

Associate Programme: Tribology in Foresight

Framework Document

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SUMMARY

This document describes the background and action plan for an OST Technology Foresight Associate Programme in tribology.

The aim of the associate programme in tribology is to develop a vision of how tribology will impact our lives and economy over the next twenty years.

It is intended primarily as a guide to decision makers so that the appropriate action can be taken in respect to tribology which will enhance wealth creation and improve the quality of life. It is also expected that the associate programme will have raised the profile of tribology in education.

The overall theme of the Tribology in Foresight Associate Programme is:

Promoting a proactive tribological approach to reducing waste and failure, especially in the design stage of engineering components and systems

The Associate Programme will be driven through the UK Tribology Forum which was initiated by the I Mech E in October 1998. This includes representation from professional institutes, trade associations, RTOs, universities and industrial firms.

The report that is developed by the Tribology in Foresight Associate Programme will be a concise qualitative description of the likely future impact of tribology on wealth creation and the quality of life in the UK in the next 20 years. It will consist of a series of short assessments of different aspects which have been categorized with respect to the different Foresight Panels.

The results of the Associate Programme will be presented at an open workshop held under the auspices of the UK Tribology Forum.

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FORESIGHT

Foresight is a government brokered scheme which develops visions of the future to guide the people who make today's decisions in business, academia and government [1]. The focus of foresight is squarely on wealth creation and quality of life as two sides of the same coin.

The overall goals are to:

- identify significant market opportunities and threats, looking beyond normal commercial timescales and outside normal sectorial boundaries;
- identify emerging capabilities of, and demand for, science, engineering and technology; highlight areas of policy, regulation, education and training where government action would deliver widespread benefits; and identify areas for action by the business, scientific, voluntary and public sectors to increase national wealth and quality of life.

The Foresight programme is managed by the Office of Science and Technology (OST).

Foresight panels are at the heart of the programme. Panels identify future trends, market drivers, barriers to progress, and challenges and opportunities for future wealth creation and quality of life. Panels make recommendations for action.

There are two types of panel:

- thematic panels addressing broad social and/or economic issues which might drive wealth creation and effect quality of life in the future.
- sectoral panels focused on business sectors or broader areas of activity and carrying forward the work of existing panels as well as tackling new issues.

The panels generally operate as relatively small strategic entities and carry forward their agendas by setting up task forces to address specific issues.

There are also two underpinning themes embedded in thesecond round. Every panel has been asked to consider education, skills and training issues and the implications of its proposals for sustainable development.

Associate programmes enable a larger number of participants to take part in Foresight. The associate programmes are often developed through professional institutions and other membership organisations working in partnership with OST.

The knowledge pool supports the work of the panels and the development of new and expanded networks of Foresight participants. It is a professionally managed library of strategic visions, views and information about the future which Foresight panels and organisations undertaken their own Foresight exercises can draw on and use to make connections across sectoral and thematic boundaries.

The thematic and sectoral panels are listed in Appendix 1.

AIM OF ASSOCIATE PROGRAMME IN TRIBOLOGY

The aim of the associate programme in tribology, in line with the objectives of Foresight described above, is to develop a vision of how tribology will impact our lives and economy over the next twenty years. The associate programme will anticipate the future trends in tribology; and will identify potential needs, strengths, threats and opportunities.

The associate programme in tribology is intended primarily as a guide to those people who make today's decisions in business, academia and government. This will enable them to take the appropriate action in respect to tribology which will enhance wealth creation and improve the quality of life. The associate programme will also be used by those people and organisations already concerned with tribology to act now to meet future challenges and to take advantage of future opportunities. It is also expected that the associate programme will have raised the profile of tribology in education.

OVERALL THEME

The overall theme of the Tribology in Foresight Associate Programme is:

Promoting a positive tribological approach to reducing waste and failure, especially in the design stage of engineering components and systems

The adoption of the recommendations of the Associate Programme will enhance wealth creation and quality of life. Aspect of this will be:

Improved economics, environmental acceptance, and functionality in manufacturing processes and equipment operation through the application of sound tribological principles.

Improved functionality and reduced environmental impact of consumer products through better awareness of tribological good practice.

Improvements in quality of life through better function of prosthetics.

Improvements in the structure for education and training for tribology.

It is relevant to many of the Foresight Panels but has particular importance to the Materials, Manufacturing 2020 and Chemical Panels. Essential elements also concern the underpinning themes Education, Skills and Training and Sustainable Development.

WHAT IS TRIBOLOGY?

Tribology as a concept was defined in 1966 as the 'Science and technology of interacting surfaces in a state of relative motion, and the associated subjects and practices' [2].

This very broad and multidisciplinary scope embraces in detail the processes of friction, traction, lubrication, and wear in all mechanical contact situations. It is essential to consider good tribological design at an early stage in the development of new machines or processes.

Tribologists are concerned with optimum machine design and maintenance leading to improvement in service life, safety and reliability. A successful tribological approach is critical to the economics and operational reliability of industrial manufacture and processing.

Tribology embraces a whole range of technologies and is an aspect of successful management as well as being a set of scientific principles.

An indication of the range of key topics in tribology is given in Appendix 2 which is taken from the I Mech E classification of different engineering topics.

An inadequate tribological approach on the part of designers, operators, or management can lead to:

- unnecessary cost and other waste
- undue impact on the environment through, for example, excessive exhaust emissions
- machine and system failure, sometimes catastrophic
- loss of life

Tribology is clearly multidisciplinary. This fact is underlined by the titles of UK university departments with a declared interest in tribology including:

- mechanical engineering
- engineering materials
- materials science
- metallurgy and materials
- engineering and product design
- mechanical, materials and manufacturing engineering
- industrial and manufacturing science - materials engineering and materials design
- physics
- chemistry
- chemical engineering

GETTING THE MESSAGE ACROSS

The Tribology in Foresight Associate Programme also aims to address a lack of awareness amongst engineers and designers in industry about the role of tribology. Currently there are several failures in knowledge transfer in the tribology area. Thus there is resistance to the use of the term itself due to misunderstanding which leads to mislabeling of information of tribological importance so that it becomes fragmented and difficult to access. Worse, all too often tribological thinking is seen solely as either a 'remedial', or maintenance matter, or merely as a question, however important, of lubrication. Also, because tribology is a multidisciplinary underpinning subject, it is in great danger of "falling between many stools" as it is not seen to be a core part of any mainstream subject at school or in university degrees.

This situation has been exacerbated recently with the multiplication of professional institutions that now have formal representation of tribology including I Mech E, IOP, IOM, RSC, IoC, UK Chapter STLE.

An underlying message, therefore, with which the Associate Programme will be concerned is the need for:

- better packaging of tribology for clearer relevance to specific sectors
- better co-ordination among those concerned
- promotion of the consideration of good tribology principles as an absolutely integral part of the design of components and systems production and operation

INDUSTRIAL AND APPLICATIONS RELEVANCE

Analysis of conference attendance, such as the 1st World Tribology Congress in 1997 (which attracted 1100 participants), regular seminars in many professional institutes, and information gained from detailed questionnaires (relating to interests in various aspects of tribological education, training and information), show that tribology has relevance for, at least, the following industries and applications:

- | | |
|-------------------------------|--------------------------------------|
| • power generation | • intelligent and advanced materials |
| • textiles | • aeronautical engineering |
| • rail transport | • agricultural engineering |
| • road transport | • automotive engineering |
| • lubricants supply | • bulk materials handling |
| • space propulsion | • bio-interface |
| • marine engineering | • chemical engineering |
| • offshore maintenance | • ferrous metals production |
| • textiles | • food processing |
| • papermaking | • machine tools |
| • pump/valve/filter supply | • minerals processing |
| • bearings supply | • mining |
| • coatings supply | • non-ferrous metals production |
| • ultra-hard materials supply | • pharmaceuticals |

Particular examples of the industrial relevance of tribology are:

Abrasive wear in materials handling: - a direct source of downtime for repair and replacement representing a major component of operating cost. Unscheduled downtime costs, in some typical steelworks areas, can be as high as £5000/h. Unscheduled stoppage of a modern blast furnace plant, incorporating several components subject to severe abrasive wear would be catastrophic. Design, development and use of cost-effective wear-resistant materials is critical.

Powder metallurgy in design for wear resistance: PM is a highly attractive, cost effective and materials-efficient processing route yielding unique parts with unique properties. The route can be used to optimise tribological properties such as wear and friction behaviour, for example by solid lubricant additions, controlled surface porosity for lubricant retention, and controlled surface structure for wear resistance. This processing route needs to be more

widely understood among engineers and others, and the potential offered by its products more widely exploited in the design process.

Automotive lubricants: Two of the drivers behind automotive development are emissions legislation and fuel efficiency. Automotive lubricants can now be formulated to give significant reductions in fuel consumption and exhaust emission. Such lubricants have lower viscosity to reduce friction in plain bearings and contain additives to reduce friction in components with boundary lubrication (such as the piston ring/linear contact). In addition to fuel economy, the vehicle manufacturer needs increased engine durability - thus the modern lubricant is also required to provide enhanced wear protection. To reap the benefits of higher-functionality lubricants, they must be seen as part of an integrated mechanical design and materials selection process for all relevant engine components.

PLANNED APPROACH

Tribology in Foresight Report

The Tribology in Foresight Associate Programme will develop a report which gives a concise description of the likely future impact of tribology on wealth creation and the quality of life in the UK in the next 20 years. The report will consist of a series of short assessments of different aspects that have been categorized with respect to the different Foresight Panels (Appendix 1). The assessments will be written by experts in the different areas (Appendix 3), and will be validated by the members of the UK Tribology Forum.

The report will also include recommendations which are clear, focussed and will provide the basis for firm action.

UK Tribology Forum

It is proposed that the Associate Programme will be driven through the UK Tribology Forum which was initiated by the I Mech E in October 1998 (Appendix 4). This includes representation from professional institutes, trade associations, RTOs, universities and industrial firms, including:

- Institution of Mechanical Engineers (e.g. the Tribology Group, but also the Industry Divisions)
- Institute of Materials (primarily the Surface Engineering Division)
- Institute of Physics
- Institution of Electrical Engineers
- Institute of Measurement and Control
- Royal Society of Chemistry
- American Society of Tribologists and Lubrication Engineers (UK Section)
- European Powder Metallurgy Federation (UK Chapter)
- British Hardmetals Association
- British Gear Association

A second Forum meeting was held in March 2000 where the Framework for the Tribology in Foresight Associate Programme was discussed and agreed (Appendix 5).

Next Steps

Define and match experts to topics	July 2000
Experts write contributions	Aug 2000
Collate contributions into draft report	September 2000
Hold workshop and validate report	November 2000
Publish report	December 2000

Publication of Report

The report will be submitted to the knowledge pool and its availability will be widely publicised in the technical press.

The results of the Associate Programme will also be presented at a workshop held under the auspices of the UK Tribology Forum.

It is also expected that the networking developed during the associate programme will continue after the exercise is complete giving a basis for coordination and collaboration between organisations concerned with tribology.

REFERENCES

- Office of Science and Technology, Blueprint for the next round of Foresight, December 1998.
2. Department of Trade and Industry, The Introduction of a New Technology, Committee on Tribology, Report 1966-1972, HMSO 1973

APPENDIX 1: THEMATIC AND SECTORAL PANELS

Thematic Panels

- Ageing population
- Crime prevention
- Manufacturing 2020

Panels

- Built environment & transport
- Chemicals
- Defence, aerospace and systems
- Energy & natural environment
- Financial services
- Food chain & crops for industry
- Healthcare
- Information, Communications & Media
- Materials
- Retail & consumer services

Underlying Themes

- Education, skills & training
- Sustainable development

Foresight Web Site

www.foresight.gov.uk

APPENDIX 2: A VIEW OF THE SUBJECT SCOPE OF TRIBOLOGY – I MECH E CLASSIFICATION

701	☐	Basics	710	☐	Materials	715	☐	Failure
702	☐	Surfaces	711	☐	materials design	716	☐	failure patterns
703	☐	contact mechanics	712	☐	materials selection	717	☐	failure analysis/diagnosis
704	☐	surface topography	713	☐	surface engineering	718	☐	Failure
705	☐	Metrology	714	☐	wear-resistant materials	719	☐	Reliability
706	☐	materials properties				720	☐	wear debris analysis
707	☐	friction and wear				721	☐	surface damage analysis
722	☐	environmental effects	729	☐	bearing technology	736	☐	Gears
723	☐	high-pressure/vacuum	730	☐	selection of bearings	737	☐	selection of gears
724	☐	high/low temperature	731	☐	plain bearings	738	☐	Lubrication
725	☐	plant environment	732	☐	rolling element bearings	739	☐	materials for gears
726	☐	chemical effects	733	☐	rubbing bearings	740	☐	Manufacture
727	☐	storage	734	☐	gas bearings	741	☐	geometry/kinematics
728	☐	contamination	735	☐	life prediction	742	☐	design/stress analysis
						743	☐	gearbox design
744	☐	lubricants	751	☐	lubrication systems	758	☐	lubrication system components
745	☐	selection of types	752	☐	selection of systems	759	☐	storage tank design
746	☐	mineral oils	753	☐	grease systems	760	☐	selection of oil pumps
747	☐	synthetic oils	754	☐	total loss systems	761	☐	Filtration
748	☐	greases	755	☐	splash lubrication	762	☐	heat exchange/cooler design
749	☐	solid lubricants	756	☐	mist lubrication	763	☐	pipework design
750	☐	fire-resistant fluids	757	☐	circulation systems	764	☐	warning/protection devices
765	☐	lubrication of components	770	☐	operation of lubrication systems and machines	776	☐	rotary drives
766	☐	plain bearings	771	☐	running-in procedures	777	☐	belt drives
767	☐	rolling bearings	772	☐	change periods/tests	778	☐	chain drives
768	☐	gears	773	☐	biological deterioration	779	☐	couplings/joints
769	☐	other components	774	☐	lubricant hazards	780	☐	Clutches
			775	☐	lub. maintenance plan	781	☐	Brakes
782	☐	seals	788	☐	maintenance	794	☐	Design
783	☐	selection of seals	789	☐	maintenance methods	795	☐	component design
784	☐	labyrinth seals	790	☐	condition monitoring	796	☐	systems design
785	☐	lip seals	791	☐	allowable wear limits	797	☐	whole-life design
786	☐	mechanical seals	792	☐	risk analysis	798	☐	designed-out maintenance
787	☐	packed glands	793	☐	repair of worn/damaged surfaces			

APPENDIX 3, CLASSIFICATION OF ASSOCIATE PROGRAMME THEMES BY THEMATIC AND SECTORIAL PANELS

AGEING POPULATION

- Bio Tribology Materials
 Design
- Mobility Aids Materials
 Design
- Miniature Devices

MANUFACTURING 2020

- Surface Engineering : through design
- Environmental – lubricants and coolants
- Noise/precision
- High speed machining
- Abrasive water-jet cutting
- Metals processing
- Manufacturing route - through life
- QA of surface engineering
- Total lifetime costs in automotive engineering

BUILT ENVIRONMENT & TRANSPORT

- Energy Efficiency & Environment (Fuel efficiency)
- Noise Vibration
- Performance Reliability
- Lower friction in bearings, seals, tyres
- Recyclability
- Design Stage
- New drive line solutions
- Railway issues

DEFENCE, AEROSPACE

- Sticking rifles?
- Condition monitoring
- Transmissions all sizes and shapes
- Erosive wear
- Aggressive environments
- Design process
- Environmental tolerance
- Spare mechanisms
- Service intervals
- Total lifetime costs

CHEMICALS

- Process lubricants
- Personal care/products - razor blades
- Base oils
- Additives
- Alternative base stocks, bio-original
- Rotating machinery, - reliability - and performance
- Chemical coating & technology
- Reducing our need for chemicals

ENERGY & NATURAL ENVIRONMENT

- Energy efficiency /emissions
- Clean coal technology
- Energy conversions
- Energy Storage
- Process lubrication - (e.g. sea water)
- Hydraulic oil leakage
- Reduction in use of natural resources
- Conservation

FINANCIAL SERVICES

FOOD CHAIN / FOOD PROCESSING

- Machinery
- Bulk materials handling
- Cutting technology
- Bio degradable / edible lubricants

HEALTHCARE

- See ageing population
- Chemicals
- Orthotics
- X-ray tube bearings
- Medical devices
- Plant wear problems
- Medical consumables – friction, grip etc

INFORMATION ETC.

- Magnetic Storage Devices
- Semiconductor manufacturing
- Mobile phones : wear, reliability of push button contact
- Electrical contacts

- Polymer processing polymers for displays

MATERIALS

- Properties of materials and surfaces
- Material substitution
- QA issues for coating and surfacing
- Design stage - “Surface Engineering”
- Materials/lubes compatibility
- Modelling inputs - nano scale
- Functionally graded surfaces
- Surface chemistry
- Composites design
- Functional materials + smart materials (multi functional)
- Improved rubbing materials
- Low energy formability
- Easy recycling

APPENDIX 4, EXAMPLES OF SOURCES OF EXPERTISE

University

Leeds University (Bio, Engineering)
IRC Bio Materials
Cranfield
Liverpool John Moores University
Birmingham
Swansea
Cardiff
Sheffield University
Nottingham
Durham
Herriott Watt University
Lancaster University
Bradford University
Leeds University
Durham University

University of Central England
Newcastle University
Hull
University of Greenwich
BGA
BLF
University of Cambridge
Sheffield Hallam University

RTOs

NPL
AEA Technology
DERA
MRPRA
RAPRA
PERA
TWI
MIRA

Industry

Rolls Royce
BAe
ABB
GKN
Siemens
Railtrack + ABB
Perkins
WS Atkins
AEA
Dowty
ICI
Unilever
Proctor and Gamble
Zeneca

Coatings Producers
Tool Materials Producers
Ricardo
Neale Consulting Engineers
Federal Mogul
Dana
Ford
Infineum
British Aluminium
Corus
Gillette
Smith Kline Beecham
Seagate
Hewlett Packard

APPENDIX 5: OPEN FORUM, OCTOBER 1998

Tribology Open Forum at I Mech E HQ

The I Mech E Tribology Group Committee meets four times annually. By way of experiment this year, the 1 October meeting was turned into an Open forum which mixed TG Committee members with invited individuals able to provide advice, views and planning input from some of the interfacing bodies with tribological interests. Active and positive participation by representatives of the central, and critically important in the context, Institute of Materials, Institute of Physics, Royal Society of Chemistry, STLE (UK), and EPMA (European Powder Metallurgy Association) ensured the success of the experiment, especially from the viewpoint of mutual understanding.

The TG Committee was particularly gratified that the CEO of the IoM, Dr Bernie Rickinson, had accepted the invitation. As individuals, the gathering represented several companies and a range of universities. While a source of some disappointment was that the attendance list included fewer than might have been hoped from the IMechE's own divisional and committee population, the Institution's Director, Engineering, Dr David Noble and the Manager responsible for the TGC Brian Robinson were there to represent the whole structure. The following reports on the event and its outcomes.

Dr Rob Rowntree gave a brief review of the TGC's activities during his two-year Chairmanship. One of the highlights had been the World Tribology Congress in September 1997 which had involved interface and collaboration with a very large number of other bodies worldwide. In addition to a full routine programme of seminars, initiatives included: a series of special lectures to spread the tribology message and a new approach to 'Tribology in lifetime education and training'.

Taking over the Chair for 1998-2000, Dr Alex Alliston-Greiner (Plint and Partners) said that the meeting had been motivated by the fact that tribology is an industrially critical and very wide subject indeed and cannot usefully be 'owned' by any one institution or association. The basic objective was to encourage collaboration and initiative sharing in forward programmes at an early stage in the interests of:

- encouraging a more effective tribology information and development system in the UK

- helping all interested individuals - the market - to gain a clearer view of the tribological programmes on offer.

Collaborative planning should make for a better market presentation and should underpin the necessary multidisciplinary approach.

Dr Rickinson's quick review of the activities of the IoM included reference to several areas of interest for tribology:

- the Materials Information Service
- the Materials Processing Initiative
- the plans to build a 'surface engineering division' around the existing Surface Engineering, Adhesives, and Corrosion Committees.

Dr Mark Gee (NPL) for the IoP said that its Tribology Group, founded in 1980 and based on the Tabor Group, was dedicated to the physics insights into tribological phenomena. The Group was quite small and welcomed an expansion of the existing collaborative efforts; matters of education and training would lend themselves very well to a cooperative approach with bigger populations.

Professor Hugh Spikes (Imperial) agreed that too many small and non-communicating groups and events would not be the best way ahead for tribology. Also, it was essential to allow participation by all interested without undue reference to 'qualifications'. There was wide support for this: Gee noted that a good proportion of people at IoP seminars were not members; Bob Wood (Consultant to the TGC) said that non-member attendance at events in the IMechE's popular CPD seminar series had varied from 19 to 42%.

In open discussion, tribological imperatives are seen to be:

- education at all levels in tribology
- the general promotion of the benefits obtainable through a correct approach
- technology transfer and diffusion in tribology (existing and emerging)

Despite efforts over many years to improve the situation, all agreed with Dr Gareth Fish (GKN and STLE (UK) Chair) and Dr Roy Mortier (Castrol) that the nature and significance of tribological knowledge is not fully and widely appreciated - even by many engineers. Perhaps many of those that know the word see it as referring entirely to lubrication; too many also view it purely as a maintenance or 'remedial' matter rather than something which must enter at the design - or 'redesign' - stage where serious economic gain is possible. Dr Rickinson likened the necessary process to a bridge linking design with applications, in which the institutions were the deck resting on three piers of materials - processing - properties.

The 'design' and 'design stage' theme was eagerly grasped and universally considered to be absolutely critical. Various versions of the 80:20 rule were seen to apply, especially Professor Colin Seabrook's (Birmingham) suggestion that around 80% of added value in a product enters at the design stage. Work is clearly needed to get the right messages across. Interest from industry certainly existed and IoM's initiatives had increasingly addressed the matter of process understanding. The IMechE's seminar series had attracted people from nearly five hundred companies over a period of 4-5 years.

While there is no doubt that information services, especially free ones, such as the IoM's MIS were popular and usable, there was less agreement on whether or not and how SMEs were encouraged to find and exploit existing expert knowledge. While it is obvious that large or very large companies might tend to 'do their own thing' technologically, consultants were frequently approached on specific issues by such companies. Many SMEs probably did not appreciate that product acceptability and possibly company survival could depend on being

up to date technically. Professor Tom Bell (Birmingham) believed that with the right design approach, smaller companies could leap forward in efficiency and cost reduction, while larger companies tended to advance in smaller increments.

There was general recognition that the mere availability of information was not the same thing as its correct understanding and optimum use; institution programmes should take account of:

- how information is sought and by whom
- how information is used

especially in light of new and improved methods of making information available and deliverable.

Collaboration on any appropriate matter was welcomed but there were warnings about the dangers of the 'top down' approach which can stifle individual and small-group initiative. The 'centre' should concentrate on getting basic themes into the programmes. Some preliminary ideas on widely applicable themes were put forward. Peter Brewin (for EPMA) suggested that the industrial and political context in which we were working was profoundly influenced by national and European legislation in environmental and energy areas. Gareth Fish agreed that such legislation had a major impact on business.

The output from the Forum was that:

1. The bodies represented were positive about collaboration on theme development. The crucial thing was to collaborate on a continuous basis on the broader programme planning and publicity functions: any perceived 'top-down' approach was no use at the workplace and ample room must be left for fast response to need as well as original initiative. How and in what forms the products and services arising from those themes were to be put on the street was a matter for the individuals in the committees and on the staffs concerned. Nonetheless, there was a good deal of scope for efficient, productive and mutually beneficial cooperation at this level too.
2. Cooperation could take the form of anything from the traditional 'cosponsor' listings to full 50:50 organisation, administration, and bankrolling. At the former end of the spectrum, greater clarity was needed about what cosponsors were supposed to do and why.
3. Tribology was undoubtedly multidisciplinary and interdisciplinary and the joint approach was essential. Indeed, it was agreed that other bodies with tribological interests should be drawn into the picture.
4. A further meeting would be arranged urgently for key representatives, aided by a facilitator and with tribology in mind, to:

establish the ground rules for collaboration

progress some initial ideas and projects relating to tribology in its widest sense in:

- seminar and conference planning 2-3 years ahead
- CPD

- straightforward instructional workshops
- scenario-based workshops
- UK Government interfaces (e.g. the Foresight programme)
- EU Framework Programme 5 interfaces
- put in place an efficient calendar and publicity system for the whole subject area

APPENDIX 6, UK TRIBOLOGY FORUM, 16 MARCH 2000

A meeting of the UK Tribology Forum was held to consider the framework for the Associate Programme in Tribology. Considering the short notice for the meeting (3 weeks due to the short time scales involved), the attendance of 17 at the meeting was considered to be good. There were participants representing the I Mech E, IOP, IOM, Royal Society of Chemistry, International Federation of Heat Treatment and Surface Engineering, International Tribology Council, Neale Consulting Engineers, NCT (AEA Technology), Castrol, UMIST, NSK-RHP European Technology Centre, University of Cambridge, UMIST, the Open University, Imperial College and NPL.

Dr Gee described the background to the meeting. Thus the I Mech E had taken the initiative in October 1998 of holding the first Open Forum in Tribology. One of the conclusions of this meeting had been to explore the possibilities of developing a Foresight initiative in Tribology. This was carried out by Alex Alliston-Greiner and Robert Wood from I Mech E who had approached Professor John Wood, the chairman of the Foresight Materials Panel, and OST in DTI with a proposal for a Task Force in Tribology under the Materials Panel.

This did not prove to be feasible, but there was the possibility that an Associate Programme could be developed in Tribology. Because of other commitments, Dr Alex Alliston Greiner, the chairman of the I Mech E Tribology Group was not able to push this process forward and the second Open Forum meeting planned for October 1999 was cancelled.

Dr Gee described how NPL was able to secure a small amount of funding to restart the Associate Programme process. However, this could not be carried out until mid February 2000 when invitations to the current meeting were sent out to interested parties.

The funding from DTI was for the limited tasks of setting up the Forum meeting and to develop the framework for the Associate Programme which would be reported formally to DTI.

Dr Gee laid out how he thought the Associate Programme could be developed, with NPL giving secretariat support to the process, acting as a "broker" for the report and organising a final workshop where the recommendations of the report could be agreed before final publication.

He emphasised that the Associate Programme could only be successful if it was owned by the UK tribological community. Key input from the community would be required to write the individual short (1 page at most) sections of the report, and to validate the final report.

The meeting was opened up for discussion. There was general agreement on the approach that should be used, but John Brophy, Royal Society of Chemistry, emphasised that the timescale for the action was short since Foresight Panel reports themselves were due by November 2000 so that at least some information would be required from the Tribology Associate Programme by the end of July 2000.

Peter Jost emphasised that the overwhelming economic argument for the importance of tribology should be foremost in the Associate Programme report, quoting a recent study he had made of a UK steel works where he had recommended that savings of £ 10 M per annum

could be made through the investment in improved tribological good practice of £300 k. Unless hard economic arguments were an integral part of the report, it was unlikely to be taken up.

Another theme that was prominent in the discussion was the need for better and more coordinated technology transfer and education in tribology. Although there had been some recent initiatives in technology transfer in tribology in recent years, they had not been all that successful. The reasons for this failure needed to be identified and incorporated into new initiatives.

With respect to education, it is clear that at present teaching about tribology is fragmented or is completely lacking in many cases both at school and university level. Again, there is a need to develop practical strategies to improve this situation.

The use of internet technologies was raised as a method for technology transfer and education in tribology. Exploitation of this form of communication is fast becoming established as a preferred medium. The Government is behind several initiatives which promote the use of modern IT and internet technology to move the UK to a knowledge based economy, and have committed themselves to delivery of all Government services by the internet by 2005. There was a clear consensus at the meeting that the development of an internet strategy for tribology was essential for the long term health of the area, but that issues of funding and organisation needed to be addressed before this could become a reality.

The rest of the meeting was taken up with discussion of the detailed content of the report, and who to ask to contribute to the report. It was decided that since tribology is multidisciplinary, the report would have more impact if the different aspects that were considered were categorised between the different Foresight Panel Areas.

This process was carried out, resulting in a list of topic areas and sources or expertise that are given in Appendix 4.