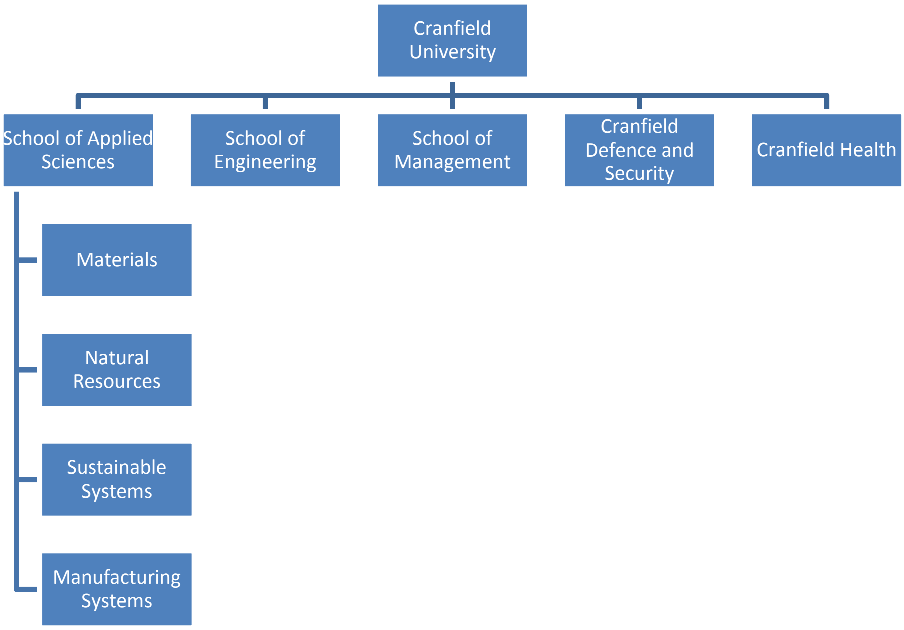
Cranfield Innovative Manufacturing Research Centre

Key Data	
Time Period	**10 Years total** Phase 1 (2002-2006); Phase 2 (2007-2011)
Total Value of EPSRC Grant	**£16.2m total** Phase 1 £6.5m; Phase 2 £9.7m
Other Funding *(Direct leverage of additional research funding specific to IMRC)*	**£12.7m total** (78% of EPSRC funding) of which £5.6m cash + £7.1m in kind support. • 94% UK private sector (£11.9m) • 6% UK public sector (£0.73m)
Projects	90 projects funded to date Average size: £180k (EPSRC funding); £321k (All funding)
Current Staff	32 staff funded by IMRC grant
PhD Students	109 PhDs completed to date + 72 current PhD students *(funded by IMRC grant or supervised by staff involved in IMRC)*
IMRC journal publications	426
Patents granted	2
Key Sectors of Focus	Generic / cross-sectoral
Current Research Themes / Specialisms (Phase 2)	• Manufacturing Technologies ○ - Precision technologies ○ - Metals processing ○ - Composite processing • Product Service Systems (helping manufacturing companies to add services to their traditional products).
Examples of key economic impacts	**1. Reducing UK government defence costs** - indicative estimate that £13 million p.a. could be saved from new cost estimation methods to improve the process of costing support and service contracts in the defence sector. **2. Helping UK defence manufacturers to win more business in global defence markets** - indicative estimate that £200 million p.a. additional business could be generated from new cost estimation methods. **3. Helping BAE Systems to win a share of the growing global market for UAVs**. A 1% share of this market would represent about £74 million per annum (based on the projected size of the market in 2020). **4. Reducing the cost of pipeline construction**. A new hybrid laser / arc welding process has the potential to reduce the cost of pipeline construction by up to £1 billion per annum. It also has the potential to transform many types of fabrication process undertaken by manufacturing companies.
Key value added aspects demonstrated by the IMRC	• More strategic focus for research • Greater responsiveness to industry needs • Continuity of research • Multi-disciplinary working • Facilitation of industry networks

Overview of the Cranfield IMRC

The Cranfield IMRC was established in 2002 and has become the main strategic vehicle through which the University plans and manages research to support high value manufacturing in the UK.

A diagram of the organisational structure of the University, which helps to explain the structure of the IMRC, is shown below.



The IMRC currently has two research themes as explained below. The Manufacturing Technology theme underpins research in the Materials Department within the School of Applied Sciences. The Head of the Materials Department (Professor David Stephenson) is the IMRC Programme Director.

The Materials Department has 5 Research Centres (Precision Engineering, Welding Engineering, Composites, Micro-systems & Nanotechnology and Surface Science and Engineering). The Manufacturing Technologies theme is based mainly around the first three of these, although there are links with other research teams. The Theme Leader is Professor Stewart Williams who is the Head of the Welding Engineering Research Centre.

The Product-Service Systems (PSS) theme requires a high level of multi-disciplinary working and although it is led by a member of staff in the School of Management (Dr Mark Johnson), it involves staff across the Schools of Management, Applied Science and Engineering.

Cranfield University is different to other universities in that a large proportion of its income is from the private sector (only 14% of income is from the funding councils). It has a long history of working with industry and hence research and emerging impacts from the IMRC predominately relate to improving business competitiveness, rather than inputs into public policy and the delivery of public services. However, it is important to highlight that elements of the research programme have been influential in the public policy and services arena. For example, Professor Steve Evan's IMRC-funded work on resource sustainability which is about the importance of not only re-use and recycling in waste management strategies, but also waste reduction across industry. This work led to Professor Steve Evans being appointed as a Specialist Advisor to a House of Lords Inquiry on Waste Management in 2008 and his research continues to be influential in shaping policy in this area

The IMRC programme has become more strategic as it has evolved. The Phase 1 programme inherited a number of legacy projects and there was a tendency to approve projects on individual merit rather than as part of an overall strategy. Phase 2 has a more strategic approach with each theme (and sub-theme) having a strategy and projects fitting around this.

The IMRC programme has also re-focussed on more basic research as it has evolved. Phase 2 has a greater emphasis on basic research to underpin more generic product and process improvement across the manufacturing sector. However, as far as possible projects bring on board potential users of the research – who are willing to make modest contributions - in return for being kept abreast of knowledge that could be useful to them in the longer term. This is illustrated by the follow-up Phase 2 project in the pipe welding case study.

IMRC Research Strategy

The **IMRC Phase 1 Programme** (2002-2006) had three research themes:

- **Manufacturing Infrastructure** – this theme covered Performance Measurement, Cost Engineering and Product Development and was stopped at the end of Phase 1.
- **Manufacturing Enablers** – this covered Innovation Management, Partnering and Supply Chains and was also stopped at the end of Phase 1.
- **Manufacturing Technology** – this theme has continued into the Phase 2 programme and covers three broad areas as shown below:

Area	Activities
Precision Technologies	Precision machining, ion beam and plasma processes, machine tool design, micro-engineering and metrology
Metal Processing	Welding, laser processing, additive manufacture, stress engineering and process modelling
Composite / Material Processing	High performance lightweight materials, nano-composites and hybridised structures

The table below provides a breakdown of Phase 1 projects and funding by research theme. It shows that Phase 1 funding was split approximately 50:50 between technology-related and management-related research.

Phase 1 - Theme	Number of Projects	EPSRC Funding (£)	Design	Technology	Management
Manufacturing Technology	22	3.5m (54%)	-	100%	-
Precision Technology	8	1.5m			
Metal Processing	3	0.8m			
Composite Processing	11	1.2m			
Manufacturing Infrastructure	22	1.6m (25%)	-	-	100%
Manufacturing Enablers	13	1.4m (21%)	-	-	100%

EPSRC organised an international review of IMRCs midway through the Phase 1 programme. The key conclusions from the review relating to the Cranfield IMRC were:

- The research being undertaken as part of the manufacturing technology theme was 'world-leading' and should be continued.

- The research being undertaken as part of the manufacturing infrastructure and enablers themes needed to be less about responding to the short term needs of individual companies and more about 'setting the agenda' and providing a lead for future manufacturing developments. This led to a different emphasis on management-related research in the Phase 2 programme as explained below. However, it is important to highlight that elements of this research programme have been influential. For example, Professor Steve Evan's work on resource sustainability referred to earlier.

The **IMRC Phase 2 Programme** (2007-2011) has two research themes.

- **Manufacturing Technology –** this covers the same three areas of research as in Phase 1 (precision technology, metals processing and composite processing) which were commended by the EPSRC international panel as being world-leading.
- **Product Service Systems –** this is management-related research as in the Phase 1 programme but with a more strategic focus, taking on board the recommendations from the international review. Increasingly, manufacturing companies are providing services linked to their products. For example, almost 50% of revenue at BAE Systems is generated from support and service contracts (approximately £11 billion per annum). However, there has been relatively little academic research on product service systems (PSS). The IMRC was seen as an ideal vehicle for developing a PSS academic research programme and when the opportunity arose to bid for IMRC Phase 2 funding in 2006, Cranfield reconfigured the IMRC so that approximately 50% of funding would be directed to this area. It is the IMRC which has made this research programme possible because servitisation is a major change management process for the manufacturing sector. It cannot be understood and promoted through isolated, individual projects. There needs to a programme of research that has sufficient critical mass to enable different facets of the system to be investigated.

The table below provides a breakdown of projects and funding by research theme. It shows that Phase 2 funding is split approximately 50:50 between technology-related and management-related research (as for Phase 1).

Phase 2 - Theme	Number of Projects (To Date)	EPSRC Funding (£) (Budget Allocation)	Design	Technology	Management
Manufacturing Technology	23	5m (52%)	-	100%	
Precision	11	1.7m	-		
Metal	7	2.2m	-		
Composite	5	0.6m	-		
Product Service Systems	22	4.7m (48%)	-		100%

IMRC Programme Management

The management arrangements for Phase 2 are set out below. Each theme has a research strategy prepared by the relevant lead Research Centre:

- **Manufacturing Technology -** The Research Theme Leader is Professor Stewart Williams. Three sub-strategies related to the three strands of research are led by Research Champions: Professor Paul Shore (Precision Engineering), Professor Stewart Williams (Metals Processing) and Professor Ivana Partridge (Composite Processing).
- **Product Service Systems** - The Research Theme Leader is Dr Mark Johnson.

The strategies are approved and monitored by the **IMRC Centre Management Committee**. This meets every two months (or more frequently if required) comprising an internal group of senior academics (plus finance / admin staff) chaired by the IMRC Programme Director (Professor David Stephenson) and including the Research Theme Leaders and Champions mentioned above. Strategies are updated and reviewed on an on-going basis by the relevant research centres with oversight from the IMRC Centre Management Committee.

Project proposals for IMRC funding are submitted to the IMRC Centre Management Committee for approval. The quality of the proposed research, how the research will support the IMRC strategy and its potential economic impact are the primary selection criteria. Consideration is also given to the level of industry interaction. It is usual for projects to have some industry funding (80% fall into this category) but this is not mandatory as sometimes there is a justification for fundamental research to facilitate more applied research in the future.

External strategic oversight of the IMRC programme as a whole is provided through the **IMRC Management Steering Committee** which meets twice a year. It comprises members drawn from industry, academia and the university and is chaired by Professor Hamid Mughal of Rolls Royce.

Economic Impact Analysis

Funding and Leverage

According to data provided by Cranfield University for this exercise:

- A total of **£12.7 million (cash and in-kind contributions)** has been provided by partners for research at the IMRC. Thus, for every £1 provided by the IMRC, £0.8 has been contributed by other partners.
- 94% of partner contributions are from private sector companies. This reflects the point made earlier about the strong links with industry at Cranfield University.
- Companies such as BP, Bombardier, Jaguar and Airbus are among the key collaborators for the IMRC.

Delivering Human Capital to the Labour Market

Approximately 121 people have worked in, but now left, the IMRC – including research students. Over half of these people have been recruited to work in industry which represents a significant transfer of skills from academia to industry.

Approximate proportion of former staff/researchers in:	
Academia	21%
Industry	56%
Government	1%
Unknown	22%

The case studies illustrate how skills have sometimes been transferred into industry through research staff and students being recruited by partner and related companies:

- **Automated pipe welding processing case study** - 3 PhD students and 8 Masters Students that have had involvement in the research have been recruited to work in industry, mostly in the UK oil and gas sector. Several of these former students are directly involved in development of advanced technology for UK-based oil and gas companies, hence providing a significant resource in UK-based development of advanced technology.

- **Airframes for the next generation of unmanned air vehicles case study** – 7 staff worked on the project on a part-time basis. Of these 3 are now working in industry (2 for UK composites materials suppliers and 1 for Airbus in Bristol).

- **Porous ceramic air bearing technology case study** – the MSc student who worked on the project was recruited by the industrial collaborator and worked with the company for a couple of years before moving to another precision engineering company.

Impact Case Study Selection (detailed case studies below)

Five case studies have been selected by DTZ in conjunction with the IMRC and EPSRC to illustrate the economic impact of research funded through the Cranfield IMRC as shown in the table overleaf. These case studies have been selected on the basis of the agreed shortlisting criteria, as follows:

- Demonstrates a range of types of economic impact as defined by BIS
- Offers convincing evidence of significant tangible impact
- Demonstrates the added value of the IMRC model
- Provides good coverage of the different research themes within the IMRC
- Provides good coverage of relevant sectors.

Overall, the case studies are reasonably representative of the types of work that the IMRC is engaged in, whilst focusing on examples which demonstrate significant impact and added value. The key points relating to case study selection are as follows:

- The manufacturing technology theme represents over 50% of the EPSRC funded IMRC programme (Phase 1 and Phase 2). Three distinct areas of research have been funded as part of this theme and there is a case study relating to each.

- Management-related research accounts for the other 50% of the EPSRC funded IMRC programme. We considered including Professor Steve Evan's work on resource sustainability as a case study but this is a broad programme of research which could not be summarised comprehensively in a short case study. The PSS theme is a new, innovative area of management research and it has taken time to develop a research strategy for this work. Consequently, most projects have only been running for 1-2 years and so there has been limited time to generate significant economic impact. However, one of the case studies on PSS cost modelling provides a good illustration of the potential economic impact from this research.

Case study	BIS Impact Headings[1]	Added Value Aspects	IMRC Research Theme	Sector
Product Service Systems – Cost Modelling	Improve existing business competitiveness Informing government policy	Strategic approach Critical mass	Product Service Systems	Defence / Aerospace
Affordable manufacturing processes for smart composite UCAV airframes	Improve existing business competitiveness	Strategic approach Critical mass	Composite Processing	Aerospace

Case study	BIS Impact Headings[1]	Added Value Aspects	IMRC Research Theme	Sector
Automated pipe welding system	Improve existing business competitiveness	Responsive to needs of industry Continuity	Metals Processing	Oil & Gas
Porous Ceramic Air Bearing Technology	Improve existing business competitiveness	Responsive to needs of industry Continuity	Precision Technologies	Precision Production Equipment
Microprobe: MEMS Micro-Coordinate Measurement System	Improve existing business competitiveness	Strategic approach Critical mass	Precision Technologies	Precision Production Equipment

[1] Most projects have attracted R&D investment through industry contributions and developed human capital so these are not listed as a type of impact as they would apply to all the projects

Added Value of the IMRC Model

The added value of the IMRC funding model (as illustrated through several of the economic impact case studies selected) is:

- It **enables a more strategic approach** to the development and management of research. It is difficult to develop a strategic programme of research through responsive mode funding as you have no control over what will be funded. Panels assess project proposals on the basis of individual merit rather than as part of a broader strategic goal. IMRC funding has enabled Cranfield to identify key manufacturing research priorities which combine its research strengths with the needs of its user community in the manufacturing sector. This is clearly illustrated through the PSS Cost Modelling case study. Cranfield identified a key manufacturing issue where relatively little academic research had been undertaken and the IMRC enabled it to structure a research programme around this issue. It can be difficult to make a breakthrough if you have to bid for funding on a project by project basis. Greater impact will be achieved from tackling the issue as a whole rather than through one-off individual projects.
- It enables the university to be **more responsive to the needs of industry**. If a particular research opportunity arises, it has the resources to pursue it immediately. There is no need to apply for funding and wait for the outcome. Sometimes this can make the difference in being able to pursue an exciting research opportunity with an industry partner. This is illustrated through the porous ceramic air bearing technology case study where Cranfield was able to engage with an industrial collaborator on a knowledge exchange project which would have been difficult to fund through normal research funding channels, despite the relatively small sum involved.
- It **enables greater continuity**. Under responsive mode funding, there is a danger that a promising area of research cannot be continued because key staff leave (or are redeployed) before further funding is secured or subsequent proposals relating to the research are not approved. IMRC funding means that a promising area of research can be developed over a period of time. For example, the follow-on project on the hybrid laser arc welding process in the pipe welding case study.
- It encourages **more multi-disciplinary working across the university**. Prior to the IMRC, manufacturing research tended to be undertaken by individual research teams. The IMRC encourages collaboration between research teams and disciplines. For example, when the

university was developing the PSS programme for IMRC 2, two ideas factories / sandpits were organised to bring academics across the university together (with external representatives as well) to identify research priorities and to develop initial research ideas into projects. There are now joint projects between academics in the School of Applied Sciences and the School of Management which would never have happened before the establishment of the IMRC. This is a step-change from the ‘research silos’ that used to exist in the past.

- It can facilitate the creation of **industry networks** that can be engaged in a particular area of research. This is illustrated through the PSS cost modelling case study where a range of companies and industry bodies collaborated with the IMRC on a new area of research. IMRCs have greater flexibility to respond and adapt research so that more, and different, partners can be brought on board.

Case Study 1: Whole Life Cost Modelling of Product-Service Systems (PSS-Cost)

Key Facts	
Time Period	2007-2010
IMRC Funding	£393,000
Other Funding	£749,000 (cash and in-kind)
Collaborator(s)	BAE Systems, GE Aviation, Lockhead Martin UK, Rolls Royce, Galorath, Cognition Europe, Ministry of Defence, Association of Proposal Management Professionals, Society of British Aerospace Companies.
IMRC Research Theme	Product-Service Systems
Research Output	The project developed new innovative cost estimation methods to improve the process of costing support and service contracts in the defence and aerospace sectors. These have been developed into four prototype tools.
Pathway to Economic Impact	**Via Collaborator(s) -** The MoD is funding further development work on using the obsolescence tool. Collaborating companies say the research has given them a new insight into costing techniques they can use to grow the UK's share of the global defence market.
Actual Economic Impact	None. Too early for actual impacts to have been achieved.
Potential Economic Impacts	**Reducing UK government defence costs** - indicative estimated saving of £13 million per annum. **Helping UK defence manufacturers to win more business in global defence markets** - indicative estimate that £200 million per annum could be generated in additional business.
Sector Focus	Defence and Aerospace (initially)

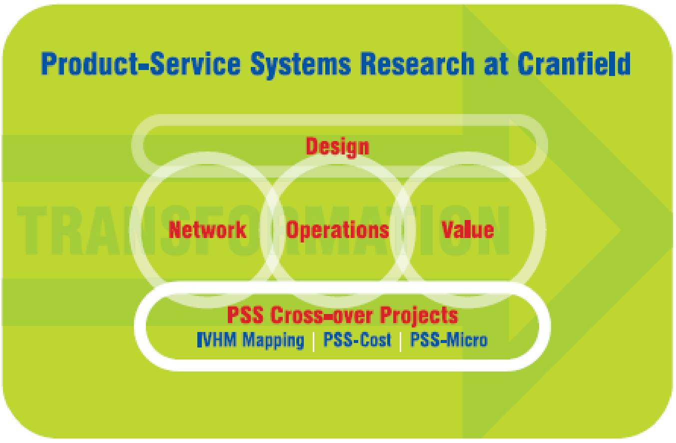
Context

Increasingly, manufacturing companies are providing services linked to their products. For example, almost 50% of revenue at BAE Systems is generated from various types of support and service contracts (approximately £11 billion per annum), as opposed to equipment manufacture. Increasingly, manufacturing companies in western economies are seeking to embrace 'servitisation' as a means of differentiating and growing their business in a highly competitive and price sensitive global economy. However, there has been relatively little academic research on product service systems (PSS).

The IMRC was seen as an ideal vehicle for developing an academic research programme on PSS and when the opportunity arose to bid for IMRC Phase 2 funding in 2006, Cranfield reconfigured the IMRC so that approximately 50% of funding would be directed to this area. It is the IMRC which has made this research programme possible because:

- Servitisation is a major change management process for the manufacturing sector. It cannot be understood and promoted through isolated, individual projects. There needs to a programme of research that has sufficient critical mass to enable different facets of the system to be investigated. For example, how PSS systems are designed, how the service can be promoted as a value proposition and what activities need to be undertaken to deliver these new services. All these different facets of PSS are inter-linked and there is no point in developing a good understanding of one without an equally good understanding of the others. Thus, the Cranfield PSS research programme has a number of core themes as shown below along with a number of cross-cutting projects that span all the thematic areas.

- Servitisation spans many areas of research. It requires a range of skills and expertise which can be difficult to put together when people are used to working in individual research centres / departments. The IMRC brings these people together and facilitates the internal collaboration across research centres that are needed for a programme of this kind.



Many IMRC PSS projects are still at a relatively early stage. However, one project on PSS cost modelling has been completed with elements being put into practice. Further information on this project is provided below.

The IMRC Project

A major servitisation challenge is being able to predict, at the point of signing a contract, the whole life costs of providing a service 10, 20 or maybe 30 years into the future. The challenge has become greater as the scale and complexity of product service contracts has increased.

The purpose of the project was to develop a set of techniques and tools to improve the process of predicting realistic whole life costs for support and service contracts in the defence and aerospace sectors at the bidding stage. The project attracted considerable interest and support from industry. Defence contractors have cost estimation teams that specialise in this type of work but information-sharing between them is restricted because they are competitors. The project represented an opportunity to bring key players together and to pool collective expertise, to produce new tools that would improve cost estimation for support and service contracts in the defence sector.

The project developed new innovative cost estimation methods that have been translated into four prototype tools. This case study focuses on the ‘obsolescence tool’ since this is most advanced in terms of being used by industry and government. This is, therefore, only part of the final impact that is likely to be achieved from the project.

Obsolescence is a major issue and cost for the MoD. Typically, MoD is procuring not just a piece of equipment (say a helicopter) but a piece of equipment and a related availability contract (which guarantees the helicopter will be available to fly to particular requirements say 95% of the time). Obsolesence is a major risk in costing availability contracts as the contract duration is typically 5-30 years, longer than the life cycle of many components – particularly electronics, electromechanical and electrical (EEE) components whose life cycle is becoming increasingly shorter. If an electronic system needs to be replaced, it is often not possible to replace it like-for-like. Instead, a new system may need to be sourced / designed at considerable expense.

As it is so difficult to predict obsolescence costs in availability contracting, they are normally excluded from the contracting process. Instead, MoD issues separate contracts to resolve obsolescence issues as and when they occur. This means it is difficult for MoD to manage its costs – it is expensive and often consumes unplanned money leaving MoD unable to fulfil other commitments. It also means defence contractors have little incentive to design equipment with a view to minimising obsolescence issues.

MoD wants to transfer the risk of resolving obsolescence issues to industry, with all obsolescence costs incorporated into availability contracts in the future. However, a stumbling block is the lack of any reliable technique for estimating obsolescence costs and the lack of agreement across defence contractors on how it could be done. This could simply encourage companies to incorporate large contingency sums into availability contracts to cover themselves for future obsolescence costs. Thus, MoD might gain greater control over its costs, but the overall level of cost could rise.

One of the key achievements of the project is that it has developed a prototype tool for estimating obsolescence costs for defence-related availability contracts – which has broad endorsement across the sector (albeit that further development and calibration is required). The MoD is funding a further two-year project at Cranfield to enhance obsolescence management processes in defence. Part of this is looking at developing the obsolesence tool into a robust model that can be used to predict EEE obsolescence costs (known as the EEE Force Tool). The intention is that it will then become a mandatory requirement to incorporate EEE obsolescence costs into availability contracts, with all contractors expected to use the EEE Force Tool to so there is a standard approach across the sector.

Stuart Kelly, Obsolesence Manager Policy Lead at MoD comments:

"The input from the Cranfield team was invaluable on this project. In particular, the ability of the university to bring a network of businesses to the project. We expect the EEE Force Tool which has been informed by this research to give us greater control of equipment support costs in terms of the risk from obsolescence and to save costs in the future."

Assessment of Economic Impact

The economic impact of the project can be quantified as follows:

- Reducing UK government defence costs
- Helping UK defence manufacturers to compete more effectively in global defence markets and increase market share.

Reducing UK Defence Costs

There is potential for defence costs to be reduced in two ways:

- The contingency sums that defence contractors would have incorporated into availability contracts to resolve obsolescence issues will be lower because the tool enables the costs to be predicted with greater accuracy and confidence.
- Defence contractors will have a greater incentive to design equipment with a view to minimising obsolescence issues.

As a result of the Government's 2010 Spending review, funding for Defence will stand at £33.8 billion in 2011/12 and fall to £33.5 billion in 2014/15. Procurement and support of military equipment consumes around 40% of annual defence cash expenditure[1], which represents around £13.4 billion per annum. DTZ has estimated that if use of the EEE Force Tool reduced this annual cost by even 0.1% (a tenth of one percent), the annual saving would be in the region of £13 million per annum. This is only an indicative DTZ estimate since it is too early to estimate cost savings accurately at this stage.

Helping UK Defence Manufacturers to Compete More Effectively in Global Markets and Increase Market Share

Increasingly, governments across the world need greater control over costs and have, or will be, moving to full availability contracting which incorporates obsolescence costs. As mentioned above, it is possible that defence contractors respond to this by making a large contingency provision against future costs that they cannot predict with any certainty or confidence.

The IMRC research enables UK defence companies to predict obsolescence costs with more certainty and companies like BAE Systems believe it will help them to reduce the contingency element of availability contracts and therefore to be more competitive in winning international defence contracts. BAE Systems is presently working to refine and calibrate the obsolescence tool by applying it to two large existing projects. It is not accurate enough as yet to be used as a stand-alone tool but BAE Systems is incorporating some of the techniques and concepts which emerged from the research into its existing in-house costing models.

Worldwide military expenditure totalled $1,531 billion in 2009 according to Stockholm International Peace Research Institute. The USA has the largest defence budget at $661 billion, much larger than the second highest budget of China at $100 billion. Procurement of weapons and equipment is included in the total military expenditure. Military expenditure is expected to continue to grow despite the global economic downturn. Global defence spending is forecast to grow to $2,010 billion in 2014[2], suggesting that military equipment procurement will also continue to grow.

In 2006 the combined arms sales of the 100 largest arms producing companies totalled $315 billion. This is an under-estimate of the global market for defence equipment but DTZ has estimated that if the cost modelling techniques helped British companies to gain an additional 0.01% of this market (a hundredth of one percent), it would generate an additional $315 million (£200 million) per annum. This is only an indicative DTZ estimate since it is too early to estimate economic return accurately at this stage.

Annual Business Survey data shows that the average turnover per employee in the manufacture of weapons and ammunition stood at £188,733 in 2008. In the manufacture of air and spacecraft related machinery the turnover per employee stood at £211,046, suggesting that a £200 million contract would support 948 jobs in the UK (assuming all the work was undertaken in the UK). Both industries have a multiplier of 1.9, suggesting there would be significant wider economic benefits from spending associated with these contracts.

Phil Wardle, Business Improvement Manager at BAE Systems comments:

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[1] http://www.mod.uk/NR/rdonlyres/78821960-14A0-429E-A90A-FA2A8C292C84/0/ReviewAcquisitionGrayreport.pdf

[2] http://www.articlesnatch.com/Article/Defense-Spending--Global-Industry-Guide---Market-Research-Reports-On-Aarkstore-Enterprise/1387608

"The research project created a trusted network of companies with people sharing not only explicit, but tacit information, that would not normally have been disclosed. There is much work still to be done but it has given all the companies involved a new insight into costing techniques that can be used to grow the UK's share of the global defence market."

Position without IMRC Funding

When assessing the economic impact of research it is important to consider the rationale for IMRC investment in the research. The only rationale for IMRC investment in research should be to address a market failure of some kind. In other words, there should be a reason why industry itself would not fund the research and why public intervention through the IMRC is justified.

In this case, it was far from clear at the start of the project that the work would provide useful information for industry. There was a feeling that PSS cost modelling was something that industry had been doing for a long time and which academic researchers were only beginning to investigate. At the beginning the academic researchers perhaps needed industry more than industry needed the academic researchers. The outcomes of the project were uncertain and industry would not have been prepared to pay the full cost of this research.

At the start of the project there was only one true industry collaborator. However, as time progressed others began to see that the project represented a unique opportunity to bring key industry players together to pool collective expertise and to possibly get a fresh insight on PSS costing issues from highly respected academics at Cranfield. Overall, the core funding and cross-industry co-ordination provided by the Cranfield IMRC created a focus on the specific research topics studied by the project. This allowed more rapid progress to be made through the exchange of new concepts and the opportunity to test ideas within a collaborative framework that would not otherwise have existed.

Consultees

The following people were consulted and reviewed a draft of the case study:

- Professor Rajkumar Roy – IMRC, Cranfield University
- Stuart Kelly – Obsolesence Manager Policy Lead, MoD
- Phil Wardle, Business Improvement Manager, BAE Systems

Airframes for Next Generation Unmanned Air Vehicles (UAVs)

Key Facts	
Time Period	Stage 1 project: 2004-2007 Stage 2 project: 2007-2010 (not IMRC funded)
IMRC Funding	Stage 1: £135,000 Stage 2: N/A
Other Funding	Stage 1: FLAVIIR (BAE Systems and EPSRC) £154,000 Stage 2: FLAVIIR (BAE Systems and EPSRC) £85,000
Collaborator(s)	BAE Systems
IMRC Research Theme	Manufacturing technology – composites technologies
Research Output	New materials and techniques that can be used to construct a very lightweight (and resilient) airframe structure suitable for a UAV at a much reduced cost to current BAE Systems airframes for combat aircraft. Costs reduced by 55% which translates into a potential cost saving of around £400,000 for a large 1 tonne UAV airframe.
Pathway to Economic Impact	**Via Collaborator(s) -** BAE Systems is currently evaluating the technologies developed through the research and believes a lot of this work will see its way into a commercial product in the future. The timescales for developing any new aircraft are long so will take time for actual economic impact to be realised.
Actual Economic Impact	None. The timescales for developing new aircraft can be 10-15 years so it will take time for the research to find application in an actual commercial product.
Potential Economic Impacts	**Helping BAE Systems to win a share of the growing global market for UAVs**. DTZ estimates a 1% share of this market would represent about $115 million (£74 million) per annum (based on the projected size of the market in 2020). **Supporting innovation and product design in other sectors**. The techniques are applicable not only to UAVs but also to other industries where composite frames are widely used. For example, in automotive and rail.
Sector Focus	Aerospace

Context

Unmanned air vehicles are the fastest growing sector of the aerospace industry. Worldwide sales are expected to double over the next decade. This represents a great business opportunity for the UK and in 2004, a £6 million research programme called FLAVIIR was set up (jointly funded) by BAE Systems and EPSRC to look at technologies that could be used to make the next generation of civilian and combat UAVs. The grand challenge for the research programme was *to develop technologies for a maintenance free, low cost UAV without performance penalty over existing craft*.

BAE Systems has a number of prototype UAVs in the pipeline but is not a key player in the commercial UAV market at this point in time. The FLAVIIR research programme was intended to help BAE Systems to develop a next generation of market-leading UAVs so it could become a competitive player in this area and capture a share of the growing UAV market globally.

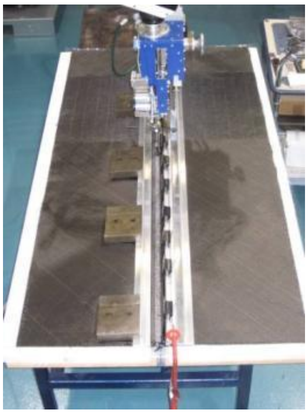
The FLAVIIR research programme involved nine university partners and was divided into various different parts such as control systems, electromagnetic research and so on. Cranfield University had lead responsibility for manufacturing-related research. The focus of the research was on **reducing both manufacturing and maintenance costs.** Current carbon fibre airframes used for combat aircraft are extremely light but require expensive materials involve a labour intensive production process which is slow (and hence expensive). The airframes of small aircraft are also fragile and easily damaged. BAE Systems required a low cost, highly damage resistant airframe structure, with near equivalent structural capability as for combat aircraft, as an urgently required technology to enable it to compete effectively in the global UAV market.

IMRC funding enabled Cranfield to increase the level of resources that could be devoted to this research. It enabled a larger project to be undertaken than otherwise would have been possible. This was considered to be a good use of IMRC funding because there was a good fit between the project and the research interests of Cranfield's composites research centre – it was a way of increasing broad knowledge of carbon fibre structures – working with an industry partner. It also ensured the project had greater critical mass to achieve real impact.

The IMRC Project

The purpose of the **Stage 1 project** was to investigate and develop a low cost, damage resistant wing structure for a UAV, with equivalent or lower weight than the current high-cost, carbon fibre composite used to make combat aircraft. The project demonstrated that a very lightweight (and resilient) airframe structure suitable for a UAV could be constructed at a much reduced cost compared to current BAE Systems airframes for combat aircraft. The three main areas of research are explained below:

- **Reducing Materials Costs**: Researchers at Cranfield University worked with a Cambridge-based chemicals company, Hexcel Composites, to develop a low cost carbon fibre reinforcement. It provided equivalent stiffness and near equivalent strength to current BAE Systems materials for both primary and secondary aircraft structure at around half the cost.
- **Improving the Efficiency of the Manufacturing Process:** For example, a moulding process was developed to suit the above material which could produce accurate parts within 0.1 mm tolerance enabling wing structure assembly without further costly machining.
- **Improving the Efficiency of the Assembly Process:** For example, a carbon fibre stitching technique and robotic application system was developed and applied to carbon fibre performs (a perform is a material that has undergone preliminary shaping but is not yet in its final form). It was found that this provided sufficient joint strength to eliminate high cost metallic fasteners in constructing a durable wing box structure.



The robotic tufting system

The techniques developed offer potentially very substantial damage resistance and manufacturing cost savings compared to current materials and process technologies. These cannot provide equivalent structural performance to current supersonic fighter aircraft structures, but offer equivalent or greater structural performance to more general purpose airframe structures with greatly increased damage resistance and greatly reduced manufacturing cost.

A stage 2 project was funded to construct a prototype UAV wing structure using the materials and manufacturing innovations conceived in the Stage 1 research. This was funded wholly through the FLAVIIR programme. The project was completed in February 2010 and successfully demonstrated the effectiveness of the techniques in a large test structure – moving the research on to TL3-4 level. To raise the level above TL4, will require scaling-up the work undertaken at Cranfield and investment in full-scale large structural testing.

BAE Systems is now evaluating the technologies developed through the research project. BAE Systems plans to launch a commercial civilian UAV product within the next few years and it is possible that some of the work undertaken at Cranfield could feed into this. BAE Systems is also working to meet MoD requirements for UCAVs. The intention is that research is developed to TL 6-7 by 2015-2020 with a view to launching a commercial product from 2025-2030. It is not possible to say definitively that the Cranfield research will be developed to be part of this process. However, Clyde Warsop, BAE Systems FLAVIIR Programme Manager comments:

"There is a seriously good chance that a lot of this work will see its way into a commercial product, if not in the short-term, then in the long-term. Some aspects of the research may fall by the wayside but a good proportion of the research will find application."

Assessment of Economic Impact

The economic impact of the project can be quantified as follows:

- Reducing the cost of constructing a high quality UAV airframe
- Helping BAE Systems to win a share of the global market for UAVs
- Supporting innovation and product design in other sectors.

Reducing the Cost of Constructing a High Quality UAV Airframe

As part of the research, the cost of constructing a wing frame 4m long, 3m wide and 0.3m deep using the FLAVIIR / IMRC techniques was compared to the equivalent cost for an existing BAE Systems aircraft wing frame, distinguishing between a higher-cost and lower-cost design. **The cost analysis showed that manufacturing costs were reduced by 55% compared to the lower-cost wing structure and 63% compared to the higher-cost wing structure.** This translates into a potential cost saving of around £400,000 for a large 1 tonne airframe. In addition, the damage resistance of the FLAVIIR / IMRC airframe is greatly increased and hence maintenance costs should be greatly reduced.

Helping BAE Systems to win a Share of the Global Market for UAVs

Teal Group is an aerospace and defence market analysis firm based in the USA. The seventh edition of its sector study, *World Unmanned Aerial Vehicle Systems, Market Profile and Forecast 2010*, examines worldwide markets and requirements for UAVs.[3] It states that UAVs continue to be the most

[3] http://www.thefreelibrary.com/Teal+Group+Predicts+Worldwide+UAV+Market+Will+Total+Over+$80+Billion...-a0217929875

dynamic growth sector of the world aerospace industry. It estimates that UAV spending will more than double over the next decade from current worldwide UAV expenditures of $4.9 billion annually to $11.5 billion. The Teal Group cites the most significant catalyst to this market as the enormous growth of interest in UAVs by the US military. The study suggests the US will account for 76% of worldwide R&D spending on UAV technology over the next decade, and about 58% of procurement. Europe will be the second largest market followed by Asia Pacific.

DTZ has estimated that if the manufacturing techniques developed through the project helped British Aerospace to gain a 1% share of this market, this would represent about $115 million (£74 million) per annum (based on the size of the market in 2020). Annual Business Survey data shows that the average turnover per employee in the manufacture of weapons and ammunition stood at £188,733 in 2008. In the manufacture of air and spacecraft related machinery the turnover per employee stood at £211,046, suggesting that an additional £74 million in UAV contracts could support around 350 jobs in the UK. Both industries have a multiplier of 1.9, suggesting there would be significant wider economic benefits from spending associated with these contracts.

Of course, these are only indicative DTZ estimates since it is too early to assess the level and type of market share BAE Systems could capture in the future.

Supporting Innovation and Product Design in Other Sectors

The research is applicable not only to UAVs but also to other industries where composites are widely used and where the techniques could find application. For example, in automotive and rail. Thus, its impact could be wider and greater than that reported above but it is too early to quantify at present.

Position without IMRC Funding

When assessing the economic impact of research it is important to consider the rationale for IMRC investment in the research. The only rationale for IMRC investment in research should be to address a market failure of some kind. In other words, there should be a reason why industry itself would not fund the research and why public intervention through the IMRC is justified.

The rationale for EPSRC funding a strategic research programme such as FLAVIIR with BAE Systems is to encourage companies to engage in more fundamental, longer-term research with the university base. Since the outcomes from such research are uncertain and the timescales for realising any commercial return are relatively long, such research would not be undertaken, or would be would be undertaken at a reduced scale, without public intervention. The value of collaborative research with the university base is that it provides a fresh perspective on different challenges. For example, Cranfield could bring experience from the automotive sector on constructing low-cost carbon fibre structures to this project.

IMRC funding enabled Cranfield to increase the level of resources that could be devoted to this research. It enabled a larger project to be undertaken with sufficient critical mass to achieve real impact. The research would have gone ahead without IMRC funding but the scale of impacts achieved might have been reduced or the timescales lengthened.

Consultees

The following people were consulted and reviewed a draft of the case study:

- Andrew Mills - Principal Research Fellow Composites Manufacturing
- Clyde Warsop - Executive Scientist, BAE Systems

Pipe Welding System for the Construction of Oil and Gas Pipelines

Key Facts	
Time Period	2003-2006
IMRC Funding	£700,000
Other Funding	£1.5 million
Collaborator(s)	BP, TransCanada (oil and gas pipeline operator in North America), Pipeline Research Committee International
IMRC Research Theme	Manufacturing technology – metals processing
Research Output	A new tandem arc welding process was developed which reduced the number of 'fill passes' required to weld two sections of pipeline together from 12 to 3, representing a 400% increase in productivity. An Austrian company that specialises in manufacturing welding equipment translated the demonstrator equipment developed as part of the research project into a commercial piece of equipment. However, it is likely that this would have happened without IMRC funding as it had been agreed before the establishment of the IMRC, that BP and Trans Canada would fund this part of the project. IMRC funding was used to broaden the scope of the project to look at other innovative pipe welding technologies that could reduce pipeline construction costs in the future. The 'root pass' is the first join when two sections of pipeline are welded together - the most time-consuming and costly part of welding two pieces of pipeline together. The IMRC research project resulted in the development of a new hybrid laser arc welding system which, in laboratory conditions, improved the speed of the 'root pass' welding process four-fold. A second project has been funded as part of IMRC 2 to develop this work with industrial collaborators who see the potential of the technology. The project (NEGALP) runs from 2008-2011 and has £875,000 funding of which about 50% is from the IMRC and 50% from industrial collaborators.
Pathway to Economic Impact	Via Collaborator (s)
Actual Economic Impact	**Cost savings to industry** - the tandem arc welding process is increasingly being adopted across the pipeline construction sector. DTZ has calculated that use of the technology means potential savings of up to $1.65 billion per year – which equates to around £1 billion per annum but this cannot be attributed completely to IMRC funding. **Retention of UK-Based R&D** - one of the UK's main competitive advantages in retaining the R&D functions of large international companies such as BP is the opportunity to work on innovative technologies with world-class researchers in UK universities – such as on this project. The majority of the UK's 252,000 full-time equivalent research community work within the private sector. Projects such as this one help to maintain that base. It is too early for actual economic impact to have been achieved from the hybrid laser arc welding system.
Potential Economic Impacts	**Cost savings to industry** - the hybrid laser / arc welding process has the potential to further reduce the cost of pipeline construction by up to £1 billion per annum. It also has the potential to transform many types of fabrication process undertaken by manufacturing companies. However, it is still early days for this technology and it would be premature to quantify potential economic impacts at this stage.
Sector Focus	Oil and Gas

Context

The research was motivated by the need to develop more efficient and effective welding technology for long distance oil and gas pipelines. It is hugely expensive to construct long distance pipelines. For example, at the time the project was conceived, BP was looking at the construction of a new trans-Alaska gas pipeline which would link into the network in Canada at an estimated cost of $16 billion.

BP being keen to explore new welding processes that could significantly reduce the cost of pipeline construction and consulted a group of industry expects for guidance. Cranfield University had an idea for a new welding process based on tandem technology and BP set Cranfield a challenging target – to develop and field test a tandem pipeline welding system within 18 months. BP had one other requirement: the field trails had to be performed in winter under Arctic conditions. This was because the process had to be suitable for use on the proposed long-distance trans-Alaska gas pipeline. BP was aware that it would only realise benefits from the research if the technology was freely available to pipeline installation companies. Hence, the emphasis was on making the technology freely available rather than keeping it within BP.

The IMRC had just been established at the time of these discussions with BP. Cranfield used IMRC funding to broaden the scope of the project, to look at other innovative pipe welding technologies that could reduce pipeline construction costs.

The IMRC Project

The project had three main components:

- Development of a new tandem arc welding process
- Development of a new hybrid laser / arc welding process
- Development of processes for welding high strength X80 and X100 steel as opposed to lower strength X70 steel (which tends to be used currently), to reduce the amount of steel required to construct a pipeline and reduce cost.

Development of a Tandem Arc Welding Process

A new tandem arc welding process was developed which reduced the number of 'fill passes' required to weld two sections of pipeline together from 12 to 3, representing a 400% increase in productivity. Essentially, two sections of pipeline could be welded four times as quickly as previously and there were also savings on the equipment and personnel required to undertake the process.

A demonstration prototype of the tandem welding system.

Cranfield worked with Fronius International, an Austrian company that specialises in manufacturing welding equipment, to translate the demonstrator equipment developed as part of the research project into a commercial piece of equipment. Fronius was considered to have the best specialist expertise for the task. The tandem welding system is now incorporated into Fronius' product range and is being used by major welding supply companies.

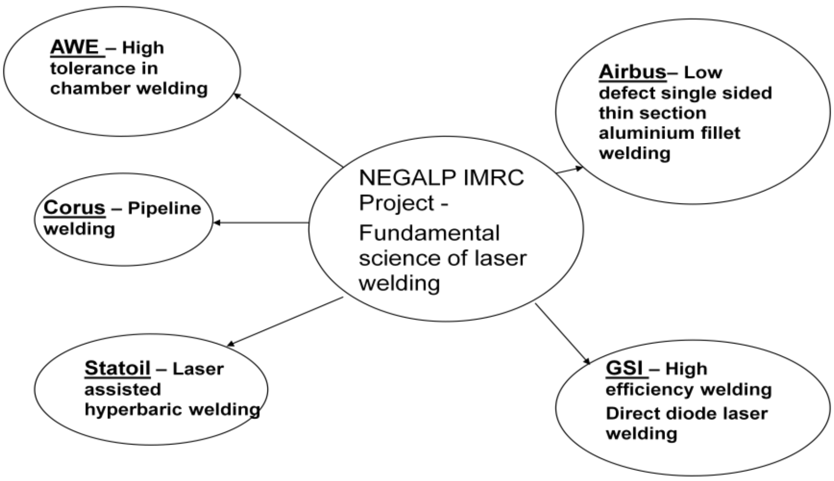
Commercial product developed by Frorinus International based on the Cranfield tandem welding system.

The current position is that the technology is increasingly being adopted across the pipeline construction sector, although it is too early to say that it is standard industry practice as yet.

Development of a New Hybrid Laser / Arc Welding Process

The 'root pass' is the first join when two sections of pipeline are welded together. This is the most time-consuming and costly part of welding two pieces of pipeline together. The IMRC research project resulted in the development of a new hybrid laser arc welding system which, in laboratory conditions, was able to improve the speed of the 'root pass' welding process four-fold.

However, it was too early to develop this process into a commercial product. The researchers needed to understand more about the fundamental science of laser welding to develop a robust and reliable hybrid laser / arc welding process for industrial use. A second project has been funded as part of IMRC 2 to undertake this work in conjunction with industrial collaborators who see the potential of the technology for their business in the future. The project (NEGALP) runs from 2008-2011 and has £875,000 funding of which about 50% is from the IMRC and 50% from industrial collaborators (shown below).



Next steps will be to undertake more practical feasibility studies with industrial collaborators like Corus / Tata Steel and if there is sufficient market potential – to commercialise the technology. However, this is some way in the future.

Development of a Process for Welding High Strength X80 / X100 Steel

Finally, the project developed processes for welding higher strength steel so that less of it could be used in constructing pipes and considerable savings achieved. Industry is now increasingly adopting the higher strength X80 steel. For instance, all the pipelines constructed in the last few years in the UK have used X80 steel. However, internationally, the use of lower strength X70 steel is still quite widespread.

Assessment of Economic Impact

The economic impact of the project can be assessed as follows:

- Reducing the cost of oil and gas pipeline construction
- Developing a new income stream for a company
- Helping the UK to retain the R&D functions of large international companies
- Helping to improve fabrication processes across UK manufacturing.

Reducing the Cost of Oil and Pipeline Construction

Cranfield University estimated that the tandem arc welding process had the potential to save $0.5 billion from the projected $16 billion cost of constructing the trans-Alaska gas pipeline (a 3% saving). Cost savings had the potential to rise to around 9% of costs if the other processes developed through the research were also adopted.

It is important to stress that the main application for the technology is in large diameter, long-distance pipelines. The technology would not achieve the same efficiencies in other types of pipeline construction.

Onshore oil and gas pipeline spend totalled $55 billion in 2010[4]. Between 2011 and 2015 a forecast of $193 billion will be spent on onshore pipeline projects worldwide according to energy business analysts Douglas-Westwood[5]. It is not known what proportion of this spend relates to large diameter, long-distance pipelines but it seems that a significant proportion falls into this category as Douglas-Westwood comment *"The most significant growth in length installed and associated Capex will be seen for pipelines with diameters in the range of 54 inches or larger. This trend is driven by a global growth in long large diameter export and cross-country pipeline projects to help meet the challenges of growing energy demand, shifting natural gas production concentrations and energy supply security."*

As explained, the tandem arc welding process is increasingly being adopted across the pipeline construction sector. DTZ estimates that use of the technology means potential savings of up to $1.65 billion per year (3% of $55 billion) – which equates to around £1 billion per annum. The savings could rise to up to $5 billion per annum (£3 billion per annum) if the other technologies developed through the project are adopted in the future.

4 The Oil & Gas Pipelines Market Analysis 2010-2020 – Aarkstore Enterprise

5 Onshore Pipelines Report 2011-15 – Douglas-Westwood

This translates into significant cost savings for British oil and gas companies such as BP. For example, BP are one of a number of partners involved in the Baku-Tibilisi-Ceyhan 1,768 km pipeline transporting oil from the BP-operated ACG oilfield in the Caspian Sea to the Mediterreanean port of Cehyan. The pipeline cost $3.9 billion, suggesting that the tandem arc welding process could have saved all of the partners involved an estimated $117 million (£75 million) on that project alone.

Developing a New Income Stream for a Company

Fronius International has benefited from the research but the company is not located in the UK and this is not generating additional economic activity in the UK.

Helping the UK to Retain the R&D Functions of Large International Companies such as BP

As countries such as China and India produce greater numbers of highly qualified scientists, there will be pressure for companies to off-shore R&D functions to lower cost locations. In particular, large international companies where investment tends to be more mobile. OECD[6] estimates suggest that China has 1.6 million full-time equivalent researchers, more than the USA (1.4 million) and the UK (252,000). India has an estimated 189,000[7] researchers and is expected to continue to grow over the next decade. The UK will never be the cheapest location for R&D. One of its main competitive advantages in retaining the R&D functions of large international companies is the opportunity to work on innovative technologies with world-class researchers in UK universities – such as on this project.

Expenditure on R&D in the UK was £25.6 billion in 2008 (Source: ONS, 2010), with 62% of R&D being undertaken by the private sector, 27% undertaken by higher education, 5% by the Government and 6% from other sources. This suggests that the majority of the UK's 252,000 full-time equivalent research community work within the private sector. Projects such as this one help to maintain that base.

Helping to Improve Fabrication Processes and Productivity across the UK Manufacturing Sector

The hybrid laser / arc welding process has the potential to transform many types of fabrication process undertaken by manufacturing companies. However, it is still early days for this technology and it would be premature to quantify potential economic impact before work on actual applications has begun.

Position without IMRC Funding

When assessing the economic impact of research it is important to consider the rationale for IMRC investment in the research. The only rationale for IMRC investment in research should be to address a market failure of some kind. In other words, there should be a reason why industry itself would not fund the research and why public intervention through the IMRC is justified.

In this case, it had been agreed before the establishment of the IMRC that BP and Trans Canada would fund the tandem arc welding and welding processes for high strength steel components of the project.

IMRC funding was used to broaden the scope of the project to look at other innovative pipe welding technologies that could reduce pipeline construction costs in the future (the hybrid laser arc welding

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[6] http://www.oecd.org/dataoecd/9/44/41850733.pdf

[7] ILO

process). The outcomes of this were uncertain and the research would not have been funded by industry alone.

Consultees

The following people were consulted and reviewed a draft of the case study:

- Professor Stewart Williams – IMRC, Cranfield University
- Mr David Yapp – IMRC, Cranfield University
- Dr Norman Sanderson – BP, Advisor Pipeline Technology

Porous Ceramic Air Bearing Technology

Key Facts	
Time Period	2006/07
IMRC Funding	£30,000
Other Funding	In-kind (partner time and equipment)
Collaborator(s)	Westwind Air Bearing Spindles (SME based in Poole, Dorset)
IMRC Research Theme	Manufacturing technology – precision technologies
Research Output	The research showed that a new porous ceramic material developed by Cranfield improved the performance of an air bearing system in a Westwind product.
Pathway to Economic Impact	**Via Collaborator(s)** – once Cranfield has demonstrated that it has a secure and stable process in place for manufacturing the material, Westwind plans to work with the university in putting this new material into air bearing systems for its more advanced high speed spindles. Via intermediary organisation (IKC) – further research is being supported in the Ultra Precision and Structured Surfaces IKC to explore the use of this material for other types of air bearing systems in other applications.
Actual Economic Impact	Too early for actual impacts – although positive developments in the pipeline.
Potential Economic Impacts	**Helping to safeguard the competitive position of a UK manufacturing company** - the collaboration with Cranfield IMRC has given the company access to a new material which has the potential to simplify the process for manufacturing the company's more advanced high-speed spindle range. This will help to reduce manufacturing costs and improve the competitiveness of this product range going forward. It is too early as yet to quantify the scale of cost savings that could be achieved but it will be important in helping to keep this type of manufacturing activity in the UK. **Enhancing the competitive position of the high-precision production engineering equipment sector in the UK** - as a result of the IMRC project which demonstrated the use and value of the new porous ceramic material in a commercial air bearing system, further research is now being undertaken within the Ultra Precision and Structured Surfaces IKC to explore the use of this material for other types of air bearing systems in other applications.
Sector Focus	High precision machine tools / production engineering equipment

Context

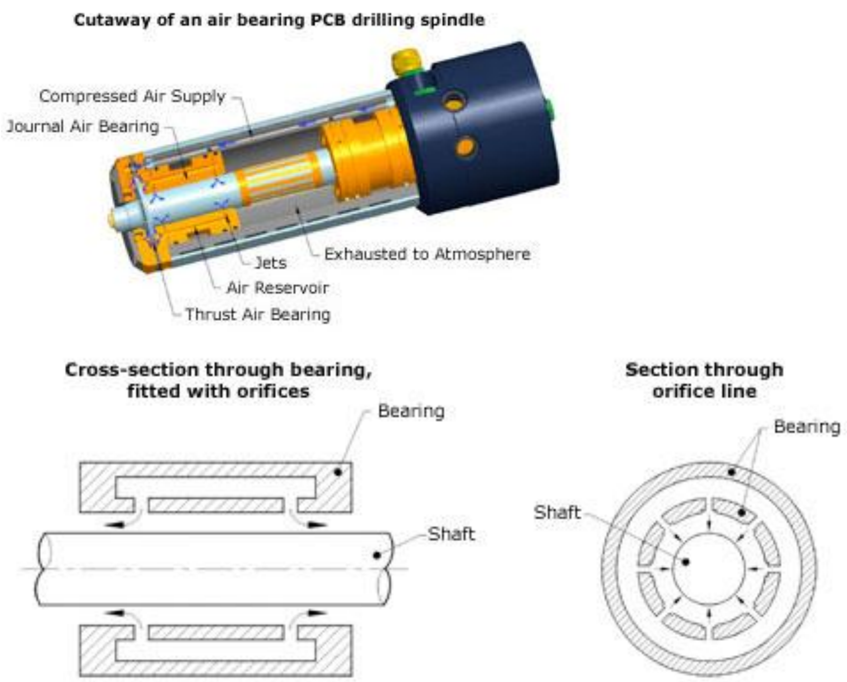
A bearing is a mechanism that separates moving parts in machinery allowing free rotation with minimal friction. There are various types of bearing. An **air bearing** is an advanced system where air acts as the lubricant that separates two surfaces in relative motion.

Air bearing technology offers real advantages to applications where the demand for accuracy, speed and reliability is crucial. One such application is in the manufacture of **air bearing spindle (drill) systems.** These are used in the manufacture of printed circuit boards (among other things). Only air bearing spindles are capable of achieving the accuracy required in this production process where drill diameters as small as 50 microns are now used. In addition, only air bearing spindles are capable of running at the required speeds to ensure acceptable tool life.

An Air Bearing Spindle

Air Bearing Spindles being used to
Manufacture Printed Circuit Boards

The air bearing system within a spindle / drill is shown overleaf. It is one of the key components of the product.



Prior to the establishment of the IMRC, researchers at Cranfield University had developed a new 'porous ceramic' material (through research contracts funded by EPSRC) and were interested in exploring its application in industry. In particular, it was felt that the new material could be beneficial in making air bearing systems because:

- It could achieve smoother machine operation (this is important, for example, in servowriting devices used by disk drive manufacturers)
- It could simplify the process of making air bearing systems and hence reduce manufacturing costs.

Westwind Air Bearing Spindles is the world's largest air bearing spindle / drill manufacturer. 80+% of its business relates to air bearing spindles for printed circuit board manufacturing, with the remainder in niche market applications such as automotive coating, semiconductor manufacturing equipment and other machine tool industries where performance needs are outside the scope of conventional bearing technology, including disk hard drive testing.

The flexibility of the IMRC funding model enabled Cranfield University to agree a small ‘proof of concept’ demonstrator project with Westwind to explore the application of the new porous ceramic material in a Westland product.

The IMRC Project

IMRC funding paid for a MSc research student to work with Westwind for a year on using the new porous ceramic material in an air bearing system for a piece of scanning equipment used by computer disk manufacturers. This was a product area that Westwind was interested in developing at the time to diversify its product range. The demonstration project proved that the porous ceramic material improved the performance of the air bearing system in this application and gave Westwind a means of creating a range of next-generation products in this area.

Market conditions mean Westwind has not, as yet, taken forward product development in this area. However, the IMRC project has convinced the company that the new porous ceramic material has significant potential across its product line. In particular, it is felt that it has potential to considerably simplify the process for manufacturing the company’s more high-speed spindle range. This could help to reduce manufacturing costs which would improve the competitiveness of the products in a highly competitive global market going forward. Once Cranfield has demonstrated that it has a secure and stable process in place for manufacturing the material (ie. that it has the ability to make consistent batches), Westwind plans to work with the university in putting this new material into air bearing systems for its more advanced high speed spindles. This product range will represent about 25% of the turnover of Westwind. A collaborative project is planned with a view to launching products that use this new material in 2-3 years time.

Assessment of Economic Impact

The economic impact of the project can be assessed as follows:

- Helping to safeguard the competitive position of a UK manufacturing company
- Enhancing the competitive position of the high-precision production engineering equipment sector in the UK.

Helping to Safeguard the Competitive Position of a UK Manufacturing Company

Westwind Air Bearing Spindles is the largest global manufacturer of air bearing spindles. It has around a 60% share of the global market in this area. It is based in Poole, Dorset where it employs around 200 people (including contract staff). Functions undertaken at Poole include design, manufacturing (of more specialised, lower volume products) and corporate / administration. The company also has a plant in Shanghai, China where higher volume products are manufactured. The turnover of the company as a whole is approximately £20-25 million per annum.

The company operates in a competitive environment and expects significant competition to emerge in the future, particularly from Asia. It cannot compete on price – its future depends on developing products which use cutting-edge technology that is difficult to copy. The collaboration with Cranfield IMRC has given the company access to a new technology which has the potential to simplify the process for manufacturing the company’s more advanced high-speed spindle range. This will help to reduce manufacturing costs and improve the competitiveness of this product range going forward. It is too early as yet to quantify the scale of cost savings that could be achieved but it will be important in helping to keep this type of manufacturing activity in the UK.

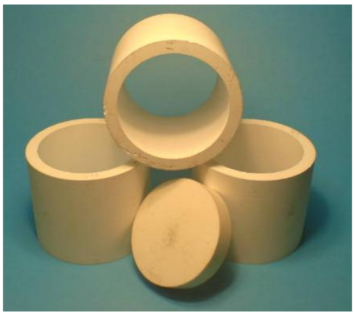
Chris Gerrard, R&D Manager at Westwind Air Bearing Spindles comments:

"*There is no way we could have developed this technology ourselves. The IMRC project represented an ideal opportunity to work together. We do not have the knowledge and expertise to develop new materials but it is one of the ways in which we can innovate and develop our products. Cranfield had a new material but no route to take it to market. This project was a golden opportunity to work together and we certainly intend to continue this relationship*."

Supporting Innovation and Growth in the High-Precision Production Engineering Equipment Sector in the UK

In 2007, Cranfield University bid successfully to EPSRC for funding to establish an Integrated Knowledge Centre (IKC) in Ultra Precision and Structured Surfaces (along with other partners). IKCs promote the early commercialisation of world class research by combining within a single integrated centre the best research with the best business opportunities to accelerate its exploitation.

As a result of the IMRC project which demonstrated the use and value of the new porous ceramic material in a commercial air bearing system, further research is now being undertaken within the IKC to explore the use of this material for other types of air bearing systems in other applications. The porous ceramic bearing material is being developed as radial (below left) and axial "pad" (below right) bearings. The "pad" bearings are being incorporated into advanced micromachining systems being built at Cranfield and commercial exploitation opportunities are being explored.



Examples of finished porous ceramic components

This on-going work will help to support innovation and new product development in the elements of the high-precision production engineering equipment sector in the UK. The machinery and equipment manufacturing sector as a whole is worth £32 billion and employs 200,000 people in the UK. Only a proportion of this will relate to high precision equipment but it shows there is considerable potential for the research project to play a role in supporting an important industrial sector in the future.

Position without IMRC Funding

When assessing the economic impact of research it is important to consider the rationale for IMRC investment in the research. There should be a reason why industry itself would not fund the research and why public intervention through the IMRC is justified.

In this case, there was a need for proof of concept research to demonstrate the commercial potential of a new technology. Studies of this kind which are high-risk with no guaranteed outcomes are difficult to fund from the private sector, hence the need for public intervention. Westland confirms it would not have embarked on this research without the resources and expertise provided through the IMRC.

However, the economic impact arising from this project cannot be attributed solely to the IMRC. The underpinning research on developing the new porous ceramic material was undertaken through earlier EPSRC contracts and the work on using the material in other parts of the high-precision production engineering sector is being supported via EPSRC through the IKC. The IMRC is only part of a package of public support which is responsible for the economic benefits outlined above.

Consultees

The following people were consulted and reviewed a draft of the case study:

- Professor Paul Shore – IMRC, Cranfield University
- Professor David Stephenson – IMRC, Cranfield University
- Chris Gerrard - R&D Manager, Westwind Air Bearing Spindles

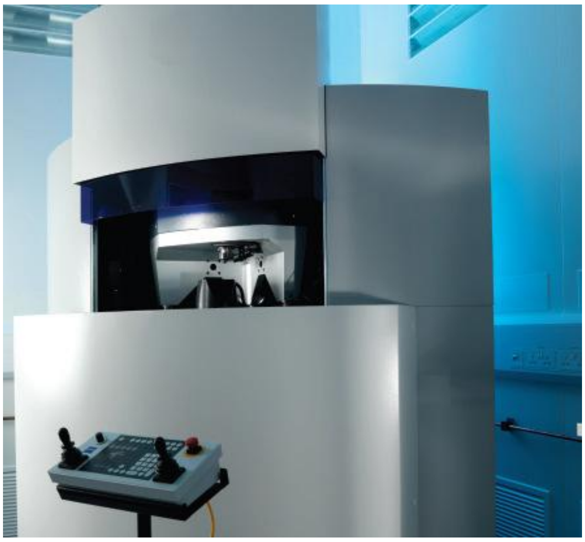
A New Generation of Micro Co-ordinate Measuring Machines (CMMs)

Key Facts	
Time Period	2008-2009
IMRC Funding	£34,000
Other Funding	£52,000
Collaborator(s)	National Physical Laboratory
IMRC Research Theme	Manufacturing technology – precision technologies
Research Output	As the manufacturing sector has evolved to produce products with ever-decreasing dimensions, the need for accurate micro-scale measurements of 3-D structures has increased. The National Physical Laboratory (NPL) designed a unique, new 'vibrating' microprobe. The Cranfield IMRC helped to translate this design into a practical device.
Pathway to Economic Impact	Licensing agreement with industry partner (via NPL)
Actual Economic Impact	Licence agreement is currently in the process of being negotiated.
Potential Economic Impacts	**Development of a new micro CMM product range**. **Facilitating more accurate measurement in manufacturing processes involving micro / nano scale parts**. Measurement plays an important role in some of the UK's largest manufacturing industries such as automotive and medical equipment. A National Measurement Office publication reports that an additional £6 million spent by Government on measurement technology delivers up to £410 million of economic impact annually. Thus, the implication is that the £1 million+ expenditure on this research project (of which the Cranfield IMRC input was a small, but vital, part) will generate additional economic activity in the region of £68 million per annum in the longer term.
Sector Focus	Cross-cutting. All manufacturing processes involving micro / nano scale parts. For example, micro-electromechanical systems, automotives, medical and optical devices.

Context

Metrology is the science of measurement. Metrology performs a key role at the interface between research and manufacturing. The aerospace, commercial nuclear power, medicine, medical devices and semiconductors sectors all rely on metrology to translate theoretical science into mass produced reality.

The development of Co-ordinate Measuring Machines (CMMs) dramatically improved metrology in manufacturing environments. However, as the manufacturing sector has evolved to produce products with ever-decreasing dimensions, the need for accurate micro-scale measurements of 3-D structures has increased. Initially micro-scale probes (styli) for mainstreamed CMMs were developed to respond to this need. The last decade has seen specialised micro-CMMs being developed and there are currently a small number of commercial products on the market.



A Micro-Coordinate Measuring Machine (CMM)

The National Measurement Office (NMO) is an Executive Agency of the Department for Business, Innovation and Skills (BIS). The NMO is responsible for the National Measurement System (NMS) which promotes good measurement practice as important for consumer protection. It also improves the competitiveness of industry as it is vital to have accurate measurement in manufacturing processes.

The NMO is responsible for funding scientific measurement research programmes at the UK's national measurement institutes to underpin the NMS. One of these is the National Physical Laboratory (NPL) which is the UK's internationally recognised National Measurement Institute.

BIS Department for Business Innovation & Skills

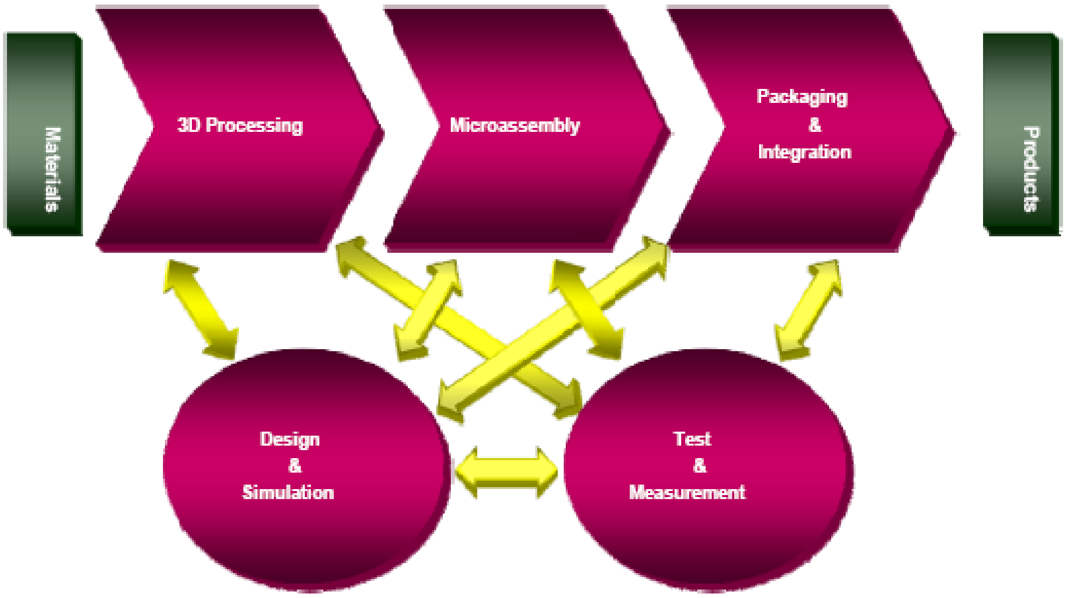
National Measurement Office

NPL National Physical Laboratory

The NPL is an international centre of excellence in developing and applying the most accurate measurement standards. NPL research, and other research around the world, suggested that current micro-CMMs were capable of higher accuracy. CMM manufacturers had tended to simply miniaturise current probe technology to build CMMs capable of ever smaller micro-scale measurements. In order to meet the demands of industry, NPL was convinced that a new paradigm in probe design was required.

Thus, approximately 5 years ago, NPL embarked on a programme of research (mainly funded by the NMO and in the region of £1million) to address this issue. This led to a unique, new 'vibrating' microprobe being designed. The challenge for NPL became how it could turn the design into an actual device, which is how IMRC involvement in the project began.

EPSRC's Grand Challenges programme aimed to encourage cross-working between IMRCs on major research challenges with the potential for significant impact on the manufacturing sector. The 4-year **3-D Mintegration Grand Challenge programme** was one of four grand challenge programmes approved by EPSRC. It involved joint working across four IMRCs (Cranfield, Cambridge IfM, Loughborough (LIMCRC) and Nottingham) in conjunction with three other research centres – Greenwich University, Brunel University and NPL. The 3-D Mintegration programme commenced at the end of 2005 and aimed to revolutionise the way that small micro / nano products and components were manufactured. As shown below, there were a number of aspects to the programme, one of which was **accurate measurement of micro / nano 3-D structures and components**.

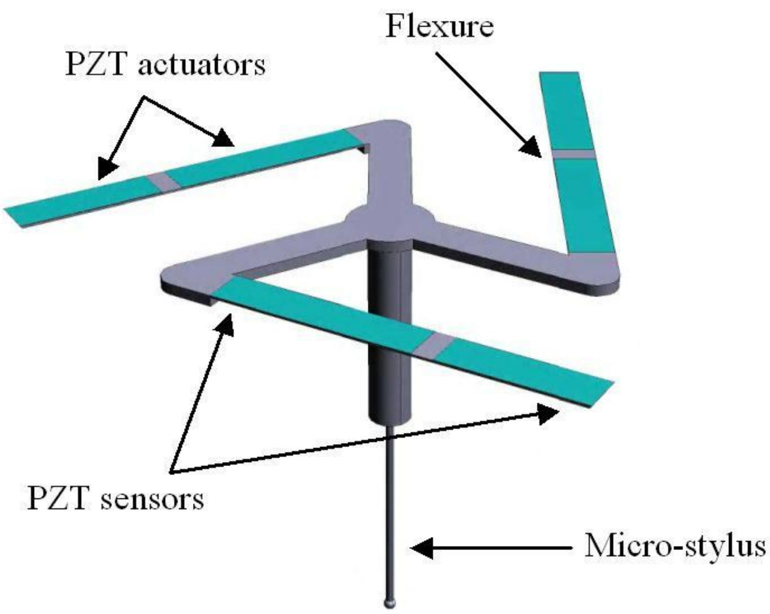


The IMRC 3-D mintegration programme provided an ideal vehicle to take forward the design work on the vibrating microprobe and turn it into an actual device that could be used by manufacturing companies. Working with NPL, a cross-IMRC research project was set up to achieve this goal. Respective responsibilities were as follows:

- Design – further work on design was undertaken by Greenwich University
- Manufacturing – work on turning the design work into a practical device was undertaken by **Cranfield IMRC**
- Assembly – work on assembling the device was undertaken by Nottingham IMRC.

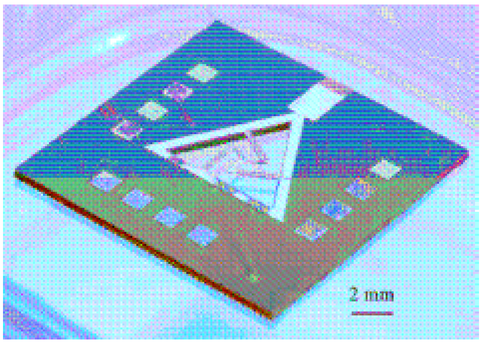
The Cranfield IMRC Project

The diagram below shows a schematic representation of the vibrating micro-CMM probe.



The probe flexures are made in nickel. A technique developed by Cranfield enabled the piezo-electrical elements (PZT) elements (sensors and actuators) to be combined with the flexures whilst maintaining a high degree of control over the thickness. It is essential that the thickness of the PZT films be controlled during production because the thickness of the sensors is responsible for 83% of the sensitivity of the device output.

Cranfield then produced the flexures as a single element, packaged onto a silicon chip for easy handling (as shown below). The stylus / probe is assembled onto the flexures to produce a fully working device.



The micro-CMM probe chip made by Cranfield IMRC. The flexures can be seen in the centre. The micro stylus / probe is assembled onto the central island to form the vibrating micro-CMM probe. This device becomes part of the Micro-CMM.

Assessment of Economic Impact

The economic impact of the project can be quantified as follows:

- Development of a next-generation range of micro-CMM machines
- Facilitating more accurate measurement in manufacturing processes involving micro / nano scale parts. For example, in micro-electromechanical systems, automotives sector, medical and optical devices. This should improve the quality and competitiveness of products in these sectors.

Development of New Generation of Micro-CMM Machines

NPL has patented the technology and is in discussion with one of the companies that manufacturers micro-CMMs to licence the technology to them. This is a Dutch-based company called Xpress Precision Engineering. They will use it to up-grade their product range and will licence it to other micro-CMM manufacturers. This is a small, niche market in which there are only a small number of manufacturers – all based outside the UK. Unit sales at Xpress Precision Technologies are expected to be no more than 1,000 units per annum so this is a relatively low volume market. Nevertheless with the exception of the licensing income, there is limited direct economic impact from this for the UK.

Facilitating More Accurate Measurement in Manufacturing Processes Involving Micro / Nano Scale Parts.

The more significant economic impact from the project in relation to the UK, will be from the way in which it is used in relevant parts of the manufacturing sector. Measurement plays an important role in some of the UK's largest manufacturing industries such as automotive and medical equipment.

A previous impact assessment[8] estimated that companies that had improved their measurement process had benefited from an increase in productivity, improved quality, greater customer

[8] *National Measurement System Impact Assessment, conducted by Databuild Ltd*

satisfaction and higher profits. The NMO reports that an additional £6 million spent by Government on measurement technology delivers up to £410 million of economic impact annually.[9] Thus, the implication is that the £1 million+ expenditure on this research project (of which the Cranfield IMRC input was a small, but vital, part) will generate additional economic activity in the region of £68 million per annum in the longer term.

Position without IMRC Funding

When assessing the economic impact of research it is important to consider the rationale for IMRC investment in the research. The only rationale for IMRC investment in research should be to address a market failure of some kind. In other words, there should be a reason why industry itself would not fund the research and why public intervention through the IMRC is justified.

In this case, it is highly unlikely that Micro-CMMs manufacturers themselves could have undertaken the scale of research necessary to develop a completely new type of microprobe. This is a relatively small market so would always be difficult to justify the scale of research required against commercial return, especially with highly uncertain research outcomes.

The Cranfield IMRC made a relatively small contribution to a much larger programme of research. However, it was a vital contribution as Professor Richard Leach at the NPL observes:

"*We made a real breakthrough at NPL in coming up with a completely different type of probe design, but we needed help to turn it into a practical device. The specialist knowledge and skills at the IMRCs and other universities helped us to turn the research into a practical device which is in the process of being commercialised*"

Consultees

The following people were consulted and reviewed a draft of the case study:

- Professor Robert Dorey, Head of the Microsystems and Nanotechnology Centre, Cranfield University
- Professor Richard Leach, Principal Research Scientist, Engineering Measurement Division

[9] National Measurement Office, *Measurement Matters http://www.nmo.bis.gov.uk/fileuploads/NMS/MEASUREMENT-MATTERS.pdf*