~in materials are~~ are on the horizon~~, as the report makes clear, and~~. The availability of new materials will ~~necessarily have~~ change designers' ~~these will force our~~ ~~designers to change their~~ traditional expectations ~~on~~ of the relationships between strength, weight and temperature resistance, and the PM believes that British ~~of materials and so cause a design revolution. [I understand the Collyear group prepared an excellent exhibition of new materials and their uses and I would like to see this before the proposed initiative comes before us for decision]. Our scientists are certainly in the forefront of some of these developments but it is vital that~~ industry must exploit~~s them effectively~~ these developments energetically if its products are to be competitive in world markets.

4. Thus I recognise some basic truths in the main conclusions of the report but I am not convinced by all the detail. For example some of the proposed R&D projects seem so close to the market place for it to be appropriate for industry to invest in the necessary developments without Government help. On the other hand, the long time-scale and the involvement of many companies, both of which seem typical of materials developments, do suggest that there may be a role for Government as does the need for better awareness to accelerate the uptake of the new technologies throughout manufacturing industry.

5. My initial reaction is that the report raises important issues which deserve to be considered carefully by Government. But before making a decision it would be helpful to hear the views of a wider cross-section of industry than have already been consulted. I therefore agree it would be sensible to publish the group's report as a consultative document but this should be as soon as possible rather than waiting for Parliament to reassemble. We can then assess industry's own reactions to the proposals and judge their likely commitment to a materials R&D initiative and their willingness to make appropriate investment to exploit the outcome of the R&D.

6. The report stresses the critical importance of involving industry in any programme of this type. As you begin to consider possible ways to administer a programme, you may like to consider the desirability of seconding industrialists into Whitehall to undertake this work alongside Civil Servants in an independent unit as you have done for the Alvey programme and for biotechnology. Alternatively, it might be preferable for

the management of the programme to be contracted out to a private sector group expert in this field, with some Civil Servants seconded out to help with the work. You will also, no doubt, be starting to think about a possible steering committee which would bring together active Government participants (DTI, MOD, DES, SERC) with industry under the chairmanship of a senior industrialist.

7. I would like to be kept in touch with the response which industry gives this report and with the way your thinking develops as a result.

FILE

R07

10 DOWNING STREET

From the Private Secretary

DR NICHOLSON o.r.
CABINET OFFICE

COLLYEAR REPORT

Thank you for your minute of 13 August. I accept with gratitude your offer to prepare a summary of the Collyear Report, and advice on it, for the Prime Minister's box on Friday, 31 August.

As you rightly surmise, only a passing reference was made to the Collyear Report at the meeting to which Mr. Tebbit refers. The Prime Minister had expressed doubts in general terms about whether the current extent of the Department of Trade and Industry's sponsorship could really be justified. The second paragraph of Mr. Tebbit's minute suggests that he shares some of this scepticism, whilst wishing to draw attention to the arguments for an element of intervention in this particular case.

I am sending a copy of this minute, as you did, to Sir Robert Armstrong.

(David Barclay)

15 August, 1984

R07

W-O559 13 August 1984

MR DAVID BARCLAY, NO 10

I have seen a copy of the Secretary of State for Trade and Industry's minute to the Prime Minister dated 8 August concerning the Collyear Report on Materials. I have also received a copy of the Report myself today. Since I'm going on leave this evening, it is not possible for me to read the Report and to comment on it until my return from leave in the week beginning 27 August. Can I suggest that I prepare a summary and some advice on it for the Prime Minister's box at the end of that week? I hope you would be able to delay submitting Mr Tebbit's minute to the Prime Minister until that time.

I notice that Mr Tebbit's minute starts off with a reference to a discussion which he's had with the Prime Minister. It seems unlikely that this is particularly relevant to the advice on the Collyear Report which I shall prepare for the Prime Minister, but if there is anything which I should know, perhaps you could let me have a copy of the relevant part of the record of the discussion.

RBN

ROBIN B NICHOLSON
Chief Scientific Adviser

cc: Sir Robert Armstrong

JF7124

DB to see

PERSONAL

PRIME MINISTER

You will recall from our "Value for Money" discussion on 1 August that I said we awaited a report from John Collyear of AE on a possible initiative on new materials technology.

2 I thought you might like to see the report, which I have just received. It contains some judgements and proposals about which I am at this stage sceptical; but I think it also points out the number of important opportunities and risks which we shall have to think about. A particular problem is that many of these developments are beyond the resources of individual companies, and ways need to be found of collaboration between them (including particularly material suppliers and materials users), and of associating effectively the efforts of universities, the Ministry of Defence and SERC. We shall have to publish the report (perhaps when the House reassembles) but I intend to do this in low key and without commitment. I shall let you have a proper assessment in due course, and you might like to consider having a presentation by John Collyear at some stage. Meanwhile, I should particularly welcome your own initial

reactions, not only on the reluctance of individual companies to finance programmes in this field without assistance and co-ordination, but also on the scientific and technical issues the report raises.

3 I am arranging for Robin Nicholson to receive a copy of the report as well.

NT

N T

8 August 1984

Department of Trade and Industry

A PROGRAMME FOR THE WIDER APPLICATION OF NEW AND IMPROVED MATERIALS AND PROCESSES (NIMP)

The Report of the Collyear Committee

12 July 1984

FOREWORD

The Materials Advisory Group (chaired by Mr John Collyear, chairman of AE plc) was formed in August 1983 by Mr Kenneth Baker, Minister of State for Industry and Information Technology, to advise on the scope for a collaborative programme of research, technological development, and for industrial exploitation in the field of new and improved materials and processes. The programme we propose is designed to build on the strengths of the UK in this field with particular emphasis on pulling through to the market place the many technological opportunities which have great potential for exploitation by industry.

A first report of the Group, which was prepared for Mr Baker at the end of 1983, was of an interim nature and its content is incorporated in this main report.

CONTENTS

1. EXECUTIVE SUMMARY

1.1 Current, imminent and subsequent changes in materials technology are going to bring continuous and important technical change. The UK cannot afford to lag behind its competitors who are already making progress in this field. Provided that a step change in research and development investment is achieved, industry will have the opportunity to accelerate progress and leap-frog foreign competition, recovering its share of world trade. The great potential for technical change and competitive advantage will be realized only by using revolutionary changes in engineering design and production technology.

1.2 The elements of these changes are on the move in the UK; they need acceleration and co-ordination; their benefits need publicising in industry, and they need stimulation through the marketing and purchasing pull of innovative designs and products for Government as well as for other major purchasers. The UK has a good scientific base for materials technology but this tends to be fragmented and needs to be well co-ordinated to encourage collaboration with manufacturing industry and within Government.

1.3 Against this background of opportunity we must highlight the long time scale for materials innovation and exploitation, and the resulting high risks, when compared to other technologies. Technological change arising from New and Improved Materials and Processes (to be referred to as NIMP) will not take place quickly enough in response to market forces alone. There is a pressing need for a collaborative programme with manufacturing industry, exploiting NIMP to give a significant boost to current UK work on materials technology.

1.4 The programme should cost in the region of £120m over a period of 5 years and industry should provide about half this amount. Government, providing the remainder, should co-ordinate the programme encouraging collaboration of different parts of industry, in some cases with higher education institutions (to be referred to as HEIs) and research laboratories.

1.5 The tremendous strides that have been made in the electronics industries of the world over the last twenty years have been led by developments in materials and processing, and the recognition of this adds great weight to our views on the importance of NIMP in general. Although there is still much to achieve in the electronics field we feel that the need is already well recognized. Our recommendations in this area are therefore designed to fill in gaps not adequately covered by other programmes. The great proportion of our work is devoted to other sectors of UK industry where there is a greater need for stimulation because of the longer time scales and consequent greater risks.

1.6 Recommendations are made to stimulate increased collaborative research and development, including demonstrator projects, in the following key technologies which are crucial to the advancement of manufacturing industry: composites, engineering ceramics, rapid solidification of metals and alloys, electronic materials, near net shaping methods of manufacture, surface and joining technology, and assurance of product performance during service. The emphasis of the programme is the stimulation of UK manufacturing industry to use NIMP as a basis for the development of new and improved products for the market place, paving the way for increased competitiveness and profitability. Unforeseen profitable markets will develop as well as market opportunities for the machinery required to make these products.

1.7 Complementing this programme in these key technologies is the presentation of a ten-point framework for accelerating the exploitation of NIMP by manufacturing industry. The major elements of this, in addition to Government support, are the needs for awareness in industry of the opportunities, co-ordination, collaboration, education and training, and longer term research.

1.8 It is essential that the DTI should establish a steering and co-ordinating committee (Materials Co-ordinating Group) having the responsibility for directing the implementation of our programme, the allocation of Government support and the determination of priorities. The Group should foster collaborative programmes, involving industry, HEIs and research laboratories, by the formation of 'clubs' and consortia, and by acting as the 'honest broker'. Collaboration between the materials supplier, component maker and end-user is regarded as having the utmost importance. Increasing awareness in industry, particularly in senior levels of management, of the potential for innovation using NIMP is also a major priority for the Group.

1.9 The education and training of engineers and technicians in the practical application of NIMP is a key element of our strategy. It is essential to ensure that initial education and training courses give appropriate priority to materials technology, but the major thrust should be aimed at engineers and technicians in mid-career who can benefit substantially from technical up-dating. The DES should be asked to co-ordinate this part of the programme and to ensure that a significant increase in support is given to longer term research on NIMP in HEIs.

1.10 The failure of the UK to grasp current opportunities in materials technology would lead to reduced competitiveness in world markets and further reductions in the manufacturing base of the UK. Government must take the responsibility for spear-heading an initiative in the materials field and thus help to ensure that the UK secures a leading share of the commercial opportunities which will arise from one of tomorrow's technological revolutions.

2. UNDERLYING REASONS FOR OUR RECOMMENDATIONS

2.1 Manufacturing industry, which is vital to the UK economy, is under considerable pressure to increase its competitiveness in world markets. Effective innovation using NIMP is essential to achieve the technical advances that will bring to the market place the new and improved products needed to increase the profitability of UK companies. Materials-led technological change is possible, as shown in the past by the leaps in technical capability precipitated by the application of iron, steel and concrete, and recently by the microelectronics revolution which owes much to the development of high quality materials using advanced processing techniques. Materials technology has, and will continue to have, a key role to play in further developments in electronics. In the mechanical and structural products and components field we are just entering into a period of two decades or so when the very substantial opportunities highlighted in our report can be exploited.

2.2 The time scale from the nucleation of a promising new idea in materials technology to its industrial exploitation yielding positive cash returns is generally very long in comparison to most other sectors of innovation. Investment in materials research and development thus carries high risks, and is required over many years before there is economic return. The rewards for persistence can however be substantial and include the development of unforeseen profitable markets for new products, and of markets for the machinery required to make them. The first, and perhaps most important, message from the Materials Advisory Group is that current, imminent and subsequent changes in NIMP are going to bring continuous and important technical change but the time scales for individual developments are very long and the investments involve high risk. The UK cannot afford to lag behind its competitors who have already begun to make progress. Provided a step change in research and development investment is achieved, industry will have the opportunity to use NIMP to leap-frog foreign competition and to recover its share of world trade.

2.3 It is our objective to present a programme of work and plans for implementation which will ensure that the UK participates in the revolution that is in the making and improves its position for the exploitation of the opportunities thereby created. NIMP have an impact on the whole of manufacturing industry. The benefits are all pervasive affecting both high technology industries, such as information technology and aerospace, and traditional industries, the latter forming a large part of UK activity. In view of the numerous areas of materials applications the specific recommendations presented in this report should be regarded only as priority topics as we see them now. During the course of the implementation of the programme new topics are certain to emerge and priorities may change. Consequently the programme should be continuously reviewed by Government.

2.4 In the mechanical engineering fields there is great potential for ceramics, reinforced materials, new metal alloys and plastics. They provide the opportunities for making components which are, for example, lighter, stronger, more able to withstand extremes of temperature, or more wear and corrosion resistant. Products can then be completely redesigned to achieve reductions in size/weight, more efficient energy use, longer lives, lower maintenance costs, greater reliability and lower overall costs. In the electrical field ceramics and polymers can be tailored to exhibit special properties which can be exploited when developing, for example, sensors and new batteries. High quality electronic materials offer the prospect of even smaller and faster computer devices, such as processors and storage components. Advances in materials technology will spawn many opportunities for the development of new and improved products for the market place.

2.5 A very significant requirement for the large scale use of NIMP is the need to develop sources of supply and methods of designing, shaping, joining, testing and maintenance. The inability to achieve any one of these can inhibit use and the effective integration of all these brings economic advantage. We have therefore given due weight to the critical importance of developments in engineering design and processing technology, and in assuring at reasonable cost the quality and reliability of products during service.

2.6 There is a conjunction of events where many materials and processes are only just being considered for commercial exploitation and where the search for increased competitiveness has reached a point at which step changes are needed. The forces of 'technology push' and 'market pull' in the materials field are poised to benefit from the stimulation of a thrusting programme on materials and their applications. Our second main message is that all this potential for technical change and competitive advantage will be realized only by using revolutionary changes in engineering design and production technology. The elements of these are on the move in the UK. They need acceleration and co-ordination, their benefits need to be widely known and appreciated in industry, and they need stimulation through the marketing and purchasing pull of innovative designs and products for Government as well as for other major purchasers.

2.7 The materials field is so wide in scope that it is impossible to address each part of the spectrum in detail, and yet it is at the detailed level that an appreciation is to be found of the opportunities offered by NIMP. Our approach is therefore to identify key technologies in the materials field where there are substantial opportunities which must be exploited by UK companies. Complementing this programme is the development of a strategy which will accelerate the exploitation of NIMP in industry.

2.8 Successful exploitation of promising new ideas in the materials field requires good communication between materials suppliers, designers, manufacturers of processing machinery, component makers and end-users. It is essential that the required links are formed at the research and development stage of product evolution. The programmes we propose for the key technologies identified are therefore designed to encourage collaborative research and development with particular emphasis on projects having great potential for exploitation in the market place. It is of paramount importance that much of the programme should be carried out by industry with some Government support, harnessing the knowledge and expertise in our HEIs, research laboratories and Research Associations.

2.9 The main emphasis of our programme is to ensure that products based on NIMP are brought quickly to the market place. We recognise the important role of longer term materials research leading to knowledge and expertise which is the seed-corn of future developments and prosperity for UK companies. The programme of work should include a research component which will allow industry, in collaboration with HEIs and research laboratories, to respond to the market needs as now known or which emerge during the implementation of the programme. In addition HEIs should be encouraged to pursue their work in key areas of materials technology and provide a co-ordinated basis for longer term research and innovation. Our third main message is that the UK has a good scientific base for materials technology but this tends to be fragmented and it needs to be well co-ordinated to encourage collaboration with manufacturing industry and within Government. A concerted effort by Government, to provide 'bridges' between the research bases in our HEIs, Government laboratories, Research Associations and those of our major companies, will bear considerable fruit, and we shall be making recommendations to that effect in this report.

3. THE NEED FOR GOVERNMENT INVOLVEMENT

3.1 The development and maintenance of an internationally competitive high technology manufacturing industry is a major national objective supported by Government as described in the publication 'DTI Aims'. The stimulation of the use of NIMP by industry will have a profound effect on achieving this target. The private sector of manufacturing industry will, however, be reluctant on its own to provide the enhanced level of effort and funding because the UK financial climate for public companies, dominated by institutional investors, does not encourage investment of this type.

3.2 The major inhibiting factors affecting investment in NIMP are:

a) the economics for investment require large scale use of NIMP which can rarely be justified by a single company,

b) investments in NIMP must be made over a long time scale before significant financial returns are achieved, contrasting sharply with investment in most other sectors,

c) investments in NIMP are usually speculative because companies can never be certain that profitable new markets will result from the applications in mind,

d) investments in research and development reduce companies' profits in the short-term and do not show as tangible assets on the balance sheet. Research and development in NIMP brings financial benefit at the longer end of the time spectrum.

Barriers to investment in the field of NIMP can be overcome only if the Government supports industry so that the time scale for materials innovation and exploitation can be reduced, and the risks can be shared.

3.3 In manufacturing industry it is rare that one company can embrace the whole manufacturing process from the basic materials to products for the market place. Commitment is also required from producers of the basic materials and components, from manufacturers of production machinery and from product designers. Prototype or pilot plants are required and these will be under-utilised during the development stages. There is a pressing need to form collaborative ventures between companies involved with these difference stages. Pre-competitive research and development carried out in 'clubs' and consortia is one very effective mechanism and the Government can help by providing both support and co-ordination. Nearer the market place collaboration between the materials supplier, component maker and the end-user is of paramount importance and in some cases Government involvement is essential by playing an 'honest broker' role and providing support.

3.4 The Government is already involved in NIMP through work being carried out in national research laboratories, HEIs and Research Associations as well as through SFI funding of specific projects. It is a large generator of NIMP through work carried out in MoD laboratories. Much of this has civil application which we are keen to see exploited in our programme. The Government and the public sector in total are very large consumers of manufactured goods and their purchasing policies can have a major impact on developments of NIMP. The Government is thus well placed to ensure that manufacturing industry is aware of the significant opportunities provided by NIMP and to ensure that programmes in this field are well co-ordinated.

3.5 The strategy of our programme involves three distinct and vitally important components requiring Government involvement.

They are the needs to:

i) encourage industry to reduce the time scale of materials innovation and exploitation, and spread the high risks
ii) ensure awareness and more effective transfer of knowledge and expertise from HEIs and research laboratories to UK manufacturing industry
iii) ensure collaboration between the various parties involved, and the co-ordination of the programme.

The Government should take on a role combining the three thrusts of our strategy and have in its grasp the opportunity of encouraging industry to take advantage of an essential technological revolution.

4. KEY TECHNOLOGIES OF OPPORTUNITY

4.1 In order to develop a priority programme of specific recommendations having maximum impact it is first necessary to select key technologies of opportunity in the field of NIMP. This section is concerned with developing recommendations for the key technologies selected. The first three paragraphs are of a general nature whereas those remaining in this section provide more detail and the reasoning behind the recommendations. Sections 5 and 6 formulate recommendations concerning respectively, accelerating the industrial exploitation of NIMP, and costing the programme. The recommendations presented in section 4, and others, are summarised in section 7 together with suggested methods of implementation.

4.2 As the materials spectrum is so wide in type and application we have narrowed our detailed studies to areas where there are specific opportunities which can benefit from timely stimulation. For the traditional materials wood, concrete and the lower grades of iron and steel, much work is being carried out which is often supported by existing mechanisms and we shall have no specific recommendations. Materials which are sources of food and energy have been excluded from consideration. New materials developments have frequently been pioneered in the Defence, particularly aerospace, and nuclear engineering sectors. Support arrangements for these sectors are well established and we shall have few recommendations for change. We do, however, recognise the need to apply more widely some developments from the aerospace and nuclear sectors using the mechanism of collaborative research and development. The manufacture of high quality electronic materials is a key technology which has been and will continue to be essential for the growth of the electronics industry. There are many schemes of support in this field and we shall therefore only consider topics in this area which are not being addressed adequately elsewhere.

4.3 In the mechanical and structural engineering fields the main materials developments which are poised for major impact on manufacturing industry can be set out as follows:

Base materials	Organic, e.g. plastics and rubbers Inorganic, e.g. ceramics, new cements Metals and alloys having improved purity, structure and composition.
Reinforcements,	fibres used in conjunction with the above base materials.
Processes,	methods of forming close to shape, surface treatments and methods of joining, e.g. adhesives.

The technologies which we consider to have most potential and urgency, and the associated recommendations, are reviewed under the headings:

Composites Engineering ceramics Rapid solidification technology Electronic materials	Materials Sectors
Assurance of product performance Surface and joining technology Near net shaping methods of manufacture	Enabling technologies

The first four items are materials sectors of particular importance whereas the last three items are enabling technologies which are vital to the application of the various materials and hence essential to their exploitation by manufacturing industry. The recommendations we shall be making in this section must be supplemented by longer term research, particularly in the HEIs, which is aimed at making provision for future market opportunities in these technologies and new ones which may emerge.

COMPOSITES

4.4 'Composites' is a generic term describing engineering materials built up of several components having different properties. This includes, for example, steel rod reinforcements used in concrete. The term is also commonly used to describe fibre reinforced materials and it is this class of materials which will be referred to, throughout this report, as composites.

4.5 It is widely recognised abroad, particularly in USA and Japan (see Annex 3), that composite materials engineering represents an important technological approach to product manufacture, offering efficient material utilisation routes, novel manufacturing options, and great scope for design innovation. The skills needed to formulate and design 'materials systems' to match particular functional needs, and the fabrication technology required to make the products economically, are different from conventional industrial practices and in many cases require a higher level of expertise. The UK has an international reputation for excellence at base science level in this field and every effort should be made to encourage full exploitation in sectors where industrial benefits can be identified. The national effort should be positively directed to develop and demonstrate in the following key areas: design methodology, process development, mechanised and automated manufacture, and quality. Although there is some scope for transferring technology from the aerospace industries, it should be recognised that the cost criteria and volume requirements for general manufacturing industry may require a significantly different approach. It should be noted also that many components may be hybrid in nature, often combining polymers, metals and ceramics.

Polymer matrix composites

4.6 It is important to distinguish between two types of polymer matrix when considering reinforced plastics. After curing, which is a chemical change sometimes requiring an autoclave treatment, thermosetting matrices cannot be reshaped plastically by heating. Thermoplastic matrices on the other hand revert to the 'plastic' state when heated. Thus articles based on a thermoset matrix must be formed directly to the final shape whereas thermoplastic matrices are amenable to intermediate forms because they can be heated and pressed in moulds, from sheet or tube form for example, to more complex shapes. The ability to form reinforced thermoplastics rapidly offers new opportunities for mass production technology in two respects:

a) intermediate forms such as sheet and tube, are suitable for automated methods of manufacture using, for example, filament or tape-winding machines. Consistency of material quality is thus possible,
b) sheet and tube preforms are more easily incorporated into a production line which is designed to manufacture more complex components by appropriate cutting and hot-pressing.

Additional advantages of reinforced thermoplastics are that they have long shelf-lives, they can be made tough and resistant to aggressive environments and furthermore they can be more easily repaired than reinforced thermosets.

4.7 Recently work has been carried out which has led to the production of aromatic polymer composites (APC) in which carbon fibres reinforce the thermoplastic PEEK (polyetheretherketone). This material, which is strong, light and stiff, is currently relatively expensive and therefore likely to find first use mainly in specialised applications such as aerospace. However the mass production advantages outlined above indicate that there is potential for use in other sectors. Steps should be taken to ensure that UK manufacturing industry exploits the potential of this recent innovation by using the material to create products of high added value.

We therefore recommend that the formation of reinforced thermoplastics 'clubs' or consortia should be encouraged, involving materials suppliers, machinery manufacturers, fabricators and end-users having the following objectives:

i) to identify application areas for reinforced thermoplastics in sectors of UK manufacturing industry which can benefit from the special properties and fabrication routes of these composite materials,

ii) to set up demonstrator projects to prove selected applications of the material and the required processing technology, and to increase awareness,

iii) to encourage the formation of a collaborative programme required to achieve a sound knowledge of materials properties and methods of design (see para's 5.17 to 5.21), and to achieve production methods which ensure the consistency of materials behaviour and of the performance of end-products.

4.8 It is recognised that reinforced thermoplastics can at best only be introduced into aerospace over long periods of time (say 10 years). They need to be thoroughly tested and their introduction has to coincide with the design of new aircraft or re-designs. Aircraft components can be large in size and the cost of equipment necessary to process reinforced thermoplastics may be prohibitively large. The first demanding applications of reinforced thermoplastics will be to manufacture relatively small components, perhaps for other manufacturing sectors.

4.9 For thermosetting matrices there remains however the need to improve the performance of large components for aircraft applications, and second generation reinforced materials of this type are being developed having substantially improved properties. In the mass production industries the introduction of reinforced thermosetting materials requires manufacturing methods which can form components rapidly at reasonable cost. Reaction processing is one such technology and reinforced reaction injection moulding (RRIM) is an example of this. Novel radiation induced curing systems and automated methods of handling pre-impregnated forms can also speed up the manufacturing process.

We recommend therefore that:

i) arrangements should be made to exploit expected aerospace-led reinforced thermoset developments in other sectors of manufacturing industry.

ii) further developments in rapid forming of reinforced plastic components are encouraged, and that emphasis is given to in-process inspection and monitoring, and the great potential for integrating the design and manufacturing control stages.

4.10 Some polymers when processed in special ways can exhibit orientation effects which lead to remarkable improvements in physical properties, especially stiffness, strength, chemical resistance and thermal stability. The technology is versatile so that materials can be produced in the form of fibres, tapes or solid section. It is also applicable to a wide range of thermoplastics, including several whose manufacturing cost is low, as well as the latest materials such as PEEK. Polyethylene fibres can be produced having stiffness comparable to glass or aluminium. Whilst the processing methods give the material 'self-reinforcing' characteristics there are clearly opportunities for use as reinforcement in the traditionally weak materials cement and concrete. Steps should be taken to encourage the commercial exploitation of these promising developments.

We recommend that a strategy for the exploitation of highly oriented (self reinforcing) polymers should be formulated, involving collaboration of the supply and user industries. This must take account of the following factors:

i) the new technology is very broadly based in application and produces a wide range of new materials each with a new portfolio of properties,

ii) in some instances, further enabling production facilities are required before the technology can be exploited. For example, polyethylene fibres need a plasma etching, or similar treatment, to produce adequate bonding in thermosets, cross-linking treatments may be needed for high temperature applications.

POLYMER MATRIX COMPOSITES WILL HAVE IMPACT ON:
aerospace, land transport, chemical plant, offshore and marine sectors, leisure, business and office machinery, telecommunications, construction, bio-engineering, machine tools, insulation and many other sectors.

Metal matrix composites

4.11 The advent of ceramic materials in fibrous form has renewed interest in metal matrix composites. Small batch quantities of materials have demonstrated increases in strength to weight ratio, stiffness and resistance to cracking in thermal fatigue environments. The key area of development is the technology of production in tonnage quantities. The aerospace industry is keen to exploit the material for structural components and needs to establish a manufacturing process technology. There are also opportunities for exploitation in land-based transport sectors, for example light-weight connecting rods for internal combustion engines. The material has already been used for piston crown inserts where the resistance to cracking in thermal fatigue environments has been exploited. This class of material has great potential for use by manufacturing industry. In view of the interest of the Japanese (see Annex 3) and the restrictions by the USA on the export of knowledge concerning the production technology of this type of material, it is vital that the UK develops a capability in this area extending the knowledge and expertise already developed in the Harwell club.

We recommend that 'club' activity in the metal matrix composites field should be broadened so that:

i) there is increased emphasis on research and development required for the provision of UK production facilities,

ii) candidate engineering components are identified and appropriate design and production methods developed,

iii) a materials data base and information system is established and awareness of its existence is fostered in manufacturing industry.

METAL MATRIX COMPOSITES WILL HAVE IMPACT ON:
all transport industries including aerospace, industrial machinery manufacturers, diesel engine manufacturers, component industries and materials suppliers.

Other composite materials

4.12 Carbon fibre reinforced carbon composites have been successfully exploited in the braking systems of Concorde, some military aircraft, the Boeing 757 and later Airbus variants. The material is light-weight, dissipates heat efficiently and has good wear characteristics. Carbon is a bio-compatible material and these composites also have high potential for use in prosthetics. The MoD has developed methods of using the material to make lightweight springs for weapon systems. Other engineering applications are beginning to emerge and the UK is in a good position to exploit them.

4.13 Fibre reinforced inorganic materials are at the research stage and have longer term potential for industrial exploitation. Reinforcing ceramics with fibres is one obvious method of attempting to improve their strength and fracture resistance but major problems have to be solved concerning the fundamental understanding of material behaviour and production technology. New cements, formed using polymeric additives and special processing methods, have been developed which exhibit strengths approaching that of aluminium. Fracture resistance can be increased by incorporating reinforcement and preliminary results indicate that tough materials suitable for use in buildings will emerge in the future having great fire resistance. These materials also exhibit attractive sound absorption characteristics and could be used in parts of diesel engines to exploit this property and also their relatively low weight.

> We recommend that work on composite materials, having matrices other than plastics and metals, should be encouraged at both the research and development stages, with particular emphasis on the identification of market applications.

> CARBON FIBRE REINFORCED CARBON WILL HAVE IMPACT ON:
> aerospace, land transport (for lightweight more efficient brakes), bio-engineering.
> REINFORCED CERAMICS WILL HAVE IMPACT IN:
> aerospace, automotive, bio-engineering.
> REINFORCED CEMENTS WILL HAVE IMPACT IN:
> building.

ENGINEERING CERAMICS

4.14 Engineering ceramics are materials formed at high temperatures, usually from compounds involving elements such as silicon, carbon, oxygen, nitrogen, aluminium and zirconium. They are light, stiff, corrosion and wear resistant and have low thermal and electrical conductivity, which are properties increasingly attractive in engineering applications. As for traditional clay-based ceramics their weaknesses have been brittleness and variability in properties which means that they could not easily be used to make engineering components supporting significant tensile or bending stresses. Recent advances in materials and processing technology, and greater understanding of the design problems encountered, are showing how this problem can be overcome. This is leading to opportunities for exploitation in fields such as gas turbine engines, reciprocating engines, cutting tools, process plant and prosthetics. These opportunities are being pursued vigorously overseas, particularly in Japan and USA (see Annex 3), and they must also be grasped in the UK. Specific projects are just being formulated in a gas turbine 'club' and a reciprocating engine 'club'. This effort should be increased and focused in line with national needs.

We recommend urgently that a substantial UK engineering ceramics programme should be supported having the following two broad objectives:

i) to enhance existing engineering ceramic technology, develop comprehensive materials properties and design bases, and develop production technology to improve quality and reliability and to lower cost,

ii) to prove selected engineering applications.

4.15 The stimulation of the existing technical ceramics industry to develop new engineering applications should be the major priority, particularly through the formation of joint projects between ceramics processors and users from the engineering industry and, where appropriate, research laboratories and HEIs.

We recommend that:

i) the planned collaborative programmes in the gas turbine and reciprocating engine fields should be strengthened. Particular emphasis should be placed on the identification of suitable ceramic components for the market place, such as gas turbine components and turbo-chargers, and on the development of the technology required for mass production.

ii) there should be support for the development of 'clubs' and consortia for applications of ceramic materials in general engineering and the processing and chemical industries, for which wear and corrosion are major problems, and also for the production engineering needed to bring improvements in cost and quality control.

4.16 Although each of these applications areas has its own particular requirements there are some features common to these which are best treated in a co-ordinated fashion.

We therefore recommend that a core ceramic technology and materials assessment programme should be supported. This should address key activities in the measurement and improvement of properties (particularly toughness), in design, in processing methods and in the quality control of engineering components required to assure product performance initially and throughout service life.

This part of the programme, which must respond to industrial needs, will be at the pre-competitive stage of research and development. In addition to involving the ceramics industry and users, participation should include HEIs and national research laboratories.

ENGINEERING CERAMICS WILL HAVE IMPACT ON:
heat engines, aerospace, automotive sector, bio-engineering, general engineering.

Hot isostatic pressing

4.17 Hot isostatic pressing (HIP-ing) is the application of high pressures to components at high temperatures and is a technique which has been used successfully to improve the quality of powder metallurgy products and castings. Evidence is growing, especially in Japan, USA, West Germany and Sweden, that HIP-ing can increase the strength and toughness of ceramic components (particularly silicon carbide and silicon nitride) and also reduce the variability of materials properties. Other benefits of HIP-ing ceramic materials are the possibilities of initial forming close to the required final shape and dimensions using encapsulation techniques, and reducing the need for sintering additives which lower strength. Ceramic materials of engineering interest have to be HIP-ed at temperatures in the region of 2000^{o}C and the UK does not have a facility large enough to treat some of the components in small gas turbine engines which are being assessed for manufacture using ceramics. In view of the relatively high cost of the equipment there is a strong case for a joint industry and Government collaborative arrangement for a national HIP-ing facility providing the initial promising results are confirmed.

We recommend that:

i) a programme to evaluate the merits of HIP-ing selected ceramic components should be urgently initiated,
ii) if justified in the light of (i), a national HIP-ing facility should be established jointly with industry, capable of producing and proving fairly large ceramic components. The facility should be located preferably in industry, but a Government Laboratory such as the NEL could be an alternative offering full commercial confidentiality.

Currently we regard HIP-ing as a development technique for demonstrating the improvements in materials properties which are possible by improving the microstructure and for enabling product development work to proceed in advance of improvements in materials and processing. The technique is unsuitable at this stage for the mass production of large ceramic components, and there remains the challenge of obtaining such microstructures by the development of new methods of processing.

HIP-ing WILL HAVE IMPACT ON:
aerospace, automotive sector, bio-engineering.

RAPID SOLIDIFICATION TECHNOLOGY

4.18 Rapidly solidified alloys, produced by either planar flow casting or spray forming, offer significant benefits because of their remarkable mechanical, electrical and magnetic properties. The process of forming, directly from the melt to foil thickness, enables alloys to be exploited which cannot be fabricated into strip form by the normal route. Furthermore, the technique is a potentially less costly route for the manufacture of any conventional metal alloy required in foil or thin strip form. Rapidly solidified alloys in powder form are also promising because of the potential for the development of alloys with superalloy properties at lower cost. They also have potential for application to metal matrix composites. There is growing industrial interest in this technology in the USA and Japan (see Annex 3) but the UK has considerable technical knowledge in this field and an embryo of industrial activity which must be further stimulated.

We recommend that the expertise and interest in industry, HEIs and Government laboratories should be developed in a co-ordinated way to address the following technological challenges for rapid solidification technology the first two of which are currently restricting market growth:

i) development of technology and equipment capable of producing tonnage quantities of amorphous and micro-crystalline metals and alloys in foil form,
ii) development of technology and equipment capable of producing thicker strip.
iii) a review of the UK needs, both now and in the future, for rapidly solidified alloys in powder form.

We note that rapidly solidified alloy in bulk form can be obtained directly from the vapour phase. The RAE have demonstrated this when developing an aluminium alloy which is now stimulating great interest in the aerospace industry because of its superior mechanical properties.

RAPID SOLIDIFICATION TECHNOLOGY WILL HAVE IMPACT ON:

manufacture of transformers and electric motors exploiting the low energy losses from hysteresis, manufacture using brazing techniques, manufacture using substrates for electronic devices and catalytic applications, aerospace, packaging and materials supply industries.

ELECTRONIC MATERIALS

4.19 The recent dramatic advances in the microelectronics industry owe much to developments in materials processing. Much of the electronic materials work is already supported by the Department under individual schemes such as the Microelectronics Industry Support Programme (MISP), the Fibre Optics and opto-electronics Scheme (FOS) and the Joint Opto-Electronics Research Scheme (JOERS) which is also supported by the SERC. There is however an opportunity to accelerate the UK's activity in the novel field of superlattices, which is a very significant new idea likely to dominate electronics research for the next decade and which is being pursued strongly in Japan (see Annex 3) and the USA. Superlattices are interleaved thin layers of semiconductor materials or thin layers of impurities introduced into a single semiconductor. The properties offer opportunities for developing novel devices and for tailoring the electrical properties of material over a far wider range than is now possible.

4.20 Basic research, including theoretical studies, should address:

multi-layer structures (i.e. superlattices),

growth processes and research on manufacturing equipment for multi-layer structures,

device processing, including special materials, where this is substantially different from silicon, e.g. lithography, dry processing, photo-resists,

chemical group III-V materials (e.g. gallium arsenide, gallium phosphide and indium phosphide for fast processing devices) and II-VI materials (e.g. zinc sulphide, zinc selenide for luminescent displays),

organic semiconductor materials.

Although support may be thought appropriate under the Alvey and ESPRIT programmes, these are concentrating on main stream silicon. Any superlattice support will be of secondary interest and will not be addressed in the earlier years. In view of the high potential of this technology to the electronics industry, and the level of activity overseas in Japan and the USA, it is vital that a specific initiative is launched now. Soundings with industry indicate strong support for such a project.

> We therefore recommend that a Joint Advanced Materials Research Scheme should be mounted, designed to stimulate additional industrial and university research activity in the field of superlattices for electronic application.

4.21 Outside the field of semiconductors the industry agrees that the rate of introducing new components and new manufacturing techniques is quickening and that there is an urgent need for further research and development in materials for electronic components. This arises both to provide a basis for new or improved components, and to resolve materials problems when introducing greater automation in the components industry's manufacturing processes. Such automation will prolong the life of the UK's manufacturing base for devices, helping to prevent volume manufacture being taken over by countries having lower labour costs. Examples of materials with potential for research and development to meet new or improved device needs include:

- new alloys for component interconnection,
- base materials and surface layers for substrates allowing surface mounting of components,
- encapsulation materials,
- passivation materials,
- piezo-electric materials for sensors, filters and delay lines, e.g. improved quartz and lithium niobate,
- resistive polymers.

> We recommend that support should be given to additional research and development in materials for electronic components, outside semiconductors, to meet the need for novel or cheaper components for the UK electronics equipment industry.

The implementation of the recommendations in the electronic materials sector will require additional expenditure in excess of £20m. In view of the importance of this key technology we feel that we should include an initial exploratory research and development project in our programme which could lead to the establishment of a further enhanced programme in this field.

ELECTRONIC MATERIALS WILL HAVE IMPACT ON:

the whole range of electronics used in industry, and in particular communications, computers, consumer electronics, industrial electronics, aerospace and Defence.

NEAR NET SHAPING METHODS OF MANUFACTURE

4.22 Processes which minimise material waste and the number of manufacturing stages are known as near net shaping methods. Cost and time savings can accrue when the manufacture of products involves just a few process stages. Machining and grinding to final shape are time consuming and are wasteful of material and energy. The techniques can often be used to enhance the properties of a component. For example, by engineering a non-uniform mix of materials during forming, graduated properties can be achieved as in the case of the manufacture of valve seats by the powder metallurgy route. Powder metallurgy, casting and forging methods are well known near net shaping techniques but more recently the aerospace industry has pioneered a new technique known as superplastic forming/diffusion bonding (SPF/DB) which is ripe for exploitation in the non-aerospace sectors of UK manufacturing industry. We have selected three techniques of near net shaping for particular attention and these will be discussed under the separate headings: powder metallurgy, precision casting and SPF/DB.

Powder metallurgy

4.23 The full potential of powder metallurgy techniques is not being realized for the manufacture of complex engineering applications at reasonable cost. This is principally because the required development cannot be supported by the supply industry itself which consists mainly of small units whose overall profits are low. In the high temperature materials field powder metallurgy methods are used to manufacture discs for aero-engines and valve seats for reciprocating engines. Important developments are also expected when using the technique to form rapidly solidified powders into engineering components having superior properties. An important objective in the powder metallurgy field is the achievement of higher densities at reasonable cost.

We recommend that a 'club' for pre-competitive research and development in the powder metallurgy field should be encouraged, involving the industry itself, the suppliers of materials and the users of components. Demonstrator projects should be supported, which are designed to show how powder metallurgy components can perform satisfactorily in engineering applications and can reduce manufacturing costs.

The DTI and SERC have appointed a joint co-ordinator on powder metallurgy to encourage appropriate collaboration, between HEIs and industry, by the allocation of some support from both the DTI and the SERC.

POWDER METALLURGY WILL HAVE IMPACT ON:
component manufacture for automotive and aerospace industries.

Precision casting

4.24 In the aero-engine industry there are substantial benefits to be obtained from manufacturing very large components (up to 1.5m diameter) using precision casting techniques. Engine designs would be simplified, avoiding fabrication from smaller components using electron beam welding methods, and machining would be minimised avoiding the waste of expensive material. Assembly and production costs would be reduced. The capability in the USA for casting larger components has increased dramatically during the past two years. In order to remain competitive the UK will have to either keep abreast of these developments or face the prospect of relying on overseas suppliers for the large components. There is also potential for exploiting precision casting in non-aerospace sectors of manufacturing industry such as chemical pumps and automotive turbochargers. Collaboration would be of considerable benefit to UK engineering companies in a number of fields, including low technology applications. This will require co-ordination to bring together the parties concerned.

We recommend that collaboration in the area of precision casting should be encouraged, through 'clubs' and consortia, between component suppliers, users and research establishments. The objective is to stimulate the industry by the further development of high technical skills and high added value products, and to provide the link between users and precision foundries that enables product design to take advantage of precision casting.

PRECISION CASTING WILL HAVE IMPACT ON:
engineering component manufacture.

Superplastic forming/diffusion bonding (SPF/DB)

4.25 Superplastic forming of metals is achieved by the large deformation induced by the application of stress when the material is heated to within a superplastic temperature range. Pressure can be used to deform thin sheets so that they are shaped to the form of the mould in which they are held. Diffusion bonding is the joining of two pieces of material at a temperature high enough to allow diffusion mechanisms to operate across the interface between them. Titanium, a material well known for its corrosion resistance, can be made superplastic at a temperature of about 950°C and at such temperatures it absorbs its own oxide film with the result that excellent diffusion bonding takes place when two surfaces are placed in contact. Thus titanium is a material which can be superplastically formed to shape and diffusion bonded in a single process. Although titanium is more expensive than aluminium the cost savings arising from removing the need for machining lead to substantial reductions in the costs of finished components (up to 40%).

4.26 The UK aerospace industry, which shares the lead with the USA in this technology, is actively exploiting SPF/DB and has recognised the potential for its application in other areas of UK manufacturing industry.

We recommend that a programme should be initiated having the objective of transferring the technology of superplastic forming/diffusion bonding (SPF/DB) to non-aerospace sectors with particular emphasis on the following aspects:

i) identifying areas of application outside aerospace. For example, heat exchangers for chemical, processing and nuclear applications are beginning to exploit the corrosion resistance of titanium and consideration should be given to the use of SPF/DB in their fabrication,

ii) collaboration, through 'clubs' and consortia, of materials suppliers, aerospace and other sectors of manufacturing industry to ensure that material is available from suppliers in the appropriate form.

SPF/DB WILL HAVE IMPACT ON:
heat exchanger manufacture, engineering component manufacture, aerospace.

General aspects

4.27 Three near net shaping techniques have been singled out for attention in this report. There are however two additional factors requiring attention relating to all these techniques and others such as cold, warm and hot forging and sintering. These are the need for:

a) awareness in senior management of the benefits of the techniques and the need to update and retrain the mid-career engineers (see para's 5.11 and 5.12),

b) reducing the time and cost of making the dies and moulds required by industry for the exploitation of near net shaping techniques.

4.28 In response to (b), CAD/CAM techniques have great potential for reducing the time and cost of manufacture, and for improving the quality and reproducibility of dies and moulds as well as many varieties of engineering components.

We recommend that a 'die and mould support' scheme for near net shaping applications in UK industry should be promoted having the following objectives:

i) increased use of CAD/CAM methods for die and mould manufacture in industry,

ii) increased rate of innovation in manufacturing industry resulting from the possibility of rapid iterative design at reasonable cost.

SURFACE AND JOINING TECHNOLOGY

4.29 In this report surface technology is considered to be a generic term for processes used in product manufacture which affect surfaces of engineering components. It includes, amongst others, the following topics which are discussed briefly in turn: coating technology, surface treatment, joining technology.

Coating technology

4.30 A wide variety of materials used as coatings are applied for many different reasons. For example, steel can be coated with zinc to provide corrosion resistance. Organic coatings also achieve this end and can, in addition, improve appearance when this is desirable. The special coating of PET (polyester terephthalate) containers has recently led to the development of plastic bottles which can store beers because of the ability of the coating to prevent the ingress of oxygen. Coating with ceramic materials can substantially improve the wear resistance of engineering components. Examples are alumina tiles applied to centrifuges separating water from abrasive slurries, or titanium nitride applied to twist drills. Ceramic coatings are also used in aero-engines as thermal barriers on blades, vanes and casings. The coating reduces the temperature of the base metal and offers the opportunity of increasing the operating temperature and hence the efficiency of the engine, or alternatively of using lower cost metal base materials. Inorganic material (vermiculites), when applied to glass fibre increases the heat and fire resistance to the extent that the coated material can match the thermal and mechanical properties of asbestos, but without the environmental hazard. Another example is ultra-thin nickel coated with a black oxide surface to achieve efficient photo-thermal conversion of solar energy. While considering solar energy, the use of special transparent coatings on one side of sheet glass leads to windows having the property of transmitting short-wave solar heat into the building while reflecting back the long-wave room heat. This coating technology has offered new opportunities in both building design and energy conservation. Silicon chip production is yet another process which utilizes sophisticated coating technologies and includes a range of methods of depositing fine coherent films on a variety of materials.

4.31 The wide range of applications of coating technology described above require a wide variety of techniques and processing equipment. The engineer thus has a wide choice of treatments, each having its own advantages and disadvantages. Examples are spraying, electro-deposition, sputter ion plating, plasma deposition, chemical vapour deposition and laser hard-facing. There is a need to make sure the engineer is aware of the potential of coating technology which will significantly improve the competitive position of manufacturing industry by adding value to engineering components whose performance is increased. The technology also extends the ranges of application of the more traditional and cheaper materials, reducing the need to use the more expensive special purpose materials such as stainless steel and superalloys.

We therefore recommend that the formation of a coating technology programme should be encouraged having the following objectives:

i) to review current methods of coating technology, identifying advantages and disadvantages as far as the industrial user is concerned, and transferring the technology through suitable awareness / education / training channels (see para's 5.10 to 5.13),

ii) to form 'clubs' and consortia, with links back to the suppliers of the substrate materials, having the objective of characterising the properties of coatings in service conditions and developing design methods for their application to engineering components. Non-destructive examination methods should be included in the programme.

COATING TECHNOLOGY WILL HAVE IMPACT ON:
virtually all manufacturing sectors.

Surface treatment

4.32 An alternative way to improve the performance of many components is to change the structure of the surfaces of the components by special treatments. For example ion implantation is a treatment, developed in the UKAEA Nuclear Programme, in which the surfaces of engineering components and tools are implanted with energetic nitrogen ions at ambient temperatures. The treatment has been shown to increase the lifetimes of wire-drawing dies and plastic injection moulding tools by factors of up to five. Surface treatment using high powered laser beams also enhances the performance of engineering components. For example laser transformation hardening on the surfaces of steel components improves performance and causes virtually no distortion, and therefore has potential for replacing the older methods of flame or induction hardening. Automation of the application of a laser beam to the work piece will be needed for mass production applications. One solution to this problem may be the application of a UK developed robot-based beam manipulation system. The technology needs to be proved for use in near industrial environments.

We recommend that suitable applications areas for surface treatments should be identified and that companies should be supported when installing high powered lasers, so that they can benefit from the new opportunities provided by the UK development of a robot-based beam manipulation system and demonstrate the potential of others.

SURFACE TREATMENT WILL HAVE IMPACT ON:
automotive sector, general engineering, equipment suppliers.

Joining technology

4.33 The joining of engineering components to form, for example, vehicles and structures, is an extremely important production technology determining the quality, reliability and cost of products. Automation is again the key to the achievement of the potential benefits, whether it is the welding of steel or the adhesive bonding of metals and plastics. Laser welding on the production line is an area of promise particularly in view of the UK development of the robotic laser. Diffusion bonding is yet another joining technology but its major benefit arises when used in conjunction with superplastic forming as discussed in para's 4.25 and 4.26. The application of ceramic materials in engineering environments will bring the problem of reliably joining ceramics to metals, composites or even plastics. The techniques likely to succeed in achieving this requirement are brazing, diffusion bonding and adhesive bonding, depending on the materials being joined and the environment of application. Layered coatings on components to be joined are sometimes necessary to counteract the differences in properties of the separate parts. Adhesive bonding will play an increasing role in manufacturing technology as it has great potential for application in robotic assembly lines. The joining technique leads to stiffer joints when compared to mechanical fixing methods and can be achieved under robot control. Adhesives which can be applied underwater have been developed in the Defence sector and these are being considered for exploitation in the offshore industry.

4.34 Joining is a key enabling technology required for the successful application and exploitation of the newer materials in UK manufacturing industry. The development of design methods is essential, particularly those which take account of the techniques to be used at the manufacturing stage.

> We recommend that the formation of a co-ordinated programme of joining technology should be encouraged for selected market areas. Particular emphasis should be placed on design, the use of demonstrators, the development of manufacturing systems, and on increasing awareness in industry of the benefits of developments in this field.

> JOINING TECHNOLOGY WILL HAVE IMPACT ON:
> virtually all sectors of engineering industry.

ASSURANCE OF PRODUCT PERFORMANCE

4.35 Product performance is as important as innovation for improving the competitive position of UK manufacturing industry and much more effort is needed, particularly with regard to consistency and the prediction of product performance during service, including lifetime estimation. In the engineering field there is a need for material from the supplier which is of a consistent quality so that it does not exhibit significant batch to batch, or within batch, variations in properties. The aspects related to product performance which are identified here for attention are: automation of materials processing, non-destructive evaluation, and product life evaluation.

Automation of materials processing

4.36 Whilst there are many reasons for variations in product performance it is recognised that significant improvement at economic cost will only result from the introduction of automated methods of material processing and greater control of the basic materials used. In the metals field the development of sensors and measuring equipment, particularly of the non-contact variety, is required for on-line control during material processing. The metering of liquid metals is also an important control process in which further work is needed to support the development of precision casting. Continuously cast bearing steel has been a technical possibility for some years and has become a commercial reality in Japan. The UK must continue the progress it has already made to process higher value steel qualities using the continuous casting route.

4.37 Fibre reinforced plastics is another very important area where product performance can be improved by automation. Filament and tape winding, although a well-established manufacturing technique, is at present mainly restricted to the production of simple geometrical shapes such as sheets, pipes, storage tanks and pressure vessels. These products can be wound on simple two-axis machines. There is great potential for extending the range of products which can be filament or tape wound by the development of computer controlled multi-axis machines. The scene is set for a major advance in reinforced plastics manufacturing technology which will lead to components of higher and more consistent quality, resulting from the replacement of laborious manual methods by efficient computer controlled mechanised processes. Potential applications for this technology include aircraft and helicopter fuselages, engine cowlings, fairings, satellite structures, rocket motor cases, pressure vessels, light-weight structural beams and honeycomb panels for marine components and structures, to name but a few.

4.38 Methods of automated handling of materials during production must be developed in order that quality components made of reinforced plastic can be mass produced. It is vital that materials are developed which can be manipulated by machines, and that such machines are produced having the flexibility and reliability of computer control. The NEL robotics project on automated lay-down of pre-impregnated compounds is very timely in this respect.

4.39 The importance of automation in the production of components having consistent quality must be emphasised. Furthermore material consistency is of critical importance to the success of automated methods of assembly on the shop floor, as is the case for robotic assembly in the car industry.

We recommend that:

i) in selected areas of potential, such as metals casting and composites manufacture, a review should be made of materials processes currently used in industry to identify where material or product performance can be significantly improved by the introduction of new or improved automated methods of process control and manufacture,

ii) the introduction of mechanisation and/or automation in manufacturing industry for selected materials applications should be stimulated making use of demonstrator projects where appropriate.

AUTOMATION OF MATERIALS PROCESSING WILL HAVE IMPACT ON:
aerospace, automotive sector, general engineering, materials producers.

Non-destructive evaluation (NDE)

4.40 Product performance can be assured throughout the design life only if the products can be non-destructively examined and evaluated at the manufacturing stage and during service. The materials used to make products may be defective because of the presence of pores and cracks which cannot be detected by superficial examination. Powder metallurgy products and castings are prone to such defects and their wider application in engineering can occur only if users have confidence in the reliability of NDE techniques. Welded steel structures are prone to cracking and NDE is an extremely important aspect of assuring safety during service. The newer engineering materials, composites and ceramics, are also susceptible to defects which can limit the performance of engineering components. There is a need to be able to examine them non-destructively before and during service. The practical application of protective coatings, surface treatments and adhesively bonded joints also needs testing methods to ensure adequate product quality at the manufacturing stage, and performance in service. Ceramic materials cause particular problems because critical flaw sizes are much smaller than those encountered when using structural steels. Standard methods for detecting such defects are not yet fully established. NDE is also required to support the new technology SPF/DB which is discussed in para's 4.25 and 4.26.

We recommend that a research and development programme should be co-ordinated in the UK to develop, prove and implement in manufacturing industry techniques of non-destructive evaluation. The objective is to assure the service performance of powder metallurgy and casting products, composites, ceramic components and welded, diffusion bonded or adhesively bonded joints. The programme should include an awareness component to bring to the attention of manufacturing industry the latest developments in this field. The involvement of the programme with similar programmes in the EEC and elsewhere should be considered.

NDE WILL HAVE IMPACT ON:
most engineering industries, materials suppliers.

Product life evaluation

4.41 A major factor in assessing product performance is judging if, and how, the increasing service time of a product will affect its future performance. Material changes will occur through the effects of temperature, moisture, corrosion, fatigue loading, chemical structure, wear and diffusion to name but a few. For materials which have been in engineering use for decades it is not too difficult to draw on experience when predicting performance. However for NIMP such experience does not exist by definition.

We recommend that a programme should be co-ordinated in the UK, involving HEIs, research establishments and others, to prepare a digest of all the currently available techniques for predicting the long term performance of engineering components, including the prediction of lifetimes. Areas where further research is needed should be identified and the establishment of a centre of expertise in this field should be encouraged.

5. ACCELERATING THE EXPLOITATION OF NIMP BY INDUSTRY

5.1 The time span ranging from the inception of a revolutionary idea in materials technology to its common application, yielding worthwhile cash returns, is usually in the range ten to twenty years. This long time scale results from the needs to prove material properties and to develop pilot plant and production facilities. In addition time is taken by designers to familiarise themselves with the new properties or processes and to exploit them in product development. Time is also required by the end-user to acquire confidence in the new products and to place large orders. When compared to other technologies, materials innovations pose special problems to industry. Their exploitation requires risk investments and they have very long lead times. In order to produce prototype samples they often need expensive capital facilities which may be under-utilised in the early stages. The combination of these factors usually means that individual companies are unable or are reluctant to embark alone on new ventures. Methods and resources must be found for accelerating innovation and development processes, and acceptance in service.

5.2 The UK has a history of excellent research and discovery, especially in HEIs and national research laboratories, but has been disappointing in taking the opportunities offered and exploiting them in the market place. We regard it of paramount importance that this report should also formulate a framework for action which ensures that the UK exploits innovations in the materials field and develops the required production technology.

5.3 A ten-point framework for accelerating the use of NIMP in industry is presented under the headings:

Co-ordination,
Collaboration,
Increasing awareness in industry,
Education and training,
Identification of centres of expertise,
Materials information and design,
Importing advanced technology,
Demonstrator projects,
Flexible processing of materials,
Longer term research.

CO-ORDINATION

5.4 Our programme of work, extending over the wide range of specific proposals presented in this report, requires support from a large number of organisations. A co-ordination focus is needed to achieve success, and this should be provided by Government. The co-ordination role should continue beyond the time span of our more detailed recommendations since materials technology is in a state of continuing development. Financial support from Government should be channelled through existing mechanisms so as not to add another layer of appraisal and bureaucracy. The DTI is best placed to take the lead for Government but co-ordination activity will need to take account of the strategies and spending programmes of other Departments. Support for HEIs, Research Associations and industry will be affected.

We recommend that a Materials Co-ordinating Group (MCG) should be established in the DTI. It should comprise representatives from industry, Government (especially DTI and MoD) and other bodies such as the SERC, and should be responsible for directing:

i) the implementation of the programme of our specific proposals,
ii) the allocations of Government support to the key technologies identified,
iii) the review and continuous up-dating of priorities.

The MCG should have a close link with the Requirements Board structure, probably through some common membership, and should be charged with identifying and responding to market needs and new opportunities for exploitation.

We recommend that the MCG should be supported by a Materials Co-ordinating Unit, a nucleus of officials centred on the DTI responsible for the day to day implementation of the programme.

The Unit should encourage the formulation of projects and, where necessary, promote collaboration (through 'clubs' and consortia) and act as 'honest broker'. It should be located in one of the DTI sponsoring Divisions and should work closely with all relevant sponsoring Divisions, other Government Departments and the SERC, arranging for support to be administered through existing mechanisms.

5.5 The effective acceleration of the application of NIMP will result only if there is active and enthusiastic support by UK manufacturing industry. It is only when the MCG begins its work that specific projects in the key technologies, supported with investment from industry, will emerge. Thus the recommendations included in our report represent a first priority for these co-ordinating bodies. The programme that eventually develops may differ in priority and extent. We have, of course, consulted widely and are confident that the proposals will be enthusiastically supported but the real test will come when investment commitment becomes an issue.

COLLABORATION

5.6 One method of meeting market opportunity and reducing the costs and risks of materials innovation and product development is for companies to collaborate with other companies, HEIs and research establishments. The cost and risk sharing resulting from collaboration is relatively straightforward to achieve at pre-competitive stages of research and development, especially if Government support ensures the cohesion of the project. Relevant here are 'club' activities which can involve many industrial participants contributing relatively small sums of money and agreeing to share the knowledge and expertise gained in the activity. Pre-competitive research and development carried out in a 'club' environment is one method of overcoming the technology transfer barrier to progress which inhibits development when performed in isolation. The Department is already supporting a number of 'club' activities in the materials field, for example:

NEL/Harwell composites programme for demanding transport applications,
NPL/Harwell corrosion co-ordination programme,
Harwell metal matrix composites programme,
NPL soldering science and technology club,
Culham laser club,
Geometric modeller / CAM development project.

We recommend that the support of pre-competitive research and development 'clubs' should be extended to the following areas:

Reinforced thermoplastics (see para' 4.7),
Ceramics for gas turbine engines, } already planned
Ceramics for reciprocating engines programme, } (see para' 4.15)
Ceramics for general engineering applications (see para' 4.15),
Near net shaping (see para's 4.23, 4.24, 4.26),
Surface and joining technology (see para's 4.31 and 4.34),
Non-destructive evaluation (see para' 4.40).

5.7 When developments are approaching the market place the open structure of the 'clubs' described above is unlikely to be acceptable for industrial collaboration because of commercial confidentiality. Collaboration in some form may however be necessary because the costs and risks, at this stage of development involving the provision of manufacturing plant, are somewhat greater than those at the research stage. This is where co-operation between, for example, a materials supplier, a component maker and an end-user should be encouraged. Their collaboration reduces costs and risks. It also ensures good communication so that the supplier is aware of the needs of the user and the user is aware of, and thus able to exploit, developments in materials innovation and processing. To establish such arrangements the help of an independent and respected 'honest broker' is often essential. This role can be played by commercial and other bodies. There are situations, particularly where Government laboratories, HEIs and other research institutions are involved, when Government will be better placed to take the lead in bringing together the interested parties.

5.8 The MoD research work on materials is carried out in a number of research establishments which undertake activities specifically oriented to the requirements of the land, sea and air military sectors. These activities are focused within the MoD by means of a Materials Co-ordinating Committee. Certain technological areas common to the three sectors are centralised at one or other of the research and development establishments. The MoD will not be allocating funds to our programme nor expect its funding of materials research to be affected in an executive way. The MoD is however very keen to assist by contributing expertise and information on the materials element of the MoD defence research programme. Furthermore the MoD may wish to consider participation in specific materials projects involving industry and the DTI where directly relevant to their product needs. MoD involvement in our programme along these lines could lead to changes in the defence materials research programme to take account of work initiated elsewhere.

5.9 It is a major priority of the SERC, which we strongly endorse, to encourage more collaboration between the HEIs and industry. In addition to participation in the specific collaborative projects proposed in this report, the opportunity must be taken to stimulate existing collaborative schemes. Examples are the Teaching Company Scheme which aims to achieve substantial and comprehensive changes in methods of manufacture, and the Co-operative Research Grants Scheme which gives companies the opportunity to join in short term partnerships with HEIs to undertake research and development which might lead to new products and processes.

INCREASING AWARENESS IN INDUSTRY

5.10 The range of technological changes in the materials field is so wide that there is an urgent need for senior managers in manufacturing industry to be made aware of new opportunities which exploit the recent advances in materials and processing technology. In the absence of awareness, users in many existing industrial sectors are at risk of being overtaken by their competitors overseas. Senior managers are responsible for the reaction of their companies to these challenges and it is vitally important that technical awareness is increased. Compared to the situation in the rest of Europe, USA and Japan, the UK is very weak in this respect, partly arising from the dearth of engineers in senior management. Failure to increase awareness will lead to the UK losing opportunities for developing new and improved products which can compete effectively in world markets.

We recommend that Government should seek to increase awareness and recognition, in senior levels of management, of the opportunities offered by recent developments in NIMP through an awareness programme directed by the MCG.

5.11 In this report specific proposals are given for the dissemination of information to industry which will also enhance awareness. The topics of these proposals are now listed:

Metal matrix composites (see para' 4.11),
Near net shaping (see para' 4.27),
Coating technology (see para' 4.31),
Joining technology (see para' 4.34),
Non-destructive evaluation (see para' 4.40),
Centres of expertise for NIMP (see para' 5.15),
Existing sources of materials properties data (see para' 5.21),
Computer-based materials information and design systems (see para' 5.21),
Sources able to supply small quantities of special materials (see para' 5.24).

EDUCATION AND TRAINING

5.12 Before NIMP can be fully exploited by industry it is vital that the engineers and supporting technicians involved in design and production have adequate education and/or training in the required new techniques. Mature engineers need technical up-dating in engineering design, manufacturing and testing techniques, and technicians require training in the use of the new equipment which is involved. The strategy for education and training should be that, in general, the employer is responsible for the training of his workforce; and that training is provided in response to market needs. However market forces do not always lead to the timely provision of sufficient training to meet the needs of industry. We consider that this is the case for knowledge about the properties and industrial use of NIMP.

We recommend that:

i) additional Government funds should be made available to promote the development of enhanced programmes of education and training, for practising engineers in industry, in the following specific areas of materials technology:

polymers (with and without reinforcement),
engineering ceramics,
metal matrix composites,
near net shaping techniques,
surface technology,
assurance of product performance,
engineering design,
manufacturing processes.

ii) existing initial education and training courses should be structured to give appropriate priority to the promotion of the use and development of NIMP in industry.

The following organisations (some of which provide initial education and training courses) have responsibilities and schemes of support for continuing education which should be encouraged to give a measure of priority to NIMP:

Department of Education and Science:-
Pickup programme of professional, industrial and commercial up-dating.

Engineering Council:-
Committee for continuing education and training.

Manpower Services Commission:-
Open Tech for technician and supervisory grades,
Training Opportunities Scheme (TOPS) for the unemployed from operative to professional levels,
Adult Training Strategy (ATS) to help employers to train or upgrade the skills of employees in key areas.

Engineering Industry Training Board:-
Courses of study in advanced technology.

SERC:-
Postgraduate study,
Teaching Company Scheme to facilitate industrial application of new science and technology,
Integrated Graduate Development Scheme (IGD) designed to attract more of the best science and engineering graduates to industry,

Distance learning programme based on the Open University and others for the updating of mature graduate employees in industry,
CASE awards encouraging postgraduate work jointly devised and supervised by HEIs and industrial companies.

Open University:-
Preparation and presentation of distance learning courses.

Industrial Research Laboratories of the DTI and Research Associations:-
Specialist courses of education and training in selected areas.

5.13 A prerequisite to the provision of effective initial professional education and subsequent updating is that those responsible for the preparation and presentation of courses should themselves be fully up-to-date and aware of the needs of industry. Although these needs are already appreciated by the Department of Education and Science and the Manpower Services Commission, more should be done.

We recommend that Government should seek to update lecturers and teachers responsible for the preparation and presentation of engineering and materials science courses by introducing / arranging special courses and exchange secondments between industry and HEIs.

The Royal Society/SERC Industrial Fellowship Scheme is designed to enhance communication on science and technology, and to develop and improve co-operation between HEIs and industry. The mechanism is one of exchange secondment and the scheme should be stimulated giving appropriate priority to the field of NIMP.

5.14 The Fellowship of Engineering has already recognised the importance of NIMP and produced a report entitled 'Modern Materials in Manufacturing Industry' (May 1983). The Fellowship is particularly well placed to influence the most senior executives in the UK on the importance of NIMP, and in particular on aspects of education and training in this field.

IDENTIFICATION OF CENTRES OF EXPERTISE

5.15 The introduction of NIMP into a company often requires consultation with experts who may reside in HEIs, Research Associations, Government Laboratories or other parts of industry. The identification of centres of expertise in a particular aspect of the technology can prove difficult, especially for smaller companies, and there is a need for a co-ordinated approach to assembling and disseminating such information.

We recommend that the MCG should encourage bodies serving industry to identify centres of expertise in NIMP and establish an information system which catalogues and disseminates the data to industry.

5.16 During the course of our work we have become aware of many centres of expertise covering a wide variety of topics in the materials field. The expertise, which is to be found in industry, HEIs and research laboratories, must be harnessed in the collaborative programme proposed in this report. We note, and commend, the efforts of the University Directors of Industrial Liaison to establish a national data base of HEI research capabilities. A directory of materials research in industry and the HEIs may also be needed.

MATERIALS INFORMATION AND ENGINEERING DESIGN

5.17 An essential ingredient in the process of materials innovation is validated information on materials properties, such as density, stiffness, strength, fatigue and creep, and agreed methods of engineering design. The lack of such information inhibits the use of the newer materials in engineering applications and as a result this extends the time scale of exploitation. It is particularly important that appropriate priority should be given to materials data and engineering design methods which relate to product consistency and reliability in service conditions.

5.18 There is a need to ensure that the required materials data are validated and readily available to design engineers in UK manufacturing industry. This activity should be focused on specific applications, preferably in high volume and/or high added value markets, in order to make the best use of the limited resources which are available.

We recommend that test methods used to obtain materials property data are further developed with a view to ensuing standardisation. The requirement is particularly urgent in the fields of plastics, composites, ceramics and other high temperature materials. The NPL, and other bodies, should be given the resources to accelerate and amplify the work they are doing in this field.

This activity needs to take account of standards used overseas in order that the UK promotes export opportunities and prevents non-tariff barriers to trade. The work of NPL in relation to international collaboration on advanced materials and standards, as proposed by the Versailles Economic Summit (1982) Working Group on Technology, Growth and Employment, should be further stimulated.

5.19 A lack of engineering design methods can seriously inhibit the application of materials by manufacturing industry and this is particularly the case for engineering applications of plastics, composites, ceramics and high temperature materials.

> We recommend that the NPL, NEL, and professional and other bodies, should be given support to extend their work on the development and dissemination of engineering design methods. Areas should be selected for priority attention following consultation with the producers of design methods and users in manufacturing industry.

5.20 It is inevitable that computers will be used increasingly in engineering design and manufacture. Consequently it is essential that new opportunities are exploited as quickly and efficiently as possible.

> We recommend that support should be given to data base standardisation and the development of 'expert' computer systems designed to help the general user in manufacturing industry master the new techniques which are needed to utilize NIMP.

The entire span of materials properties, engineering design methods, processing parameters and component production should be considered. Provision should be made for integrated computer systems, encompassing materials information storage and retrieval, engineering design, materials processing and component manufacture, in programmes on advanced manufacturing technology being developed by the Department.

5.21 In the field of materials information and engineering design there is a need for good communication between the users and the producers of materials data and design methods. The HEIs have much expertise which can be exploited in conjunction with industrial and Government research laboratories. In developing a strategy for stimulation in the field of materials information and design an immediate need is to increase awareness of existing sources of properties data and engineering design expertise. Centres of expertise should be identified in the UK and abroad where users can seek advice when they are contemplating innovations involving materials which are unfamiliar to them. In the metals field extensive properties data and design methods are available. Examples are the publications of the Engineering Sciences Data Unit (ESDU) and the 'Metals

Datafile' data base for which the Metals Society is the UK sponsor.

We recommend that

i) existing sources of properties data and design expertise for engineering applications of materials should be catalogued and the information disseminated widely in the UK. The review should include an assessment of the validity of these data and information concerning cost / performance and cost competitiveness of different materials and processes in relation to product (or volume) needs. Independent assessments of data will be needed to help identify and fill important gaps.

ii) there should be an urgent review of the current utilisation of computers in the field of materials information and engineering design, and that information gathered should be disseminated as widely as possible in industry.

IMPORTING ADVANCED TECHNOLOGY

5.22 In order that our materials programme has maximum impact it is vital that there is some selectivity when identifying projects which should receive additional resources. This impact can be increased by supplementing programmes in selected areas through the licensing of advances in technologies from abroad. An essential part of our strategy is the recognition that the UK must import some advanced technology in order to remain competitive rather than dilute the impact of the programme by developing it ourselves.

We recommend that initiatives taken by UK companies to import technology should be supported in those areas of NIMP where there are no unacceptable limitations on its use, and where there is potential for further exploitation by integration with UK expertise.

DEMONSTRATOR PROJECTS

5.23 Before a new material, or an advance in processing technology, can be fully exploited there is a gap to be bridged between the laboratory scale development and full scale production. This is where the 'demonstrator project' features as one method of providing confidence in new technologies before the irrevocable commitment of major project funding. Demonstrator projects are expensive and, because of the uncertain outcome, they add risk to the investments of companies involved. Unless ways are found of sharing the costs and the risks, many promising innovations in materials and processing technology will be exploited abroad instead of in the UK. The principle of technology demonstrator projects is now well established in the aerospace and Defence industries. The demonstrator principle should be further extended to other manufacturing sectors.

We therefore recommend that 'demonstrator' projects should be an integral part of our programme with particular emphasis on applications involving the collaboration of materials suppliers, component makers and end-users.

Demonstrators will speed up the process of industrial exploitation of innovations in the materials field and they will also encourage further innovations. We see the need for a demonstrator reciprocating engine utilizing where appropriate, advanced materials such as ceramics, composites, plastics, adhesives and new cements.

FLEXIBLE PROCESSING OF MATERIALS

5.24 During the innovation process there is often a need for material in small batches for assessment in experiments and pre-production trials which can be very time-consuming and expensive. There is much to be gained from ensuring that small quantities of new materials can be quickly obtained in the required form and having consistent properties. Without them exploitation could be delayed as has happened with, for example, rapidly solidified alloys. Metal matrix composites is another area of great potential where there is a supply problem. In the polymer field, particularly for such high value materials as electro-conductive and highly oriented polymers, there are also supply difficulties which can inhibit the development of new or improved products. Flexible manufacturing should be considered as a means of avoiding over-capacity of materials production and of providing a UK supply of other materials which are normally imported, such as polycarbonates, polyacetals, aramids, high quality ceramic powders and some metal powders.

We recommend that the MCG should take steps to:

i) identify sources able to provide small quantities of special materials for development purposes and disseminate this information to industry,

ii) support proposals to develop flexible manufacturing systems to produce samples and small batches of material.

There will be some occasions when, in order to provide sufficient quantities of an advanced material for product development, it will be necessary to construct a pilot plant. This would be financed normally by private sector partners but some situations will require a public contribution, at least for a limited period. Government should act to establish the required facilities.

LONGER TERM RESEARCH

5.25 The recommendations we have made relating to research and development in the key technologies identified in section 4 are for relatively short term projects (up to five years duration) for which market applications can be foreseen. In order to remain competitive in the future the UK must make provision for materials innovations beyond the time scale of our programme. It is therefore essential that our proposals are supplemented by longer term research in these key technologies and also in new areas. Much of this work should be carried out in the HEIs and we are extremely concerned that during recent years the ability of the SERC Materials Committee to support essential research on materials in the HEIs has been seriously undermined by a shortage of funds. Over the last four years the total annual demand from the academic community for the support of materials research has grown from £9.2M to £19.2M whereas the funds made available have decreased from £4.9M to £3.8M per annum. Last year the SERC could fund only 63% of the project proposals which had been rated as of top quality.

> We recommend that the DES should allocate increased funding to the SERC Materials Committee so that further support can be given to essential longer term research on materials and associated processing technologies. The additional funding should be matched by that which the DTI is recommended to make available to the HEIs, through the SERC, for collaborative research and development with manufacturing industry (see Table 1).

6. COSTING OF THE PROGRAMME

6.1 It is very difficult to make precise estimates of the cost of each part of the programme. The wide-ranging and unpredictable nature of the materials field, and the long time scale of the programme (at least five years), has not allowed us the opportunity of formulating projects at the detailed level which is required for costing purposes. Much more investigation and preparation is required to specify projects in detail and we look to the MCG to direct this ground-work. Our approach is to adopt a broad-brush treatment which can be used as a guide-line for a more detailed analysis by the MCG.

6.2 We are confident that manufacturing industry will be keen to participate in our programme and will be prepared to fund one half of the total research and development costs. In order that significant impact is made in the key technologies, a step-change in DTI spending in these fields is essential. Current SFI expenditure on materials is in excess of £15m per annum which we estimate, on the basis of unchanged policy, could result in an expenditure on the key technologies identified of £12m over a 5 year period. A large increase in this level to support our programme is essential to ensure that manufacturing industry, across the wide range of sectors identified earlier, can compete effectively in existing and new markets for products.

> We recommend that the total cost of the programme on NIMP should be in the region of £120m over a period of five years. The Government should share the cost with manufacturing industry and expect to contribute just over half.

6.3 Table 1 indicates the various categories of spending involved in our programme and shows how funding should be shared with industry and between Government Departments.

Category of spend	£m	Industry to contribute	Govt. to contribute
Collaborative R & D in industry	30	15	15 DTI
Collaborative R & D in HEIs	6	-	6 DTI
Collaborative R & D in IREs, Harwell etc	6	-	6 DTI
Spend by individual companies on R & D	36	27	9 DTI
Demonstrators	24	12	12 DTI
Under-pinning research in HEIs	6	-	6 SERC
Total R & D	108	54	54
Awareness	2	-	2 DTI
Education and Training	10	-	10 DES
TOTALS	120	54	66

TABLE 1

6.4 Depending upon the type of activity, the distribution of spending throughout the five year programme will vary. Table 2 indicates the likely pattern of spending (in £m).

Activity	year 1	year 2	year 3	year 4	year 5	TOTAL
R&D including demonstrators	6.5	12.5	21.5	31.5	30	102
Awareness	0.5	0.5	0.5	0.5	-	2
Longer term research Education and Training	1	3	4	4	4	16
TOTALS	8	16	26	36	34	120

TABLE 2

6.5 It is not reasonable to allocate precise amounts of funding to each activity of the programme because materials technology is evolving continuously and priorities can change over relatively short periods of time. Furthermore the spend in specific areas of the programme may be determined by the degree to which industry is prepared to invest. Based upon the situation now pertaining we envisage that spending could be distributed between the various activities of our programme as indicated in Table 3. It should be noted that the recommended 20% of the total programme cost allocated to demonstrator projects would be distributed between the key technologies listed.

Activity	% of total programme cost
Composites	15
Engineering ceramics	15
Rapid solidification technology	5
Electronic materials	5*
Near net Shaping	10
Surface technology	10
Assurance of product performance	10
Demonstrators	20
Awareness	2
Education and training	8
TOTAL	100

* For an initial exploratory research and development programme

TABLE 3

6.6 We recommend that the programme should commence immediately.

7. SUMMARY OF RECOMMENDATIONS AND HOW THEY SHOULD BE IMPLEMENTED

RECOMMENDATIONS ADDRESSED TO THE DTI

7.1 One of our major recommendations is that the DTI should set up a Materials Co-ordinating Group (MCG) having the responsibility for directing:

i) the implementation of our programme of specific proposals,
ii) the allocations of Government support to the key technologies identified,
iii) the review and continuous up-dating of priorities.

It should comprise representatives from industry, Government (especially DTI and MoD) and other bodies such as the SERC. The MCG should be supported by a Materials Co-ordinating Unit, a nucleus of officials centred on the DTI responsible for the day to day implementation of the programme.

(see para' 5.4)

7.2 The total cost of the programme on NIMP should be in the region of £120m over a period of five years. The Government should share the cost with manufacturing industry and expect to contribute just over half. The programme should commence immediately.

(see para's 6.2,6.6)

Recommendations addressed to the MCG

7.3 The main thrust of our programme is to encourage, through the MCG, the formation of pre-competitive research and development 'clubs' and consortia in specific key technologies of opportunity and to supplement this with the setting up of demonstrator projects in suitable areas. The MCG should also encourage individual applications for support from companies for development work which is nearer the market place. The specific recommendations to be implemented by the MCG are as follows:

1. The formation of reinforced thermoplastics 'clubs' or consortia having the following objectives:

   i) to identify application areas for reinforced thermoplastics in sectors of UK manufacturing industry which can benefit from the special properties and fabrication routes of these composite materials,
   ii) to set up demonstrator projects to prove selected applications of the material and the required processing technology, and to increase

awareness,

iii) to encourage the formulation of a programme required to achieve a sound knowledge of materials properties and methods of design, and to achieve production methods which ensure the consistency of materials behaviour and of the performance of end-products.

(see para' 4.7)

2. Further developments in rapid forming of reinforced plastic components should be encouraged, with particular emphasis on in-process inspection and monitoring, and the great potential for integrating the design and manufacturing control stages.

(see para' 4.9)

3. 'Club' activity in the metal matrix composites field should be broadened so that:

i) there is increased emphasis on research and development required for the provision of UK production facilities,

ii) candidate engineering components are identified and appropriate design and production methods developed,

iii) a materials data base and information system is established and awareness of its existence is fostered in manufacturing industry.

(see para' 4.11)

4. Work on composite materials, having matrices other than plastics and metals, should be encouraged at both the research and development stages, with particular emphasis on the identification of market applications.

5. A substantial UK engineering ceramics programme should be supported having the following two broad objectives:

i) to enhance existing engineering ceramics technology, develop comprehensive materials properties and design bases, and develop production technology to improve quality and reliability, and to lower cost,

ii) to prove selected engineering applications as follows:

a) in the gas turbine and reciprocating engine fields the planned collaborative programmes should be strengthened. Particular emphasis should be placed on the identification of suitable ceramic components for the market place such as gas turbine components and turbo-chargers, and on the development of the technology required for mass production,

b) there should be support for applications of ceramic materials in general engineering and the processing and chemical industries, for which wear and corrosion are major problems, and also in the production engineering needed to bring improvements in cost and quality control.

A core ceramic technology and materials assessment programme should be supported. This should address key activities in the measurement and improvement of properties (particularly toughness), in design, in processing methods and in the quality control of engineering components required to assure product performance initially and throughout service life.

(see para's 4.14 to 4.16)

6. The expertise and interest in industry, HEIs and Government laboratories should be developed in a co-ordinated way to address the following technological challenges of <u>rapid solidification technology</u> which are currently restricting market growth:

i) development of technology and equipment capable of producing tonnage quantities of amorphous and micro-crystalline metals and alloys in foil form,

ii) development of technology and equipment capable of producing thicker strip.

(see para' 4.18)

7. A programme in the <u>powder metallurgy</u> field should be encouraged, involving the industry itself, the suppliers of materials and the users of components. Demonstrator projects should be supported, which are designed to show how powder metallurgy components can perform satisfactorily in engineering applications and can reduce manufacturing costs.

(see para' 4.23)

8. Collaboration in the area of <u>precision casting</u> should be encouraged between component suppliers, users and research establishments. The objective is to stimulate the industry by the further development of high technical skills and high added value products, and to provide the link between users and precision foundries that enables product design to take advantage of precision casting.

(see para' 4.24)

9. A programme should be initiated having the objective of transferring the technology of superplastic forming/diffusion bonding (SPF/DB) to non-aerospace sectors with particular emphasis on the following aspects:

   i) identifying areas of application outside aerospace,
   ii) collaboration of materials suppliers, aerospace and other sectors of manufacturing industry to ensure that material is available from suppliers in the appropriate form.

(see para' 4.26)

10. The formation of a coating technology programme should be encouraged having the following objectives:

   i) to review current methods of coating technology, identifying advantages and disadvantages as far as the industrial user is concerned, and transferring the technology through suitable awareness / education / training channels,
   ii) to formulate projects having the objective of characterising the properties of coatings in service conditions and developing design methods for their application to engineering components. Non-destructive examination methods should be included in the programme.

(see para' 4.31)

11. The formation of a co-ordinated programme of joining technology should be encouraged for selected market areas. Particular emphasis should be placed on design, the use of demonstrators, the development of manufacturing systems, and on increasing awareness in industry of the benefits of developments in this field.

(see para' 4.34)

7.4 Some of our proposals involve aspects of technologies which are either already well established or are at a stage near the market place where collaboration is more difficult to achieve. The following recommendations fall in this category and the MCG should take the responsibility for their implementation:

1. Arrangements should be made to exploit expected aerospace-led reinforced thermoset developments in other sectors of manufacturing industry.

(see para' 4.9)

2. A strategy for the exploitation of highly oriented (self reinforcing) polymers should be formulated, involving collaboration of the supply and user industries. This must take account of the following factors:

i) the new technology is very broadly based in application and produces a wide range of new materials each with a new portfolio of properties,

ii) in some instances, further enabling production facilities are required before the technology can be exploited.

(see para' 4.10)

3. A research and development programme should be co-ordinated in the UK to develop, prove and implement in manufacturing industry techniques of non-destructive evaluation. The objective is to assure the quality during service of powder metallurgy and casting products, composites, ceramic components and welded, diffusion bonded or adhesively bonded joints.

(see para' 4.40)

7.5 The MCG should take an active role in the assembly of information which can be used for determining policy in particular areas of materials technology. It should also have the responsibility for ensuring that such information is disseminated as widely as possible in UK manufacturing industry when this is appropriate. We therefore recommend that the MCG should:

1. co-ordinate the preparation of a digest of all the currently available techniques for predicting the long term performance of engineering components, including the prediction of lifetimes. Areas where further research is needed should be identified and the establishment of a centre of expertise in this field should be encouraged,

(see para' 4.41)

2. seek to increase awareness and recognition, in senior levels of management, of the opportunities offered by recent developments in NIMP through an awareness programme,

(see para' 5.10)

3. encourage bodies serving industry to identify centres of expertise in NIMP and establish an information system which catalogues and disseminates the data to industry,

(see para' 5.15)

4. identify sources able to provide small quantities of special materials for

development purposes and disseminate this information to industry, and support proposals to develop flexible manufacturing systems to produce samples and small batches of material.

(see para' 5.24)

5. review the UK needs, both now and in the future, for rapidly solidified alloys in powder form,

(see para' 4.18)

6. in selected areas of potential, such as metals casting and composite manufacture, review materials processes currently used in industry to identify areas where material or product quality can be significantly improved by the introduction of new or improved automated methods of process control and manufacture.

(see para' 4.39)

Recommendations addressed to sponsoring Divisions of DTI and the IREs

7.6 A number of our proposals are best implemented by the DTI through relevant sponsoring Divisions and IREs. These recommendations are now grouped together as follows:

1. A Joint Advanced Materials Research Scheme should be mounted, designed to stimulate additional industrial and university research activity in the field of superlattices for electronic application. Support should be given to additional research and development in materials for electronic components, outside semiconductors, to meet the needs for novel or cheaper components for the UK electronics equipment industry.

(see para's 4.20 and 4.21)

2. A 'die and mould support' scheme for near net shaping applications in UK industry should be promoted having the following objectives:

   i) increased use of CAD/CAM methods for die and mould manufacture in industry,
   ii) increased rate of innovation in manufacturing industry resulting from the possibility of rapid iterative design at reasonable cost.

(see para' 4.28)

3. Suitable applications areas for surface treatments should be identified and companies should be supported when installing high powered lasers, so that they can benefit from the new opportunities provided by the UK development

of a robot-based beam manipulation system and demonstrate the potential of others.

(see para' 4.32)

4. The introduction of mechanisation and/or automation in manufacturing industry for selected materials applications should be stimulated making use of demonstrator projects where appropriate.

(see para' 4.39)

5. The formation should be encouraged of:

i) a programme to evaluate the merits of HIP-ing selected ceramic components,

ii) if justified in the light of (i), a national HIP-ing facility, jointly established with industry, capable of producing and proving fairly large components. The facility should be located preferably in industry, but a Government Laboratory such as the NEL could be an alternative offering full commercial confidentiality.

(see para' 4.17)

6. Test methods used to obtain materials property data should be further developed with a view to ensuing standardisation. The requirement is particularly urgent in the fields of plastics, composites, ceramics and other high temperature materials. The NPL, and other bodies, should have the resources to accelerate and amplify the work they are doing in this field.

(see para' 5.18)

7. The NPL, NEL, and professional and other bodies, should be given support to extend their work on the development and dissemination of design methods. Areas should be selected for priority attention following consultation with the producers of design methods and users in manufacturing industry.

(see para' 5.19)

8. Support should be given to encourage data base standardisation and the development of 'expert' computer systems designed to help the general user in manufacturing industry master the new techniques which are needed to utilize NIMP.

(see para' 5.20)

9. Steps should be taken to ensure that existing sources of properties data

and design expertise for engineering applications of materials are catalogued and the information disseminated widely in the UK. The review should include an assessment of the validity of these data. There will be a need for independent assessments of data in some cases and, in order to fill important gaps identified, a need for obtaining additional data. There should be an urgent review of the current utilisation of computers in the field of materials information and design, and information gathered should be disseminated as widely as possible in industry.

(see para' 5.21)

10. Initiatives taken by UK companies to import technology should be supported in those areas of NIMP where there are no unacceptable limitations on its use, and where there is potential for further exploitation by integration with UK expertise.

(see para' 5.22)

RECOMMENDATIONS INVOLVING THE DES

7.7 The DTI should seek DES support and co-operation in the implementation of the following recommendations:

1. Increased funding should be allocated to the SERC Materials Committee so that further support can be given to essential longer term research on materials and associated processing technologies. The additional funding should be matched by that which the DTI is recommended to make available to the HEIs, through the SERC, for collaborative research and development with industry.

(see para' 5.25)

2. Additional Government funds should be made available to promote the development of enhanced programmes of education and training, for practising engineers in industry, in the following specific areas of materials technology:

polymers (with and without reinforcement),
engineering ceramics,
metal matrix composites,
near net shaping techniques,
surface technology,
assurance of product performance,

engineering design,

manufacturing processes.

(see para' 5.12)

3. Existing initial education and training courses should be structured to give appropriate priority to the promotion of the use and development of NIMP in industry.

(see para' 5.12)

4. Government, principally through the DES, should seek to update lecturers and teachers responsible for the preparation and presentation of engineering and materials science courses by introducing / arranging special courses and exchange secondments between industry and HEIs.

(see para' 5.13)

ACKNOWLEDGMENTS

The Chairman of the Materials Advisory Group would like to thank the many people who have contributed during the preparation of this report.

He is especially grateful to the members of the Group for their many valuable contributions both in writing and during stimulating discussions at meetings; also to the national research laboratories Harwell, NEL, NPL, RAE and RSRE for their constructive input and for the preparation of papers requested during the course of our work.

The Group was supported by, and is most grateful to members of a series of Working Parties which had to report within very demanding time scales. Many other contributions were received which helped greatly with our deliberations and with the formulation of our recommendations.

The Group has had tremendous support from the Secretariat. Robert McVickers has provided Departmental and inter-Departmental co-ordination, personal technical and practical input, and significant commitment and guidance. The principal task of organising, preparing and drafting our work requires a very special tribute to our Secretary Neil McCartney who has worked with outstanding commitment and dedication and has provided in addition a personal contribution to the development of the Group's approach.

Thanks are also due to Dr Paul Dean, Director NPL, for allowing the Secretariat to make use of the word-processing facilities at NPL, including specialist

typists; and especial thanks to Mrs Pamela Cooper who co-ordinated this work at NPL in her usual efficient and dedicated way.

Members of the Materials Advisory Group:

Mr John Collyear (Chairman)	Chairman, AE plc
Mr E M Briscoe	Managing Director Doulton Industrial Products Ltd.
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Mr B Murray	Under Secretary, MM Division, DTI
Dr A J Robinson	Director, WSL to end of January 1984
Mr P J Cooper	Director, WSL from February 1984
Mr H G R Robinson	Director General Research (General), Procurement Executive, MoD
Mr A Williams	Under Secretary, RTP Division, DTI
Dr L N McCartney (Secretary)	MEE Division, DTI (seconded from NPL)

ANNEX 1

Terms of reference

a) To identify the areas offering the greatest opportunity to extend the benefits to user industries of knowledge in the materials field where the UK is ahead or abreast of its major competitors.

b) To advise the Minister on the scope for and content of a collaborative programme of research, technological development and exploitation by industry in the field of new materials and improved traditional materials.

c) To recommend how Support for Innovation funds might be channelled to encourage and demonstrate the pratical application in the civil field of developments already under way in aerospace, defence, universities and research laboratories.

d) To suggest a time scale for the Programme and to provide a first report by end December 1983.

ANNEX 2

Consultation procedure

In order that UK industry could be consulted as widely and quickly as possible, approaches were made to selected Research Associations, Institutions, independent research and public bodies, and materials producers. Apart from the materials producers all organisations were invited to bring to the attention of the Advisory Group:

a) new developments in the materials field which can benefit from a collaborative programme of research, technological development and exploitation, involving Industry, Government and Universities,

b) recent materials developments of potential benefit to British industry which are not being exploited at present (including reasons for the lack of exploitation).

The materials producers were asked to:

a) identify materials likely to be in increasing use in the future, mentioning the reasons why and also any inhibiting factors which are preventing their use in manufacturing industry,

b) indicate their willingness to participate in collaborative R & D (product oriented) involving component manufacturers, end users, Government Research Laboratories and Universities.

The following organisations have contributed:

Research Associations

BNF Metals Technology Centre
British Ceramics Research Association Ltd
British Glass Industry Research Association
Building Services Research and Information Association
Cement and Concrete Association
Construction Industry Research and Information Association
ERA Technology Ltd
Machine Tool Industry Research Association
Motor Industry Research Association
Paint Research Association
Pira (RA for Paper and Board, Printing and Packaging Industries)
Production Engineering Research Association
Rubber and Plastics Research Association
Steel Castings Research and Trade Association
The Welding Institute.

Institutions and other Professional Bodies

Fellowship of Engineering
Institution of Mechanical Engineers

Institution of Metallurgists
Institution of Mining and Metallurgy
Materials Forum
Metals Society
Plastics and Rubber Institute
Society of British Aerospace Companies Ltd.

Other organisations

Alcan International Ltd
BL (Technology) Ltd
BP plc
British Aerospace plc
British Plastics Federation
British Rail
British Steel Corporation
British Technology Group
Courtaulds plc
Culham Laboratory (UKAEA)
Fulmer Research Institute Ltd
AERE (Harwell)
ICI plc
IMI Titanium Ltd
Inco Alloy Products Ltd
Johnson Matthey plc
Pilkington Brothers plc
Ricardo Consulting Engineers plc
Rolls Royce Ltd
RTZ Corp. Ltd
Springfields Nuclear Power Development Laboratories (UKAEA)
Standard Telecommunications Laboratories Ltd
Technical Change Centre
Tube Investments Ltd.

In order that information gathered during the early stages of the work of the Group could be assessed for completeness, and in order that indications of priorities could be obtained, a series of Working Parties were set up covering the topics:

Ferrous metals
Non-ferrous metals
Organic materials
Inorganic materials
Composites
Materials information and design
Education and training
Management of the programme.

Generally each of the Working Parties comprised about twelve industrial members and the following organisations outside the Government and HEI sectors were represented:

AE plc
Anderman & Ryder Ltd
Babcock Power Ltd

BISPA
BL (Technology) Ltd
BP Research Centre
British Aerospace plc
British Alcan Aluminium Ltd
British Steel Corporation
Confederation of British Industry
Doulton Industrial Products
Dunlop Holdings plc
Engineering Council
Engineering Industry Training Board
J H Fenner and Co Ltd
GEC Hirst Research Centre
GEC Power Engineering Ltd
GEC Turbine Generators Ltd
Hepworth Plastics
Hysol Grafil Ltd
ICI plc
IMI Titanium Ltd
Inco Alloy Products Ltd
Johnson Matthey Research Centre
Lucas Group Services
Lucas Cookson Syalon
Metal Box plc
Morgan Thermic Ltd Technological Centre
Permabond Adhesives Ltd
Pilkington Brothers plc
Rolls Royce Ltd
Shell Chemicals (UK) Ltd
SCRATA
TI Research Laboratories
Whessoe Heavy Engineering.

ANNEX 3

PUTTING THE PROGRAMME INTO PERSPECTIVE

1. Materials technology and the range covered by the definition of NIMP is not identifiable separately within the classifications used to record the statistics of industrial production. Our programme falls broadly within the R & D sector and the last survey of R & D in industry was carried out in 1981. In this survey there is no single product group, nor collection of product groups, which completely identifies expenditure on materials technology. It is thus not possible to assemble detailed statistics on either the scale of R & D expenditure on materials technology or the size of the related markets existing now or arising from the new products which will appear.

2. Information on national expenditure in overseas countries, and related support from Government programmes, is also fragmented making direct comparisons difficult.

3. We are, however, conscious of the need to put our programme into perspective in relation to work now being carried out in the UK and elsewhere, and to programmes already announced by other countries. The information that follows seem to us to be the relevant data although we recognise that they include figures which to some extent fall outside the materials technology field and so they must be regarded as 'best estimates'.

Market Sizes

4. The manufacturing sector contributes about 20% of the Gross Domestic Product. Of the output from manufacturing industry, about 75% is internationally tradeable and as a result contributes very significantly to exports. Table 4 indicates the sizes, in terms of UK value-added and employment, of seven of the many industrial sectors in which our report will have impact (1981 figures).

	Gross Value Added (£m)	Average number employed
Ferrous castings	481	60,000
Non-ferrous metals	600	66,000
Non-ferrous castings	147	20,000
Polymers	2324	245,000
Composites	38	4,000
Ceramics and glass	1020	109,000
Vehicles	3749	427,000
Mechanical Engineering	8143	825,000

TABLE 4

Materials Work in the UK

5. Government is much involved with materials technology. Through the DTI it sponsors research and development in industry, the Research Associations and the industrial research laboratories (LGC, NEL, NPL and WSL). The MoD is involved in materials research and development through extra-mural support in industry and through many establishments, for example RAE for aircraft applications and RSRE for electronics applications. The Department of Education and Science, through the SERC, supports much materials research in the HEIs. The UKAEA carries out much materials research in establishments such as Harwell and Springfields Laboratories which has impact in the non-nuclear sectors. There are no statistical classifications identifying the spend by the UK on materials technology. However Table 5 gives an indication of Government Support.

Organisation		Approximate Annual spend (£m)
DTI	SFI Grants (excluding electronics)	15
DTI	IREs	6
MoD		20
SERC		4.5

TABLE 5

The average proposed annual spend of our programme is £24m of which £13m would be provided by Government. The total R&D spend in manufacturing industry was £3.5bn and Table 6 shows how this was spent in those sectors of relevance to this report.

Sector (£m)	Private Industry	Public Corporations	RA's	Total Industry
Iron and steel	4.8	23.4	3.5	31.7
Non-ferrous metals	17.2	1.2	3.2	21.6
Synthetic resins and plastics	39.8	0.2	2.3	42.3
Mechanical engineering	198	28.2	7.8	234
Electrical and electronic engineering	1008.7	168.1	4.3	1181.1
Motor vehicles and parts	171.9	4.8	3.7	180.4
Aerospace equipment manufacturing and repairing	758.4	0.2	4.3	762.9
Processing of rubbers and plastics	27.9	-	2.1	30

(Analysis based on 1980 Standard Industrial Classification)

TABLE 6

Materials work abroad

6. Throughout our report reference is made to work already in progress abroad, particularly in the USA and Japan. The following information provides a picture of this work.

7. Total US Government financial support for material research is estimated at over £750m per year, with basic research funding estimated as 30% and applied research funding at 60% of the total expenditure.

Research activities range over the following topics:-

Rapid solidification technology
Ceramics for high temperature applications
Carbon fibre reinforced composites
Biomaterials
Metal matrix composites
Silicon based materials
Exploitation of Resources
Materials processing and manufacturing
Re-cycling technology
Polymer research

The research activities if successful are expected to have most impact upon the following industrial sectors:-

Information Technology
Transport
Photovoltaic
Energy
Chemical
Steel

8. In Japan MITI's project on basic technologies for future industries is its most important current programme. It is funded in the region of £300m over a period of at least eight years and concerns three technical fields, materials, electronic devices and biotechnology. The programme on materials includes the following topics:

Fine Ceramics

Develop ceramics with improved toughness, strength, anti-corrosion and anti-abrasion properties.

Materials for Membrane Technology

To improve separation technology and energy efficiency in the chemical industry.

Electro-conductive Polymers

To achieve new electrical or electronic properties.

High Crystalline Polymers

Develop new polymers having comparable mechanical properties to metals for structural applications.

High Performance Crystalline Controlled Alloys

"Single crystal" superalloys, superplastic forming, strip casting of steel.

Composite Materials

High performance metal and polymeric matrix composites.

Bioreactors

Cell Mass-Culture

Re-combinant DNA Applications

Superlattice Elements

Materials and processes, superlattice elements in semi-conductor thin films.

Three Dimensional Circuit Elements

Multi-layer VLSI.

Enforced Environment-Resistant Elements

Element, packaging and integration technology for severe environments.

The total R&D work on materials in Japan is probably in excess of £200m per annum, and it is well co-ordinated by MITI.

ANNEX 4

List of Abbreviations

APC	Aromatic Polymer Composites
ATS	Adult Training Strategy
CAD/CAM	Computer aided design/Computer aided manufacture
CASE	Co-operative Awards in Science and Engineering
CTP	Chemicals, Textiles, Paper, timber and other miscellaneous industries Division of DTI
DES	Department of Education & Science
DTI	Department of Trade & Industry
EEC	European Economic Community
ESDU	Engineering Sciences Data Unit
ESPRIT	European Strategic Programme for Research and Development in Information Technologies
FOS	Fibre Optics & opto-electronics Scheme
HEI	Higher education institution
HIP	Hot Isostatic Pressing
IGD	Integrated Graduate Development Scheme
IRE	Industrial Research Establishment
JOERS	Joint Opto-Electronics Research Scheme
LGC	Laboratory of the Government Chemist
MAG	Materials Advisory Group
MCG	Materials Co-ordinating Group
MEE	Mechanical and Electrical Engineering Division of DTI
MISP	Microelectronics Industry Support Programme
MITI	Ministry of International Trade and Industry (Japan)
MM	Minerals and Metals Division of DTI
MoD	Ministry of Defence
NDE	Non-destructive evaluation
NEL	National Engineering Laboratory
NIMP	New and Improved Materials and Processes
NPL	National Physical Laboratory
PEEK	Polyetheretherketone
PET	Polyester terephthalate
RAE	Royal Aircraft Establishment, MoD
RRIM	Reinforced reaction injection moulding
RSRE	Royal Signals and Radar Establishment, MoD
RTP	Research and Technology Policy Division of DTI
SERC	Science and Engineering Research Council
SFI	Support for Innovation
SPF/DB	Super-plastic forming and diffusion bonding
TOPS	Training Opportunities Scheme
UKAEA	United Kingdom Atomic Energy Authority
WSL	Warren Spring Laboratory


Grey Scale #13
C Y M
A 1 2 3 4 5 6 M 8 9 10 11 12 13 14 15 B 17 18 19