A Strategic Review of the Surface Engineering Industry in the UK

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A Strategic Review of the Surface Engineering Industry in the UK

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The Department of Trade and Industry
and Yorkshire Forward

NAMTEC

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This review report has been produced for the Department of Trade and Industry and Yorkshire Forward by A. Clarke and A. Partridge, NAMTEC. Additional comment is gratefully acknowledged from Professor Allan Matthews of Sheffield University, Dr Nick Farmilo of Sheffield Hallam University, and Paul LeGood of Corus RD&T. It should be noted however, that the conclusions and opinions expressed within the report are solely those of the authors. These conclusions and opinions cannot be taken as those of the organisations petitioned within this report. This report has been prepared by the authors using the best available information at the time of writing.

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1.0 Executive Summary

The surface engineering industry in the UK is extremely diverse, and serves a wide range of market sectors and industries. These market sectors include aerospace, automotive, catering, construction, the off-shore industries, power generation and bio-medical applications. Within each of these market sectors a diverse array of coatings are utilised, including hard and wear resistant coatings, high temperature coatings, corrosion resistant coatings, aesthetic coatings, etc. Similarly a broad range of deposition techniques are used to apply these different forms of coatings.

This report intends to provide a Strategic Review of the Surface Engineering Industry in the UK, investigating the barriers to greater exploitation of the current technology base. Data was complied using one-to-one survey interviews, and complemented using a comprehensive questionnaire. The information assimilated was organised under areas indicated from the one-to-one interviews. A full analysis of the data is presented within this report.

From the discussions during interviews and from the information gathered from questionnaires, the following areas were identified as priority requirement areas for the surface engineering industry:

- A structured and formal approach to technology exploitation and an increased co-ordination of research and development activities
- Increased co-ordination and collaboration across the Surface Engineering sector as a whole
- The formation of increased links and knowledge transfer between academia and industry
- A greater understanding of available funding streams
- Identification of an improved route to market for ground breaking technologies
- Increased availability of information and support services
- Increased availability of high quality reliable generic design data
- Improved communication links to highlight the potential impact of environmental legislation

From the analysis of the data, it is concluded that the needs of the surface engineering industry would be best served by the formation of a centralised information networking resource. The information gathered during interviews showed that formal and informal structured associations of expertise currently exist, and further development of these would give UK plc an extremely valuable resource for the wider surface engineering industry as a whole. By including the wealth of resource within these associations into a revised framework, an effective network could be established. This network would allow continuity across the industry, and also permit academia to liaise with industry on a formal basis, allowing the formation of a direct route to market for novel technology exploitation.

From the findings of this review, this continuity would be best provided in the form of a Surface Engineering Network, which will bring together current technical proficiency and form a knowledge database of independent industrial and academic experts. The network should incorporate and directly liaise with existing specialist centres, groups and networks, for example training schemes and databases, and make these accessible for the industry as a whole. The geographic location of this network was seen as irrelevant, but it was noted that inclusion of current knowledge and practices, and availability for all, was vital for success.

2.0 Introduction

Surface engineering is a critical enabling technology underpinning major industry sectors. Its influence is broad and of major economic importance, and can be defined as the design of surface and substrate together to form a functionally graded system possessing properties not achievable in either component alone [1]. From the broad sector viewpoint surface engineering encompasses many and varied processes and techniques. These are normally associated with [2, 9]:

- Electroplating;
- Engineering Paints;
- Anodising;
- Vitreous and Stove Enamelling;
- Heat Treatment and Case Hardening;
- Powder Coating;
- Metal spraying, including Spray Painting;
- Emerging and novel technologies.

The UK has a diverse and relatively advanced coatings industry, ranging from established technologies such as carburising and electro-plating industries through to companies employing innovative coating processes, such as the emergent sol-gel, SMART and functional coatings technologies [3]. These emergent technologies present a major opportunity to the UK to exploit these coatings across a range of market sectors. However, the inherent diversity of the industry means that it is relatively fragmented and limited co-ordination or co-operation between organisations within the supply chain occurs. This restricts the industrial growth and the exploitation of business opportunities available to UK plc. Although the surface engineering sector has proved to be highly innovative over the last few years, technology transfer from one market sector across into other sectors has been limited [4-6].

The UK market for surface engineering processes in 1995 was estimated to be valued at £10bn [7], of which £4.5bn was 'engineering' coatings and surface treatments to improve wear or corrosion resistance as opposed to 'functional' (optical, magnetic, etc.) layers. These treatments critically affected manufactured products valued at £95.5bn (about 7% of UK GDP). Based on the previous data [1] it is conservatively estimated that in 2005 the UK market for surface engineering processes was £21.3bn and that these treatments critically affected £143bn manufactured products (in 1995 prices).

The surface engineering sector within the UK has been highly innovative over many years, and continues to develop novel cost effective coatings technologies that have the potential to create and maintain a competitive edge over non-UK based technologies. The potential to successfully exploit these technology advances, and the prospective significant impact on the current global markets, could well result in the development of completely new supply chains creating opportunities in the export market for UK industry. In light of these technology driven opportunities, this strategic review of the surface engineering sector will provide valuable foresight for the UK surface engineering industry.

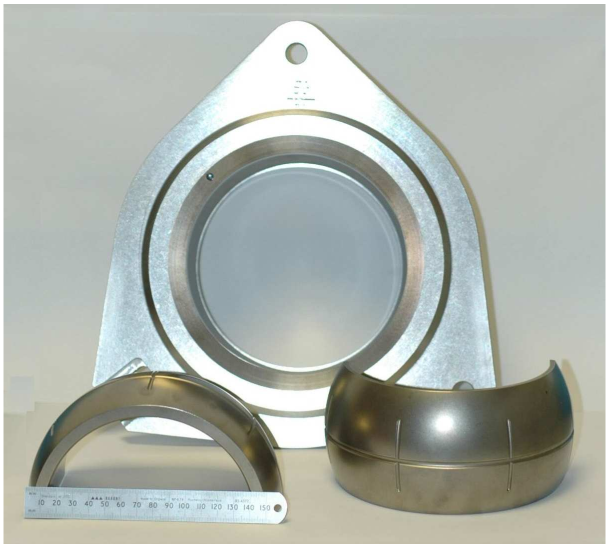
3.0 Background

Over the last 20 years, a number of studies have been carried out to evaluate the status of the surface engineering industry within the UK [4-12]. These reports have highlighted the relative fragmentation of the sector in relation to other technical sectors, the low level of co-ordination across the sector, and the need for a more integrated approach to realise the full economic benefits that the sector could bring to the UK economy.

A serious attempt to address the issues highlighted in the various studies was finally initiated in 1994/5 when the DTI announced its intent to establish a National Surface Engineering Centre (NASURF, www.nasurf.com); to create a focal point for the surface engineering industry in the UK. After an extensive tendering process the management of the Centre was awarded to the Defence and Evaluation Research Agency (DERA) in conjunction with British Telecom. The Centre was launched in March 1996.

After a promising start, and much good work, the Centre struggled to establish itself and secure the full support of industry. After four years of operation NASURF had failed to achieve self-sustainability, resulting in its services being scaled down, and ultimately its activities were incorporated into the Institute of Materials, Minerals and Mining (IoM^3). NASURF is now managed as a website and an industry helpline by IoM^3. The reader is referred to § Appendix 1 for a fuller discussion of NASURF and other related industry initiatives.

This report will seek to establish the current state of the industry and assess what practical support could be offered that would assist the industry in establishing a long-term competitive advantage over its non-UK based competitors.



4.0 Project Aims

The aims of this review are to:

- Determine the current infrastructure and the geographical distribution of the industry;
- Identify capability gaps in the supply chain, and determine whether additional capital equipment is vital to the development of the supply chain;
- Identify further education and training needs within the surface engineering sector;
- Identify opportunities to improve communications between the surface engineering industry and academia;
- Establish the exploitation opportunities presented by emerging and novel technologies.
- Determine the drivers for research and development.

5.0 Methodology

The collation and analysis of the data, collected as part of this study, was based on a standardised methodology. This involved the collation of primary data (interviews and questionnaires), the collation of secondary data (background reports and information), and the formal analysis of this data using conventional analysis techniques; including a sector PEST and SWOT analysis. The strategic review process was carried out in collaboration with the surface engineering sector involving representatives drawn from industry, trade bodies, professional institutions and academia. A steering committee, representative of the sector, was established to review the findings of the study, and offer expertise and guidance to assist in the implementation of the findings of this review.

A more detailed description of the methodology, a list of the organisations interviewed, the findings of the primary data analysis and the PEST and SWOT analysis are presented in § Appendices 2, 3, 4 and 5.

6.0 *Analysis*

In this section an analysis of the data collated in § Appendix 4 and 5 is presented.

6.1 The current infrastructure of the Surface Engineering Industry

At one end of the spectrum it is clear that some companies, mainly drawn from the more traditional sections of the industry, have failed to invest and develop robust quality and environmental management systems, and that these companies are being increasingly excluded from the high value supply chains. In many cases these companies' only product discriminator is price, and have mainly retained market share through their established links with local supply chain companies. As a consequence of the increasing readiness of companies within the supply chain to re-source their products and services, combined with fierce competition from low cost economies, these companies face an uncertain future. At the other end of the spectrum, numerous examples can be found of vibrant and innovative companies that fully utilise the knowledge base within the UK.

The majority of UK surface engineering companies reside between these two extremes. They are committed to maintaining their position within the supply chain and work hard to establish and retain competitive advantage in the market place. They will invest, where possible, to increase their productivity and to maintain their compliance with regulatory requirements, and do seek to monitor the market place to identify emergent markets and new product innovations and opportunities. However, it is clearly evident from the data collated for this report that companies require assistance to support their ability to innovate and develop.

The key infrastructural issue that was highlighted by the majority of respondents to this study was the need to improve access to information, support (both financial and technical) and enhance innovation through greater collaboration.
The respondents identified a number of key support services:

1. The maintenance of a national helpline
2. Access to reliable information on the impact and implications of emerging legislation
3. Support to facilitate the exploitation of innovative products and processes
4. Improved dissemination of industry news, emerging technologies and market information
5. Assistance in developing and securing grant applications
6. Access to technical information and sources of expertise

6.2 Geographical distribution of the industry

A wide population was sampled for data collection within this report; from the organisations petitioned it was clear that the surface engineering industry does not have a regional focus. The industry is more aligned to the geographical location of the end user or the point of final manufacture. A more detailed focus of the location of those organisations petitioned is at § Appendix 3.

It is worth noting that a number of the regional development agencies recognise the importance of surface engineering within the manufacturing supply chain and actively support the development of surface engineering initiatives and programmes (Yorkshire and Humberside – Regional Surface Engineering Centre, West Midlands – Nano-technology Centre, East Midlands – Cranfield National High Temperature Surface Engineering Centre under the SRIF, etc.) At present there appears to be very little co-ordination between these initiatives, potentially resulting in the duplication of activities and programmes within the UK. A higher degree of communication between these Centres should be encouraged, as should the development of a national Surface Engineering strategy.

6.3 Supply chain development and capital equipment

The companies interviewed as part of this study are involved in a wide range of supply chains, with many individual companies serving a number of different sectors. These companies largely took the view that where market opportunities existed, and where a strong business case could be made, investment in capital equipment was forthcoming. As a consequence of this no major gaps in capability was highlighted by the industrial respondents. However, it was highlighted that public sector support in relation to the development of R&D programmes was important and that support for the purchase of capital items should be maintained.

In terms of R&D support the perception was that the UK was relatively well served in terms of its university and RTO infrastructure (§ Appendix 7). However, the maintenance, development and support of these existing Centres of Excellence around the UK was seen as paramount. In contrast there was limited interest in the establishment of new "physical" centres. This can be attributed to the fact that a number of the companies interviewed already have strong links with specific research institutions, and agreed IPR exploitation agreements in place. However, these links were noted to be limited and exclusive, and therefore only of benefit to a few targeted institutions. Given the ageing research infrastructure within the UK the establishment of new facilities and equipment is inevitable, but should seek to build upon the extensive expertise already existing within the UK.

6.4 Education and training needs

As expected, the need for education and training came less from academia, and more from industry and the trade bodies. It was generally noted that training courses exist, but in a fragmented, regional manner. The wide range of education and training provision available is detailed in § Appendix 7. Three key issues arose from the study:

1. A central point of information should be established defining the training provision available.
2. Greater regional provision would need to be established to improve the accessibility of courses.
3. The level of training provision and the availability of skilled staff would need to be increased significantly.

6.5 Communication between the surface engineering industry and academia

As noted above the relationship between the research base and industry is relatively mature, with a number of the larger industrial producers and users having a well established network of academic partners. However, the respondents highlighted a number of areas that needed to be addressed. These were:

1. Greater inter-institutional, inter-company and company-institution collaboration was essential to achieve increased levels of innovation.
2. Access to better generic design data.
3. Assistance in securing routes to market for emerging technologies.

6.6 Technology drivers and exploitation opportunities

The major technology drivers within the Surface Engineering sector are:

- Environmental: The need to develop products and processes that eliminate harmful emissions and the use of proscribed chemicals and elements.
- Reliability and life cycle analysis: The ability to model the behaviour of coating-substrate systems under a range of thermo-mechanical loading conditions and environments to predict coating integrity and life cycle costs.
- Performance: The development of surface and coatings technologies to provide enhanced corrosion, wear, opto-electrical and thermal behaviour.

- Functional enhancement: The development of high value added functional and SMART coatings to create intelligent systems.
- Cost reduction: The development of high performance coatings and processes at reduced cost.

It is beyond the scope of this report to attempt to identify all of the emergent technical innovations that will arise from these key technology drivers. However, during this study a number of generic issues were identified that will form the basis of research and development programmes over the coming years. These are:

1. The elimination of Cd and Cr VI bearing coatings and the elimination of specific solvent based cleaning processes through the introduction of new coating and treatment processes, such as the sol-gel process.
2. The development of micro and nano-engineered coatings and surfaces, including the development of multilayer and composite systems, to optimise mechanical, thermal, opto-electric and magnetic response under specific operating conditions.
3. The creation of validated design data to accurately predict the behaviour of coating-substrate systems under a range of thermo-mechanical and environmental loading conditions.
4. The “tailoring” of surface physical properties by various means (doping, implantation, layering, etc.) to create functionally responsive surfaces that are pre-tuned to respond to specific external stimuli; and the subsequent incorporation of these functional surfaces into a component to create intelligent (SMART) systems.
5. The deployment of advanced coatings technologies (sol-gel, plasma, EB-PVD, etc) to provide enhanced corrosion, wear, opto-electrical and thermal behaviour.

It is clear from the data that the Surface Engineering Industry would benefit from greater centralisation and focus to exploit the wealth of technology that UK plc can provide. The need for a focal point to establish greater integration across the sector, and for a network of expertise, was identified in the early 1990’s, and still exists within the industry today. The UK contains a wealth of innovation and ground breaking research, and exploitation of this resource has been seen as the driver for success on the world stage. Industry as a whole has changed focus and direction in terms of competition. Historically, competition came from within the UK, however with the rise in emerging markets and the ease of transport, competition is now seen on a global scale. This has had the direct effect that unification is now a necessity to enable UK plc to compete on a level playing field with our EU, US, and global neighbours. The need for a strategic change in approach is vital to maintain a competitive edge against our EU, US and global competition. Harnessing the resources within the UK is seen as vital to maintaining the position of the UK on the world stage.

7.0 Recommendations

Based on the findings of this study, the industry requirement is primarily for improved information, communication and exchange of best practise, and the continued support of surface engineering related research and development programmes. This objective can be achieved by:

1. Co-ordinating central and regional government funding initiatives and policies;
2. Targeted funding and support to create improved collaboration between academia and industry;
3. The establishment of a national industry wide knowledge transfer initiative.
4. Continued support of surface engineering related research and development

Any initiative should:

- Establish a structured and formal approach to improve the level of technology exploitation across the surface engineering sector as a whole, and develop mechanisms to establish routes to market.

- Create increased links and knowledge transfer mechanisms between academia and industry, and by offering a greater understanding of available funding streams, increasing the amount of R&D activity within the UK.

- Provide an information resource to the industry through the provision of newsletters and e-bulletins, highlighting: market trends, environmental legislation, breaking technology, industry news and information.

- Incorporate and directly liaise with existing specialist centres, groups and networks, incorporating for example employee training schemes, technology watching, market reviews and databases, and make these accessible for the industry as a whole.

- Provide up to date information on the training available within the sector, and where appropriate assist in the development of programmes to address skills gaps.

This proposed scheme could be delivered under the Materials UK initiative as part of the DTI sponsored Knowledge Transfer Network (KTN) programme, or as a separately funded activity. This network would need to bring together industry, academia and the trade bodies under a single umbrella activity. The geographic location of this proposed network was seen as irrelevant, but it was noted that inclusion of current knowledge and practices, and availability for all, was vital for its success. In this regard, the inclusion of the remnant NASURF activity, and its extensive company network, and engagement with the trade bodies and institutes is seen as essential.

The establishment of a central focal point for the industry would result in an industrial base that was better informed, worked more closely with academia, was able to improve its exploitation of new technologies, and ultimately better placed to compete in global markets.

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Appendix 1 - History

Over the last 20 years a number of studies have been carried out to evaluate the status of the surface engineering industry within the UK [4-12]. These reports have highlighted the relative fragmentation of the sector in relation to other technical sectors, the low level of co-ordination across the sector, and the need for a more integrated approach to realise the full economic benefits that the sector could bring to the UK economy.

Following previous concerns regarding the fragmentation of the surface engineering sector a serious attempt to address these issues was initiated in 1994/5 when the DTI announced its intent to establish a National Surface Engineering Centre (NASURF, www.nasurf.com), to create a focal point for the surface engineering industry in the UK. A tendering process was consequently commenced and seven organisations were short-listed to produce full-scale bids to operate and run NASURF. Following an extensive evaluation process the Defence and Evaluation Research Agency (DERA), in partnership with British Telecom, were awarded a grant of £2m to establish and operate NASURF. As part of the establishment of NASURF, the Research Centre in Surface Engineering (RCSE) of Hull University was awarded a sub-contract to establish and run technical and market databases and to develop helpline support software. The Centre was launched in March 1996.

The initiative aimed to improve the competitiveness of the UK surface engineering industry by providing a range of services including technical advice, technology transfer, market intelligence and training. The Centre had excellent links to the wider surface engineering community, and offered a wealth of expertise and impartial advice. From the information collected within this review, it was observed that NASURF was a good idea in principle, but that NASURF lacked independence and direction due to ownership. It was felt that the ownership structure meant that the direction of NASURF was overly reliant on the owner company remit, and therefore lacked vital independence. The lesson here is that any knowledge transfer based activity needs to be operated by an organisation or group that can remain independent. This is critical to gain the trust and respect of the industry, and to offer the industry the balanced information and advice that is required.
NASURF was formed to give the industry continuity and to offer a 'one-stop-shop' for expertise and advice for the industry as a whole, and is a partnership between the UK's Surface Engineering and Surface Finishing Industries. The NASURF partnership comprises: The Surface Engineering Association (SEA) representing the Metal Finishing Association (MFA); The Paint and Powder Finishing Association (PPFA); The British Surface Treatment Suppliers Association (BSTSA); The Contract Heat Treatment Association (CHTA); The Galvanisers Association (GA); The Thermal Spraying and Surface Engineering Association (TSSEA); The Vitreous Enamelling Association (VEA); The Aluminium Federation representing the Aluminium Finishing Association (AFA); The Institute of Metal Finishing (IMF); and The Institute of Materials, Minerals and Mining (IoM^3). NASURF aimed to improve the competitiveness of the UK surface engineering industry by providing a range of services including technical advice, technology transfer, market intelligence and training, had excellent links to the wider surface engineering community, and offered a wealth of expertise and impartial advice.

After a promising start, and much good work, the Centre struggled to establish itself and secure the full support of the industry. After four years of operation NASURF had failed to achieve self-sustainability, resulting in its services being scaled down, and incorporated into the Institute of Materials, Minerals and Mining (IoM^3). NASURF is now managed as a website and an industry helpline by Mr. Steve Harmer of the IOM^3.

From an investigation to assess the potential industrial and academic response to a LINK programme in surface engineering in 1991 [8], the DTI and EPSRC jointly launched the £10m LINK Surface Engineering programme in April 1994 to facilitate research into new and improved surface engineering. National schemes such as the LINK Surface Engineering programme look set to make a major contribution to British industry. Over the following five years, commercial sales alone were predicted to reach around £420 million. This would represent a direct benefit to the UK economy worth 75 times more than the total government investment of £5.62 million. Further research and development and other non-tangible benefits are also anticipated [22, 23].

Appendix 2 - Methodology

The collation and analysis of the data, collected as part of this study, was based on a standardised methodology. This involved the collation of primary data (interviews and questionnaires), the collation of secondary data (background reports and information), and the formal analysis of this data using conventional analysis techniques; including a sector PEST and SWOT analysis. The strategic review process was carried out in collaboration with the surface engineering sector involving representatives drawn from industry, trade bodies, professional institutions and academia. A steering committee, representative of the sector, was established to review the findings of the study, and offer expertise and guidance to assist in the implementation of the findings of this review.

Data Compilation

Data was collected from across the surface engineering industry. This method of data collection was supplemented by questionnaires which were posted out to organisations to further increase the sampled population size. As expected, the most effective method of data collection was through direct interview. Direct interviews also allowed further interrogation of subject responses to permit a more detailed data response set to be established.

Data was compiled using 36 one day survey visits to selected organisations (§ Appendix 3), and complemented using a comprehensive questionnaire supplied to 100 targeted companies. This allowed direct feedback from representatives of all levels of the UK surface engineering supply chain.

The results of the review were compiled and are presented in § Appendix 4. The analysis of this data included the performance of a PEST and SWOT analysis (§ Appendix 5)

Appendix 3 – Selected organisations involved in one-to-one interviews

Organisation Name		Region	Type
1	Institute of Metal Finishing	West Midlands	Institute
2	Institute of Corrosion	South East	Institute
3	The Surface Engineering Association	West Midlands	Trade Body
4	The Contract Heat Treatment Association	West Midlands	Trade Body
5	The European Powder Metallurgy Association	West Midlands	Trade Body
6	University of Salford	North West	Academia
7	UMIST	North West	Academia
8	Sheffield Hallam University	South Yorkshire	Academia
9	University of Leeds	Yorkshire & Humber	Academia
10	Cranfield University	South East	Academia
11	University of Sheffield	South Yorkshire	Academia
12	Corus STC	South Yorkshire	Industry
13	Balzers Ltd	South East	Industry
14	Teer Coatings	South West	Industry
15	Poeton Industries Ltd.	West Midlands	Industry
16	Anachrome Group	West Midlands	Industry
17	Stadco Coventry	West Midlands	Industry
18	Wallwork Heat Treatment	North West	Industry
19	CAPCIS	North West	Industry
20	Bodycote Heat Treatment	South Yorkshire	Industry
21	Airbus	South West	Industry
22	MacDermid Inc.	West Midlands	Industry
23	DePuy	Yorkshire & Humber	Industry
24	ATI Allvac	South Yorkshire	Industry
25	Hardide	East Anglia	Industry
26	Plasma Coatings	East Midlands	Industry
27	Eurocut	South Yorkshire	Industry
28	Refmet Ceramics	South Yorkshire	Industry
29	Marshalls Hard Metals	South Yorkshire	Industry
30	Indestructible Paint	West Midlands	Industry
31	Metal Injection Mouldings	North West	Industry
32	Symmetry Medical	South Yorkshire	Industry
33	Penistone Hard Metals	South Yorkshire	Industry
34	Plasso Technology	South Yorkshire	Industry
35	Smith and Nephew	Yorkshire & Humber	Industry
36	Swann Morton	South Yorkshire	Industry

Appendix 4 – Primary Data

As an integral part of the review a series of companies were interviewed. Figure A1 shows the total number of organisations contacted, and the breakdown of organisations by industry type. Figure A2 provides a breakdown of the type of support each organisation indicated that they required.

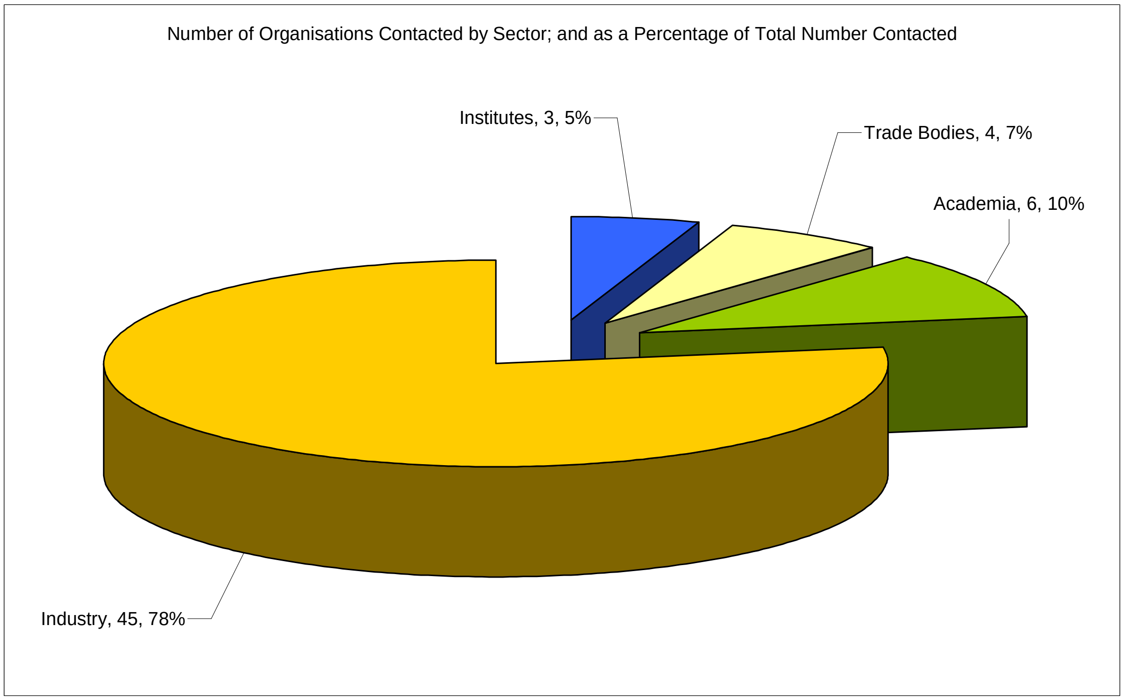

Figure A1: Number of organisations contacted by industry type.

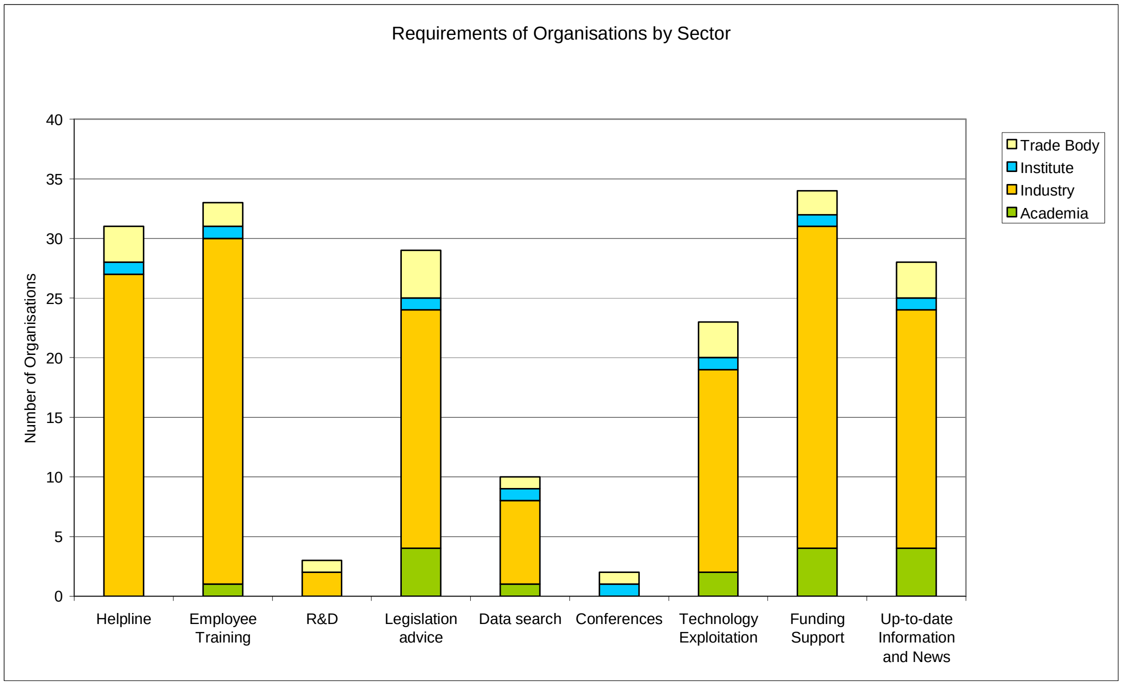

Figure A2: Requirements of the organisations by industry type

Primary Data Analysis

From an analysis of the primary data in Figure A2, it can be seen that the organisations interviewed have expressed a strong desire for support in six main areas, these are: the provision of an effective technical helpline; relevant employee training; access to advice pertaining to changes in legislation; assistance with technology exploitation; assistance to secure public sector funding; and the provision of up-to-date information and news. To assist with the evaluation of the primary data, the responses have been normalised by the number of respondents from each industry type and displayed as a percentage. This information is shown in Figure A3. This analysis shows a broadly similar pattern to that shown in Figure A2. An analysis of the data summarised in Figure A3 is shown below.

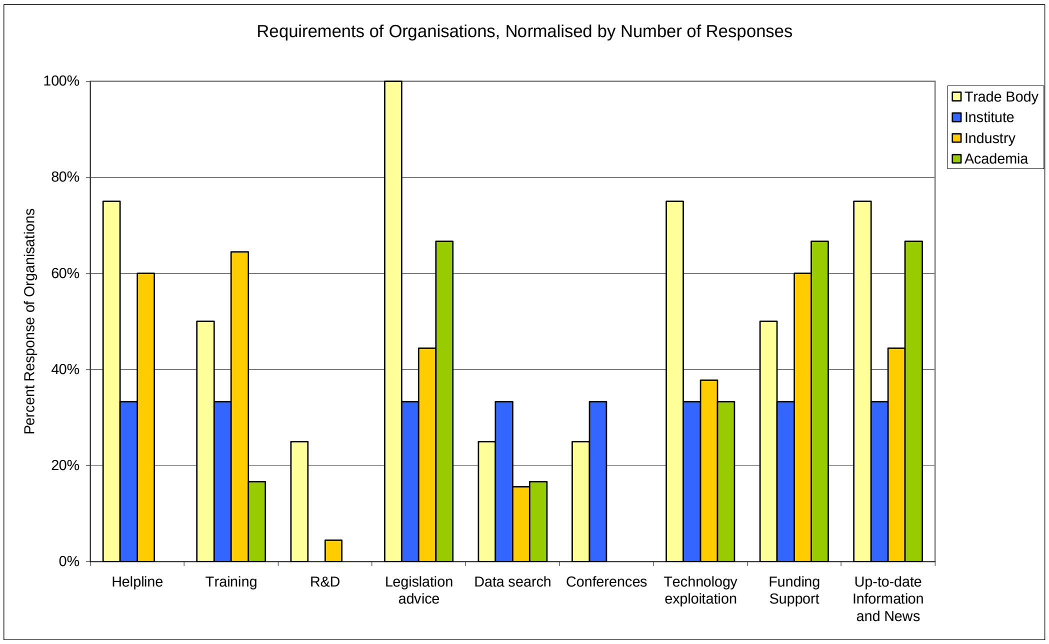

Figure A3: Requirements of the organisations, normalised by number of responses.

Technical support and helpline: The data indicates the both the trade bodies and industry are supportive of the need for a technical helpline and for access to informed technical assistance. Conversely, as may be expected, academia does not identify the need for a technical helpline. Currently many companies' first port-of-call in seeking assistance is their trade body or institution, but it is interesting to note that neither the companies concerned nor the trade bodies themselves feel that adequate information is available. This may in part be attributable to the fact that for some trade bodies and institutions their prime role is in the provision of non-technical support and that they feel the provision of additional technical support would be of benefit to their members.

It was suggested that by establishing a system whereby an organisation in need of assistance might only have to contact one person to gain advice, a comprehensive network of established experts could be drawn upon for signposting from the established trade bodies and institutes; similar to the current NASURF support system. The respondents indicated that the need for a helpline exists in the following areas:

- Signposting and information dissemination.
- Expertise and technical advice, problem solving and research.
- Sourcing and selection of materials for a given application or need based on performance, price and availability.
- The trade bodies and industry showed strong support for a technical helpline.

- Academia felt that their needs are best served in-house, and all expertise is incorporated within the academic movement.

Training: The perceived inadequacy of current training provision was identified by many respondents from all industry types; although less so within academia as might be expected. Training courses were often noted as being delivered from a single location within the UK, and many SME's felt that, due to travel costs and time away from the workplace, these courses were prohibitively expensive. Both trade bodies and institutes indicated that a wide range of education and training courses were on offer at both technician and graduate level (§ Appendix 6), but that industrial take up was limited. This was attributed to three reasons: i) the perception that the courses did not meet the needs of the user company, ii) that the courses were delivered at a remote location that made it impractical to attend, and iii) information on the availability of courses was hard to come by.

All of the respondents indicated that greater levels of training was important and was seen as vital for the UK if the sector was to compete on a global level. The provision of a central point for the promotion of courses was proposed.

- Training courses are often delivered from a single UK location remote from the companies requiring support. A need for the local provision of courses was identified to enable organisations with limited training budgets to attend training courses.

- Training courses are available at both technician and graduate level, but uptake by UK companies was limited.

- The provision of training within the sector is fragmented across a range of providers, at disparate locations, and information relating to the applicability of courses is difficult to come by.

- A central source providing information on the variety of courses available was requested.

Research and Development: Responses for the need of a centralised R&D facility were low. This was in part due to the established research base within the UK, and the fact that relatively strong links exist between individual companies and specific academic institutions. The desire of industry to maintain the intellectual property rights (IPR) to R&D activities was also a factor in limiting the demand for the provision of third party R&D facilities. However, respondents did highlight the fragmented nature of the research infrastructure within the UK, and noted that inter-institution co-ordination and collaboration could be improved. However, it should be noted that the desire by both companies and research institutes to maintain control of IPR hinders both the ability of inter-institutional working, and the readiness of companies to work on a collaborative basis with other competitors; although some collaborative working was noted.

- The establishment of further R&D facilities was not deemed necessary.

- The research base within academia is well-established.

- Facilitation of greater inter-institutional and inter-company collaboration was considered to be necessary.

The current research base was investigated and the main research institutions in this sector were identified; their activities are collated in § Appendix 7.

Legislation Advice: The data in Figure 3 shows that there is a strong requirement for information on emerging legislation and on access to good quality advice pertaining to the potential impact of the legislation and mitigation measures that can be taken. Interestingly, the trade bodies and academia were the two types of institutions that noted the greatest need for more information. For the trade bodies the need to inform their members of impending legislation, and where appropriate to lobby for changes in legislation, is of paramount importance. However, the trade bodies have identified that mechanisms for the early identification of impending legislation are lacking and that dissemination could be improved. For academia, the improved awareness of impending legislation would allow them to target their research efforts into areas that allow them to address the potential impact of legislation and enable companies to modify their process routes.

Many companies recognise that a lack of understanding of the potential impact of legislation has the possibility to be catastrophic to their competitiveness. Therefore, in order to mitigate the possible effects of ignorance, a comprehensive network of advice dissemination is necessary. The companies indicated that this dissemination could come in the form of conferences and seminars, technical bulletins or web based information.

- Access to information and relevant advice on the impact of impending legislation is lacking.

- A complete network of advice dissemination has been noted as necessary.

Data Search: This refers to the need of the sector to establish a centralised information database and search facility for substrate and coatings information. The data in Figure 3 shows a low response rate across the various industry types for the provision of this service. However, a number of respondents stated that generic data is difficult to come by, and as such is highly sought after. The overall impression from the survey was that although access to a comprehensive database would in principle be of benefit, in general centralised databases are often characterised by the existence of partial datasets and the population of unreliable information. For the datasets to be valuable to an end-user, the method and extent of data collection needs to be tailored to the needs of the user. The generic data itself was noted to be in high demand, but access to that data via a web-based search function was seen to be of limited use.

- A general need for generic design data was noted.
- Reliability and continuity of data collection across the industry was seen to be an issue.
- Limited interest was expressed in a web-based data search function.

Conferences: The response rate for conferences was predictably low. Academia is well served internally, and industry responses indicated that the time and cost required are prohibitive. The interest from the trade bodies and institutes comes ostensibly from a wish to serve their members. Responses suggested that a representative from an independent body might attend conferences on behalf of numerous industrial organisations. This is a possible route, but the industrial organisations will ultimately have their own strategy and agenda so areas of interest will become widespread; this may have the result that any information gained by the independent body will be too diluted to be effective. A method of highlighting relevant conference information in advance may give industrial organisations the ability to express an interest, and a summary of major points post conference which is placed in the public domain would allow organisations across the industry as a whole to gain valuable information.

- The organisation of large scale conferences was not considered to be of great benefit.
- The collation and dissemination of information from conferences was considered to be of benefit.

Technology Exploitation: Figure 3 indicates that a similar response of ~33% was noted across the data population set, with one exception being the trade bodies at 75%. This reflects a concern that innovative and ground breaking technologies are not fully exploited across the industry as a whole. Responses from both industry and academia indicate that there is a fundamental lack of information relating to what technologies are being developed, where the current hubs of research are located, and what research is being carried out. Information is also lacking relating to the market sectors which offer a route to market for these emerging technologies. A far greater understanding is needed across the industry as a whole if an improved exploitation strategy is to be established and implemented. In order to address this, a structured approach for a route to market from academia to industry is vital to maintain the position of UK plc as a world leader within novel technologies.

- Concerns were raised about the lack of exploitation of innovation across the industry as a whole.

- A structured approach to improve the effectiveness of exploitation is considered vital.

- More information is required relating to developing technologies, and where companies can source appropriate and informed R&D support.

- More information relating to market sectors and the route to market for emerging technologies is needed.

Funding support: As anticipated, there was a high demand for the maintenance and extension of public sector funded schemes to support the development of the sector. The main areas of interest identified by industry were in support of R&D investment and capital expenditure. Predictably, industry and academia showed the greatest interest in securing this type of support. The need for increased expenditure to support technology exploitation was also highlighted by the trade bodies and institutions. Although it was recognised that a number of funding bodies currently support the UK and its regions, companies indicated that the diversity of schemes, the varied qualification criteria and the associated paperwork meant that it was often difficult to assess the suitability of schemes and time consuming to secure funding. Assistance in understanding and securing grant funding was therefore highlighted as a requirement.

- The maintenance and extension of public sector programmes to support R&D investment, capital expenditure and technology exploitation was requested.

- Assistance in accessing information on grant funding and support with the application process was highlighted as a requirement.

Up-to-date information and news: Figure 3 shows that up to date information is required across the industry as a whole. It was noted that the current level of journals and periodicals is sufficient; however, up-to-date relevant news was seen as an important method of informing organisations as to any changes in legislation, highlighting future trends, raising awareness of the marketplace, etc. It was noted that due to the time constraints within industry the most effective method would be an electronic bulletin with e-mail links to articles containing further detail.

- Up-to-date information and news has been noted to be important for organisations to keep abreast of changes in the industry.

- A simple, bullet point email with links to relevant further detail was noted to be the most effective method of disseminating news.

Appendix 5 – PEST & SWOT Analysis

PEST Analysis

To establish the environment in which the surface engineering sector operates a standard PEST analysis has been carried out. This PEST analysis will identify the Political, Economic, Socio-cultural and Technological drivers which have contributed to the situation that the sector finds itself in today.

Political: Over the last 25 years major changes in Government policy, and its underlying rationale, have occurred. The UK has seen a move from the development and implementation of a macro-economic industrial policy that was often tailored to meet the needs of large scale manufacturing industry, to a policy of supporting high technology, high growth businesses; these are typically much smaller and more diverse in nature [13-16].

A key element of this transition is the desire of the UK government to raise company R&D expenditure from around 1% of turnover currently to over 3% by 2010. The UK Government's policy on R&D is set out within its 2003 DTI Innovation Report [16]. This paper clearly sets out the need for UK companies to invest in R&D and training if they are to maintain their competitiveness in the global economy. As part of the implementation of the report's proposals, an extensive Technology Foresight activity was undertaken. The Foresight programme sought to identify potential opportunities for the economy or society from new science and technologies, and to consider how science and technology could address key future challenges for society.

Against this backdrop of increasing support for R&D investment and training, the other major change in the political environment is the increasing degree of environmental related legislation. Increasing regulation, from both the EU and UK central government, in relation to the use of hazardous substances has significantly impacted on many traditional coating and surface preparation processes; requiring alternative solutions for traditional coating applications to be found. For example The European Union (EU) Directive on the Restriction of use of certain Hazardous Substances, restricts the use of Cadmium (Cd), mercury (Hg), hexavalent chromium (Cr (VI)), lead (Pb), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) [17, 18]. This legislation has had far reaching impact on the UK's electroplating industry.

Economic: The UK's macro-economic situation has recently seen a notable period of stability; characterised by stable economic growth in the economy as a whole of typically 2.0-3.5%. However, this macro-economic picture does not represent the trends within the manufacturing sector. Generally the sector has underperformed the wider economy, and the performance of industry sub-sectors has varied markedly due to sector specific factors, such as the impact of 9/11 on the aerospace sector and the impact of Chinese demand on the commodity markets.

It is difficult to generalise for the Surface Engineering sector, since it spans many diverse industries. However, across the manufacturing sector the emergence of the low cost economies as significant market players has had a major impact on the industry. The readiness, and arguably necessity, of the original equipment manufacturers (OEM's) to source globally, to take advantage of the low labour and material costs in the developing economies, has created a highly competitive market place. It is also evident that the technical complexity and quality standards within the emerging economies are rising rapidly and that the assumption that these economies would only be able to compete in low value high volume businesses is increasingly difficult to sustain. The implication of this is that UK companies will need to demonstrate clear product differentiation or regional benefit if they are to maintain their competitive position.

This position is exacerbated in some sections of the surface engineering industry, where there is a high concentration of customers in a particular area (such as the automotive industry) with highly competitive markets, and surface engineering overcapacity [19].

Socio-Cultural: The major socio-cultural impact on the industry is the globalisation of world markets as a result of the emergence of the low cost economies and the relatively low transportation costs for manufactured goods. Increasing competition has resulted in a change in purchasing policy in the UK away from long-term local agreements to open tendering processes, where the lowest cost supplier who is able to meet the quality and delivery requirements is selected. In many cases the OEMs actively co-operate with businesses in the emergent economies to ensure that they are able to meet the quality and delivery requirements.

Nevertheless, local sourcing does continue within the industry, driven by a range of factors, including: company and personal relationships; transportation costs; turnaround times; trust; common culture; technical competency; and of course price. The importance of these elements, even in a global market, can not be completely discounted and still have an important role in the market place.

Historically, the desire to "Buy British" has had some, albeit limited, currency within the market place. However, given the market factors now in play this factor can largely be discounted within business to business transactions, and can increasingly be discounted in business to consumer transactions.

Technological: The Surface Engineering industry in the UK has a wealth of technical resources at its disposal. This expertise is contained within both the academic science base, the research base and within industry. This has resulted in an industry that has continued to innovate and has maintained its ability to bring leading edge products to market. This high technology base has been sustained in spite of the migration and consolidation of significant sections of the supply chain outside of the UK. The retention of this high technology surface engineering capability within the UK is predominantly due to the presence of a range of prime end-users within the UK, who continue to require UK based support in the production of their components and systems. These companies cover a range of industry sectors including amongst others: aerospace; defence; oil and gas; bio-medical and automotive.

The retention of a high technology R&D infrastructure within the UK is entirely consistent with the current UK science policy, noted above, and several UK government initiatives have been undertaken to further stimulate technology transfer and the dissemination of best practise; such as the establishment of NASURF and the LINK Surface Engineering programme.

Political	**Economic**
Changes in government policy Rise in R&D expenditure Increased environmental legislation	Stable economic growth Emergence of low cost economies
Socio-Cultural	**Technological**
Globalisation of world markets Increased competition	Wealth of expertise Academic and research High technology capability

Table A1 PEST analysis

SWOT Analysis

Drawing upon both the secondary data analysis, extensive interviews and discussions, and the foregoing PEST analysis, a SWOT analysis has been performed of the Surface Engineering sector. The SWOT analysis will highlight the threats facing the sector, capture the key sector strengths and weaknesses, and define the opportunities that present themselves.

Threats: The sector faces four key threats: i) direct competition from low cost economies; ii) progressive outsourcing of the supply chain; iii) increasing regulation and legislation; and iv) increasing technical innovation in overseas markets. The first two issues are clearly closely related, but nevertheless separate.

As was clearly highlighted in the PEST analysis the low cost economies, such as China and India, are having a major impact on the traditional low value, low technology sections of the market: such as electroplating; carburising and nitriding. This is simply driven by the fact that the UK can not achieve competitive advantage in a global market, where entry barriers are low and price is the primary discriminator. This situation is further exacerbated by the increasing tendency of the OEMs to outsource sections of the supply chain to low cost economies. Many surface engineering processes are additive processes; i.e. they are applied to a semi-finished or finished component. Once a component is outsourced to a low cost economy there is a clear rationale for the additive surface engineering process to be carried out locally, especially where the process is a relatively low technology process. Although, it should be noted that the converse is true. Where high value, high technology components (i.e. where there is a high technology entry barrier) are retained within the UK, the additive processes tend to be retained also.

The third factor is the threat from increasing environmental regulation and legislation within the UK and European Union. Compliance with both mandatory and non-mandatory environmental standards is increasingly seen by the OEM's as a basic requirement for the supply chain. However, the progressively more demanding regulation on the control and use of hazardous substances is in many cases leading to a growing cost of compliance for those companies based within the European Union. These compliance costs are nowhere near as onerous in the developing economies and directly impact on the ability of European Union based companies to compete in a global market.

Finally, the fourth but highly significant threat that UK companies face is that of the rate of technical development within the emerging economies [20, 21]. Many of these economies, and especially China, are investing a significant proportion of their GDP in education, training and development. Combined with the advantages of establishing new manufacturing facilities on green field sites, the ability of these economies to work to Western standards of quality and control has dramatically increased, and it is increasingly inappropriate to argue that these economies can only compete in the high volume, low quality markets.

Weaknesses: From discussions and feedback during the review, it became apparent that the Surface Engineering sector continues to be a highly disparate sector and remains relatively fragmented. Although, there are a number of larger players within the marketplace, such as Bodycote, Sultzer Metco, etc., the sector is characterised by small and medium sized businesses often serving niche sectors. Some consolidation has taken place within the sector, but this has been relatively limited. An example of this is the consolidation of many companies involved in heat treatment, carburising and nitriding, into larger confederated business; such as the development of the Bodycote Group.

The fact that the sector does remain diverse and relatively fragmented means that the extent of technology transfer and the transference of best practise within the industry is limited. Often this is exacerbated by competitive rivalry within the sector. Similarly, although many of the companies are involved in R&D activities and do engage with the university sector, this tends to be on a single client basis and limited collaborative working is in evidence; although with some notable exceptions.

With regard to the coatings sector the UK no longer has a manufacturing base, of any note, for the production and development of coating equipment. Traditionally the loss of machine manufacturing capability has lead to the decline of associated R&D activities, and the migration of technology to the location of the machine manufacturers. In the Surface Engineering sector there is little evidence that the quality or quantity of surface engineering research has been significantly impacted by this situation. This is in part due to the relationship between the research centres and the end-users and the fact that the links with the machine manufacturing companies have been maintained.

Strengths: The industry as a whole is well established, and vast areas of expertise and knowledge exist within UK companies and organisations. These companies serve a diverse market place, and many of the premier organisations continue to re-invest heavily in research and product development. The willingness, and the need, for these companies to continually drive innovation is supported by a strong and dynamic university and research base within the UK. As detailed later in this report the UK has retained an extensive surface engineering related research base, and UK universities lead the world in the creation of innovative and ground breaking surface technologies, i.e. Hybrid sol-gel coatings, plasma assisted PVD coatings, nanolayer coatings and nanostructured PVD ceramic films.

As noted above the industry has retained strong relationships with the end-user community, which has helped limit the impact of global outsourcing. Examples can be found of coating and surface finishing being retained within the UK even though component manufacture has migrated overseas. This situation will continue where the surface engineering community can continue to demonstrate a clear differential in terms of quality, performance and responsiveness.

Opportunities: The sector continues to be supported by a vibrant research community within the UK, which appears to be maintaining its capability in spite of the wider changes in the economy. In part this is due to the continued existence of a strong OEM and supply chain infrastructure within the country, which is able to provide strategic direction to the research and development programmes, and provide technical and financial support. The effective exploitation of this extended infrastructure will enable companies to continue to innovate and differentiate themselves within the marketplace.

It has to be recognised that the ever increasing degree of regulation and legislation applied to the industry is also driving change and product innovation. As specific substances are either banned or have restrictions placed on their use, new surface treatment methods and coating technologies are developed. This enforced product development process has the ability to create higher entry barriers in the market place to companies in low cost economies (provided the legislation is effectively applied to imported goods), and can maintain the competitiveness of UK companies.

The realisation of the opportunities that present themselves is in part dependent upon companies maintaining their awareness of the marketplace, adapting at an early stage to impending changes in legislation and being able to exploit emergent technologies. The ability to do this requires companies to have ready access to the relevant information and advice. The provision and effective dissemination of high quality information, advice and best practise, which caters for the surface engineering industry as a whole, yet still offers sector specific expertise, can therefore have far reaching beneficial effects on the industry.

Threats	**Weaknesses**
Competition from low cost economies Outsourcing of the supply chain Increasing legislation and regulation Innovation in overseas markets	Highly disparate sector Limited technology transfer Limited collaborative working
Strengths	**Opportunities**
Well established industry Vast areas of expertise World leading university base Strong supply chain	Legislative driven changes Exploitation of the UK infrastructure Maintaining awareness in marketplace Exploitation of emerging technologies

Table A2 SWOT analysis

Appendix 6 - Description of Technologies

This section of the review will highlight and describe the main technologies that are affecting the Surface Engineering Industry as detailed by the findings of this review. The information contained within this section is abridged from previous work carried out by Matthews et al., for a more complete study, the reader is directed to [9, 11].

Electroplating

Electroplating is used for five main purposes: for corrosion protection; for aesthetic reasons; to form wear and abrasion resistance; to add material for dimensional increase; and as a step during multiple coating processes. Electroplating was noted to be one of the principal processes for corrosion protection, and is therefore still seen as having significant market potential. Despite shifts in the surface engineering industry to powder coatings and electro and electro-less plating, electroplating is still competing successfully in the marketplace.

Engineering Paints

This is a generic term for a group of coatings applied as a liquid, and cured by temperature or radiation into a solid. The 1990's saw the introduction of legislation which has brought about changes in the way metal finishers select and apply coatings. The Environmental Protection Act was aimed at reducing the emissions of volatile organic compounds (VOC's) into the air. Compliance with legislation such as this will obviously lead to increased costs, with Matthews predicting that the Environmental Protection Act will lead to an industry cost of an estimated €80bn. The UK continues to be well represented in the engineering paints sector, with UK companies highly competitive within the international arena.

Anodising

This is a method by which an adherent oxide film is formed on an aluminium, magnesium or titanium substrate via the electrolytic process. The oxide film gives improved properties in terms of wear and corrosion resistance, acts as a keying layer for paint, and in some cases to act as a form of crack detection. The industrial sectors which are the main users of anodising are construction, aerospace and automotive. The increased use of the light alloys will give rise to increased interest in anodising, especially in the aircraft and automotive sectors.

Vitreous and Stove Enamelling

This surface engineering method involves fusing a thin layer of glass containing pigmentation onto the surface of a substrate, usually steel or iron. This method is differentiated from painting in that a glassy or ceramic material is formed on the surface of the substrate. Vitreous enamelling is a mature industry with little or no product development. Some work is being carried out however on the enamelling of the cladding of buildings to provide an aesthetic and weather resistant appearance.

Heat Treatment and Case Hardening

Modification of the mechanical properties by surface heat treatment can be sub-divided into:

1. Stress relieving methods such as annealing, tempering etc;
2. Through-hardening processes such as quench hardening, ageing etc;
3. Surface hardening such as flame, induction etc;
4. Thermo-chemical treatments such as carburising; nitriding etc;
5. Other methods such as sintering, firing, glazing etc.

The industry as a whole was seen to be improving its image by moving away from environmentally harmful technologies. The drive towards computer controlled heat treatment facilities offer further improvements in the control and reduction of effluents and toxic materials usage. Improvements in methodologies for plasma nitriding and carburising were noted within the UK and EU research base, with Germany and France noted to have the lead in terms of commercial exploitation of plasma nitriding and carburising.

Powder Coating

This method involves applying the material in the form of a dry powder, to the substrate by either electrostatic means (which is limited to electrically conducting components), or by heating the component and plunging it into the powder, which may be a fluidised bed. Pre-treatments are often necessary before powder coating to ensure good adhesion. This method is distinct from paints as it uses materials in a dry powder form; the process offers superior adhesion over painting, and defects are easier to rectify.

Metal spraying, including Spray Painting

This section includes processes that fit into thermal spraying and welding, which deposit hard or soft metals or alloys. Within this category are:

1. Thermal spraying;
2. Plasma spraying;
3. High Velocity Oxy-Fuel (HVOF) spraying.

These technologies are in use mainly in the aerospace sector, with limited use in the printing, oil and gas, automotive and biomedical sectors.

Physical-Chemical Vapour Deposition

Ion assisted deposition methods use a vacuum coating process in which high energy ions bombard the surface of the work-piece to produce either an enhanced coating or a diffusion layer. The industry uptake of methods such as this in high volume engineering was noted by Matthews to be dependent on the achievements of cost and variability reductions.

Sol-Gel Processes

The process includes the bond formation of a colloidal suspension of solid particles (the sol); with a substance that contains a continuous liquid phase (the gel). Sol-gel coatings offer the advantages of mechanical toughness and flexibility in the matrix, while the coating has hardness and thermal stability properties. Sol-gel technologies provide functional hybrid surface pre-treatments and coatings which can offer alternative coating systems to traditional Chrome (VI) and Cadmium anti-corrosion coatings.

Appendix 7 – Surface Engineering training provision in the UK

Course title	Course content	Course duration	Suitable for / Qualifications	Provider
IGDS courses				
IGDS (Integrated Graduate Development Scheme) – Surface Science and Engineering	The MSc has 12 taught modules and a project. The PgDip has six taught modules and a project. Module delivery is shared between the partner universities.	Each module requires a few days of residential attendance. Normally 6-modules are taken per year. The project takes a further year.		Universities of Loughborough, Sheffield, Sheffield Hallam, Nottingham
IMF courses				
Foundation course	Electroplating Anodising Quality procedures	24 hours of attendance run over 12 weeks One evening per week	Tutored course for shop-floor operators and off-line personnel such as sales, laboratory and administrative staff Optional exam leading to the award of a certificate of competency	The Institute of Metal Finishers, the IMF
Technician & advanced technician Certification courses	Electroplating Pre- and post- treatments Anodising Electroless plating Conversion coatings Metal colouring Printed circuit boards Organic finishes	64 hours of attendance run over 32 weeks One evening/week, and a further 40 hours of private study or study by Distance Learning throughout	Tutored Course for the Technician Certificate Technical staff and more senior production people seeking a greater in-depth knowledge (Knowledge of chemistry to GCSE standard or a completed Foundation Course is preferred.) Final examination supported by continual assessment during the course leads to Certification. Technician Certificate plus a further examination can lead to International Certification.	IMF

Course title	Course content	Course duration	Suitable for / Qualifications	Provider
The Advanced Technicians Certificate	General principles (MF1) Plating practice (MF2) Powder coating application (MF2 Powder) The application of paints, lacquers and varnishes (MF2 Paint) Electrochemistry (MF3a) Material science (MF3b) Surface coating (MF3c) Process management (MF4)	Only available through Distance Learning	Completion of MF1 & MF2, or MF1 + MF2 Powder and MF2 Paint, leads to the Technician Certificate Completion of the further MF3 and MF4 modules leads to the Advanced Technician Certificate.	IMF
Short courses				
Surface Science and Engineering	Introduction: Philosophy of surface engineering, general applications and requirements. Corrosion processes Friction and wear Analytical techniques Surface engineering Coating manufacture	6 - 10 February 2006	Anyone with a good engineering or science background, preferably to degree or HND level.	Cranfield University
Annual Corrosion Engineering and Control Course	Concern degradation of all eng mater interpreting corrosion in its widest sense Studies embrace metal, natural stone, concrete, polymers and new advanced materials like semi and superconductors, ceramics and composites	five day intensive short course	Design engineers with a need to provide a corrosion input to a design team Maintenance engineers for assessing existing plant and specifying maintenance programmes Sales personnel Recently appointed graduates	University of Manchester Corrosion Protection Centre CAPCIS Ltd.

Course title	Course content	Course duration	Suitable for / Qualifications	Provider
Short courses				
General Surface Engineering	Surface Engineering Surface analysis			University of Surrey
Thermal spraying coating	Thermal spraying Coatings Corrosion protection	1-day seminar each in spring, summer and autumn		TSSEA (Thermal Spraying and Surface Engineering Assoc.)
Painting and coating	Institute of Corrosion qualification in coating inspection	Tailored training course	Painting Inspector Pipeline Coatings Inspector Cathodic Protection Technician Metallic Coatings Inspector Insulation Inspector Fire Proofing Inspector	Argyll-Ruane Ltd
Painting and coating	Practician's training	In-house training		Rolls-Royce

The information in the appendix is a partial list based upon the information available within public domain and the relevant web sites. This is therefore not a comprehensive list, but one indicative of the activities of the particular organisation.

Appendix 8 – R&D activity in the UK

HEI	Key Interests	Type of Coatings
Birmingham University Department of Metallurgy and Materials Prof T. Bell	Surface treatment to improve tribology of Ti and to improve the corrosion and wear of stainless steel	Thermal diffusion treatments Low temperature plasma nitriding and carburising of stainless steel
Cambridge University Prof B. Clyne	Improved spallation resistance of thermal barrier coatings Development of coatings for high temperature superconductors	PVD plasma spraying Liquid phase epitaxy (LPE)
Cranfield University National High Temperature Surface Engineering Centre Prof J. Nicholls	High temperature surface engineering Erosion and wear Oxidation and corrosion SMART coatings development	Electroplating plasma spraying (LVPS) EB-PVD thermal barrier coatings ITO and YSZ deposition by sputtering and EB-PVD
Imperial College Department of Mechanical Engineering Prof H. Spikes Department of Materials Prof A. Atkinson	Lubrication, friction, wear fatigue Damage of contacting mechanical and biological components Fuel cells	

HEI	Key Interests	Type of Coatings
Leeds University Corrosions and Surface Engineering Group Prof A. Neville	Corrosion and tribo-corrosion Lubrication and wear (elastohydrodynamic lubrication) Engine tribology Tribology in manufacturing	Lab based magnetron coating facility
Loughborough University IMPTE, Institute of Polymer Technology and Materials Engineering Prof D. Gabe	Surface and interface engineering Electrochemical surface modification Corrosion Electrochemical thermodynamics Surface engineering and finishing High speed electrodeposition using rotating cylinder electrodes	Electrodeposition of Pd-Co, Pd-Fe Copper electrodeposition
Manchester University Corrosion and Protection Centre Prof G. Thompson	High temperature oxidation Erosion corrosion Surface treatment, surface engineering and tribology to metals, alloys and composites and electronic materials Organic coating Aqueous and marine corrosion Coatings for corrosion control	Thermal barrier coatings – aluminide bond coats Alumina and silicon carbide, ceramics Zn-Ni and Zn-N-P electrodeposited layers CrN/NbN superlattice PVD coatings Chromate, Ce-Mo conversion coating Anodizing Al, Ti-Ta
Manchester Metropolitan University Centre for Materials Science Research Prof J. Verran	Corrosion protection Wear resistant coatings Surface modifications to improve cleanability and hygienic status	PVD coatings, TiAlN, AlZn Nano-thin film coating of alloys for cutting tools Surface topography: lubricant flow over bearings CVD hard diamond films for dental burs Biocompatible films

HEI	Key Interests	Type of Coatings
Newcastle University School of Chemical Engineering and Advanced Materials Prof S. Bull	Coatings and surface treatments Mechanical behaviour of multi layer optical coatings Tribology of coated systems Surface topography	Scratch testing of polymers and polymer coatings Analysing the mechanical properties of CNx coatings
Nottingham University Prof G. McCartney	Thermal spray coatings Vapour deposition techniques Gas-solid interactions Electrochemistry Tribology and wear mechanisms	HVOF thermal spraying of TiC based powders PVD/CVD multi layer TiNx-TiC ESAVD/AACVD for ceramic, polymer, inorganic/organic nano film and powder Electrodeposit and electroless deposit Thermal spray of SHS powders
Northumbria University Advanced Materials Research Institute Prof S. Datta	Surface engineering for corrosion and wear resistance Nano structure coatings Morphological studies of glaze layer on alloys and oxides on alloys DLC coatings	Diffusion thin film Sputtering Plasma Spraying
Oxford University Spray Processing Group, Department of Materials Polymers and Biomaterials Group	Vacuum plasma spraying of coatings and composites Atmospheric plasma spraying for Ti Polymer interfaces Corrosion protection of metal packaging	Organic coatings Electrodeposition of active coatings

HEI	Key Interests	Type of Coatings
Surrey University Advanced Surface, Particle and Interface Engineering Prof J. Watts	Organic coatings for corrosion prevention Surface Modification of polymers	
Salford University Prof D. Arnell	Unbalanced magnetron sputtering (UMS) Use of UMS to improve the tribological properties of materials	
Sheffield University Department of Engineering Materials Prof A. Matthews CellTran Ltd Prof R. Short Prof S. McNeil	Plasma treatment Plasma immersion ion implantation Plasma electrolytic oxidation (PEO) Duplex treatments (plasma/coating) Doped metal/metal nanocomposite coating Gas barrier coatings for polymer sheet Deposition of Alpha phase alumina at low temperatures Test and evaluation of coatings – friction, wear, adhesion and corrosion behaviour	Thermal barrier (yttria stabilised zirconia) coatings and NiAl bond coats
Sheffield Hallam University Advanced Composites and Coatings Research Centre Prof C. Breen Nanotechnology Centre for PVD Research Prof. P. Hovsepian	Thin film solar cells HIPIMS Corrosion and wear resistant coatings High temperature oxidation resistant coatings High speed cutting (HSC) tools Dry lubricants characterization: XPS	CdS/CdTe, CuO/Cu_xS, CdS/$CuInSe_2$ Nanoscale multi layer PVD CrN/NbN TiAlCrYN, TiAlN/CrN TiAlN/VN and C/Cr TiAlYCrN/VN multi layered coatings Niobium coatings

HEI	Key Interests	Type of Coatings
Southampton University Engineering Materials and Surface Engineering Prof R. Wood Prof F. Walsh	Wear corrosion interactions Solid particle erosion Flow effects on corrosion Coating selection, electroplating and anodised Characterisation of plasma electrolytic oxidation coatings Development of fuel cells	CVD boron carbide coated systems CVD diamond coatings HVOF Al alloy and NAB based coating
Swansea University Dr N. McMurray Dr D. Worsley	Coatings for corrosion protection	

The information in the appendix is a partial list based upon the information available within public domain and the relevant web sites. This is therefore not a comprehensive list, but one indicative of the activities of the particular organisation.

RTO	Dept/Centre	Key Technology	Type of Coating	Sector
AEA Technology		Modelling of effects of wind and travel over track Modelling of people evacuation Wheel/rail interaction and adhesion Crash worthiness Accident investigation Analysis and investigation		Rail Environment Portable power
CERAM CSMA	Powder Group The Centre for Surface and Materials Analysis	High energy gas atomisation for metal powders Mech alloying of metallic/metallic oxide powders Spray deposition Corrosion Adhesion failure Contamination analysis and quantification Tribology	PVD, CVD Plasma nitriding, carburising Electroplating Magnetron sputtering	Automotive Aerospace Medical Paints and coatings Tribology and oil Performance coatings
NPL	Surface Technology Focus Point Sensors and Functional Materials Surface and Nano-analysis	Wear of materials and coatings Characterisation and performance measurement for thick coatings Measurement of surface degradation Surface residual stress measurements		Multi-sectoral
QinetiQ		SMART materials Nano-materials Metal Powders Electronic Materials		Medical Aerospace Automotive Sport and Leisure
TWI		Arc spraying Arc surfacing Flame spraying HVOF spraying Plasma spraying Sol-gel coatings Strip cladding	Thermal barrier coatings MCrAlY coatings	Oil and Gas Aerospace Automotive Rail Medical