

Working together, **making an impact**

knowledge & expertise guide
2010



UNIVERSITY OF
LIVERPOOL

Working together, making an impact

Knowledge, know-how and expertise are as critical in today's global economy as any other economic resource. As a University with a world-class research portfolio and growing international connections, we actively engage with serious global challenges that impact upon the wellbeing of companies, our economy, and the lives of countless individuals.

In this guide you'll find an overview of the unique expertise available. From health to engineering, social policy to management, our academic experts deliver innovative solutions that benefit a whole host of organisations. Solutions can be delivered to suit the needs of your organisation, whether it's through professional development, collaborative research, consultancy, Knowledge Transfer Partnerships (KTPs) or by recruiting our graduates.

As a University with a strong civic mission and global outlook, we take knowledge exchange very seriously. Through this two-way exchange with external partners we are able to enrich our knowledge assets and make a positive impact on society.

If you are interested in any of the services we have to offer, we would be very pleased to work with you. For more detailed information on our expertise and how we can help contact the Business Gateway.

Professor Sir Howard Newby
Vice-Chancellor

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Key

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- Energy & Sustainability 
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- Cities, Culture & Regeneration 

Welcome to the
University of Liverpool



Many commercial and public sector organisations benefit from our knowledge, skills and expertise, developed as a result of this University's commitment to staying at the forefront of innovation and research.

Businesses and public sector organisations are being driven to become more innovative and efficient by adverse economic conditions, restrictions in public funding and increasingly global trade and competition. With a revolution in digital communications, competitive advantage increasingly relies upon the ability to use innovative thinking in what is becoming a knowledge-driven economy.

The University of Liverpool is one of the UK's top research-led universities with increasingly strong international connections. At the core of our mission lies the aim to actively engage with the serious global challenges that impact upon the wellbeing of companies, our economy and the lives of countless individuals. We do this by ensuring that the expertise developed as a result of our research is made accessible to those who can benefit.

The University's **Business Gateway** helps organisations to achieve their objectives by providing access to a wide range of expertise; transforming ideas into creative solutions, new technologies, strategies, applications, products or skills.

- Profitability
- Cost effectiveness
- Product design
- Innovation
- Recruitment
- Consultancy
- Efficiency
- Competitiveness
- Staff development

In 2007-08 alone, the University participated in £39.2 million of collaborative research funded jointly by business and the public sector – up from £29.3 million in 2006-07. More than £22 million of this was funded by the EU and involved collaborations with 256 businesses or research and technology organisations.

In addition, the University received 564 commissions, worth a total of £17.3 million, for contract research. Many clients placed multiple contracts with the University – for instance, 28 commissions from a single pharmaceutical company and 14 from a single household products company. In the same period, the University provided consultancy services worth £12.7 million; facilities and equipment-related services totalling £1.4 million; and nearly £0.9 million of courses for businesses and other organisations.

This annual guide provides a snapshot of our key areas of expertise available at the time of publication. There is, however, potential for much more – the product of working together to combine our expertise with your objectives.

This is the first guide developed by the University to give you an overview of our key knowledge exchange capabilities and the different ways in which they can be delivered. There is much more information and help available. If you have specific interests or questions, contact the **Business Gateway** who will be happy to help with your enquiry.

Professor Jon Saunders
Deputy Vice-Chancellor

Different ways to access our expertise

The University of Liverpool has an unusually wide breadth of disciplines – from medicine, science and veterinary science to engineering, law, social sciences, arts, humanities and management. This variety enables us to research and develop innovative, multidisciplinary solutions for organisations like yours.

There are many ways to benefit from our knowledge, skills and expertise. The University's **Business Gateway** aims to share the benefits and build mutually beneficial partnerships through a broad range of services and facilities. These include:

- Research
- Business development and services
- Graduates and professional development
- Intellectual property and commercialisation
- Public engagement

Research

Clinical trials

In medical research, clinical trials are conducted to allow safety and efficacy data to be collected for new drugs or devices. Clinical trials may test new drugs, new approaches to using existing treatments, or newly developed methods of treatment.

Collaborative research

Collaborative research is the ideal solution where the research topic is likely to have relevance to solving problems, or enabling new or improved products or services to be developed. It often involves multilateral relationships and the research goals are defined by all concerned – though they may have different motivations for wishing to achieve them.

All partners are responsible for undertaking specific parts of the research programme, and share their interim results, review problems and agree any changes to project goals or research methods.

These partners contribute financially to the costs of the research, which may also be part-funded via public schemes operated by the UK government or the European Commission.

The agreement between the partners covers the ownership of the research results and any associated intellectual property. It also specifies user rights and benefits for non-owners, and makes provision for restrictions on disclosure, where appropriate. Where public funding is harnessed, there are often 'model contracts' which specify the terms of the agreement between the partners.

Contract research

Contract research can entail straightforward testing and analysis. However, it often involves a larger-scale project which breaks new ground. It is likely to involve experimental work and a team of project-specific research and technical staff, working under academic supervision.

Contract research allows the client to determine the project's goals. Where research outcomes are concerned, the University does not expect to publish the results or disclose any of them to third parties – including its own students. The client generally wishes to own all the research results and any intellectual property generated, and to have the exclusive right to use it and exploit it commercially.

Feasibility studies

A feasibility study is a process which defines what a project is and what strategic issues need to be considered to assess likelihood of succeeding. The research and information uncovered will support the detailed planning and reduce the research time. Key issues to be addressed can be financial, technical, environmental or social, managerial and value-related.



Postgraduate studentships

Research can be undertaken by postgraduate students in the context of a Masters (MSc) degree or a Doctorate (PhD). Funding a postgraduate studentship offers a cost-effective means of having research carried out, although companies must accept that the primary objective of any postgraduate research degree is to train the graduate.

Companies should also consider that there is a limit to what can be achieved by a single postgraduate student over a two or three-year period. However, in some disciplines postgraduate students may operate as part of a larger investigative team. Also, it should be taken into account that a postgraduate student cannot be awarded a Masters degree or a Doctorate unless their thesis is made publicly available within a reasonable period. It may only be possible to agree a maximum 'embargo' of a year or two.

Many companies find that they can work within these parameters and the University has numerous postgraduate research students who are fully or part-funded by business and industry.

Business Development and Services

Knowledge Transfer Partnerships (KTPs)

Knowledge Transfer Partnerships enable businesses with a strategic need to access the University's expertise and knowledge to improve their competitiveness, productivity and performance.

The scheme, funded by the Technology Strategy Board, involves a high calibre graduate (KTP Associate) working in a company with academic supervision. This often results in strategic advantages for the company, academic benefits to the University and valuable industrial experience to the Associate.

Depending on the needs of the organisation and the desired outcomes, KTPs can vary in length from one to three years (classic KTP) or from 10-40 weeks (shorter KTPs).

www.liv.ac.uk/ktp

Consultancy

Academic staff at the University of Liverpool can devote a proportion of their working year to providing a consultancy service for external clients. A consultancy relationship allows clients to set their own goals and these generally involve obtaining advice or specialist information relating specifically to the client's organisation, or the results of one-off, short studies which are often desk-based, rather than experimental.

Student-led consultancy service

The University draws from a broad base of students on Master of Business Administration (MBA) and Master of Public Administration (MPA) programmes, who present unique and diverse skills drawing on their previous work experience and current studies. Through a new student-led consultancy service, these students can help your business answer a straightforward query or provide a basic diagnostic service, like market analysis. All work is supervised by an industry liaison officer and University staff, ensuring a high quality output.

www.liv.ac.uk/ulms

Innovation Academy

The **Innovation Academy** helps organisations deal with a variety of business-contingent issues across technological, product, service, and business model innovation. The Academy works with the UK's leading innovators and forward thinking organisations to develop sustainable practices and processes to deliver long-term value.

www.liv.ac.uk/ulms/innovationacademy

Conference and meeting venues

The Foresight Centre and The Hub

The award-winning Foresight Centre is a business and meeting venue, providing a unique environment for a wide range of events and conferences all year round.

Located within the Foresight Centre is The Hub, an innovative space for professionals to meet, network and exchange knowledge and information. Offering full business service backup including Wi-Fi, laptops linked to high speed broadband, photocopying and print facilities and an inviting coffee bar serving a range of speciality coffees, teas and snacks, The Hub caters for all your needs. Access to The Hub Lounge and its facilities is via annual membership.

www.liv.ac.uk/hub

Other venues and facilities

The University has a host of venues available for hire ranging from large, modern conference and banqueting facilities, to intimate Georgian dining rooms. From seminar rooms to sport halls, lecture theatres to theatres of the performing-arts, bedrooms (including 437 en-suite rooms) to bars, there are rooms of every shape and size.

Whether it is banqueting, accommodation for delegates, room hire or a full conference service, the University offers outstanding value and quality. Facilities and venues are available both in within the city centre and in more suburban and rural environments.

www.liv.ac.uk/conferenceservices

Conferences and seminars

Academic research conferences provide an open forum where the top researchers in a particular field come together, present their latest findings, and debate the issues surrounding their subject. Companies in attendance gain unprecedented access to top-level research and learn about the latest developments, but there is also a valuable chance to make personal contact with the people who are at the forefront of your area of interest.

Scientific and technical facilities

Departments within the University offer analysis and testing services to external clients. These may involve routine, standardised or customised systems. Organisations may be able use their own staff to operate equipment facilities available at the University, or you can take advantage of our sophisticated apparatus and specialist operators.



Graduates and Professional Development

Graduates

As a world-class University, Liverpool attracts and retains a wealth of enthusiastic and talented students and graduates whose energy, knowledge and creativity can deliver real benefits to a wide range of organisations. Employers can tap into our pool of talent through special projects, placements, voluntary work, sponsorships, government-subsidised collaborations, and full-time recruitment.

Engagement with our students and graduates can offer businesses a cost-effective solution which can also provide wider access to our high level skills, cutting-edge research and the latest academic knowledge and expertise.

Student placements and projects

Organisations can add real value with the specialist knowledge of highly motivated students, while some schemes also include support by leading academics. Students can undertake various forms of work experience, ranging from part-time employment through to formal work placements, vacation work, volunteering, sandwich and industrial placements, work-based projects and internships.

Student sponsorships

To gain access to a talented undergraduate student with knowledge and expertise that can be of benefit to your organisation, the University provides opportunities for student sponsorship. Typically, individual sponsorship can be arranged in return for vacation and/or graduate employment.

CASE studentships

Inject high-level skills and expertise into your business with world-class PhD researchers. Industrial CASE awards provide funding for PhD studentships where businesses take the lead in arranging projects with an academic partner of their choice. Projects should be in the area of engineering and the physical sciences.

Graduate employment

Competition for the top graduates can be intense. To help you recruit the best and brightest graduates with relevant expertise, our Careers and Employability Service provides a wide range of direct, efficient and cost-effective ways to access large numbers of students.

www.liv.ac.uk/careers

Professional development

Continuing Professional Development (CPD)

Continuing Professional Development allows organisations and individuals to retain cutting-edge knowledge and effectiveness. From the latest veterinary expertise to management, health, engineering and much more, you can update your knowledge and skills with the latest professional development courses from the University, and, through this, directly impact on the human resource and business strategies of your organisation.

Our research-led CPD approach ensures that whatever the format of the programme, you will receive the latest high level skills and knowledge input. The University offers a wide range of courses as well as executive training programmes. All of these are designed to maximise personal and professional development, whether your goal is to gain a full postgraduate award or to fill a knowledge or skills gap in your workforce.

Courses can be tailored so you achieve the competitive advantage, growth or increased effectiveness you are seeking. In many cases they are linked to specific postgraduate programmes, enabling delegates to gain credits towards a postgraduate certificate or diploma qualification.

www.liv.ac.uk/cpd

Executive education

The University's Open Executive Education Forums are structured to equip senior managers with the competencies required to effectively stimulate and embed innovation within their own organisations. One-day sessions provide the challenging stimulus for unconventional thinking, as well as the proven approaches to implementing innovation. Materials used are original, forward thinking, and robustly scrutinised. Peer-to-peer interaction is an important feature so participants can learn from each other.

Intellectual Property and Commercialisation

Intellectual property (IP)

Intellectual property is created when an innovative idea is acknowledged as having a tangible commercial value.

IP rights and protection

IP rights protect the interests of the owners of these ideas and can be broadly defined as copyright, patents, trademarks, design rights and the protection of confidential information.

Patent

A patent needs to be applied for to protect and cover how these ideas work, what they can do, how they do it, or what they are made of, for up to a maximum of 20 years. The patent gives the owner the right to prevent others from making, using, importing or selling the invention without their permission.

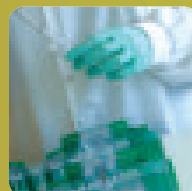
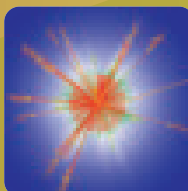
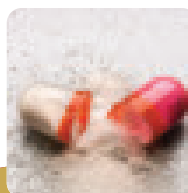
Copyright

Copyright is an automatic legal right to protect an author against unauthorised copying of their work, and lasts for 70 years after the author's death. Under copyright law, computer programs are protected as a literary work, but some software can also be patented.

The University recognises that valuable intellectual property may be generated as a result of its collaborations with third parties. In such cases the University adopts a flexible approach in deciding the most appropriate route for ownership and subsequent exploitation of such intellectual property. For example, arising intellectual property may be owned by the University or the collaborating partner or jointly. If the collaboration is likely to produce commercially valuable intellectual property the University will work closely with the collaborating partner to ensure that appropriate contractual terms and conditions are agreed before the collaboration commences, thereby maximising potential opportunities.

Furthermore the University understands that collaborating partners will often require access to pre-existing intellectual property of the University - often referred to as background intellectual property rights. The University is willing, wherever possible, to grant access to such background intellectual property to enable successful exploitation of intellectual property generated from collaborative work.

The University's commitment to protection and successful exploitation of its intellectual property was underlined by the establishment of Ulive Enterprises Limited in 2008. Ulive is a subsidiary company of the University which was set up to commercialise intellectual property in which the University has an interest. Ulive employs a team of dedicated professionals who work closely with both the University and collaborating partners.



Public engagement



The University's approach to public engagement is built upon its heritage as a civic institution and its original mission to strive for the 'advancement of learning and ennoblement of life.' Our drive to have a positive impact upon the society in which we live and work means that we are involved in a whole spectrum of activity and engaged with a truly diverse range of people and organisations, from local residents and voluntary groups, through to the UK and international governments and agencies.

The University's public engagement comprises three central, interconnected elements: **public events and access, communities and the voluntary sector, and public policy.** Put simply, the aim of each strand is to:

- Open up the University campus to the city and the public
- Reach out to our local communities
- Influence policy and improve public services.

Public Events and Access

The University campus is at the heart of city life where people can come together to exchange ideas, learn and be inspired to make a difference. The University's Victoria Gallery & Museum and excellent sports facilities are open to the public throughout the year.

Public Lectures

More than 7,000 people attended the University's 2009 Public Lecture Series on the theme of the environment. Speakers at these free events included; comedian, author and actor Alexei Sayle, survival expert Ray Mears, environmental pioneer Dick Strawbridge, co-founder of the Eden Project Tim Smit and the environmentalist and writer Jonathon Porritt. The 2010 programme will connect to the city's Year of Health & Wellbeing.

www.liv.ac.uk/public-lectures

The Victoria Gallery & Museum

Her Royal Highness The Princess Royal officially opened the Victoria Gallery & Museum (VG&M) following an £8.6 million restoration of the Victoria Building, the University's original redbrick headquarters. This was funded by the University with philanthropic support from the Wolfson Foundation and the Heritage Lottery Fund, among others. The VG&M now houses the University's art and heritage collections and, in its first year of opening, welcomed more than 65,000 visitors.

www.liv.ac.uk/vgm

Museum collaborations

Beyond the campus, the University has played an important role in education and awareness by making its research accessible to a wider audience and helping to create exhibitions and develop collections.

Just one example is the **Centre for the Study of International Slavery**. Founded as a partnership between the University of Liverpool and National Museums Liverpool, the Centre contributes to the understanding of slavery and its legacies and to foster research and debate in this field. The Centre is central to Liverpool's pioneering International Slavery Museum and it is part of a network of other research institutes across the globe, with partners in France, the US and Senegal.

www.liv.ac.uk/csisis

Communities and the Voluntary Sector

The University has always had strong connections with local communities and the voluntary sector, both through research and the contribution of staff and students to local projects and initiatives. We are committed to building partnerships, such as the **Merseyside Social Inclusion Observatory**, which deliver mutual benefits and enrich the learning experience of our students, enhancing the value of our research activities, and enable us to make a positive contribution to the quality of life in the city.

Voluntary work

The University has an established track record in helping voluntary and community groups meet their strategic objectives. The University's students can bring the enthusiasm and skills to drive projects forward. We match students based upon their knowledge skills, career ambitions and skill sets. The University's broad range of degree programmes means that we are well placed to respond to issues across the themes of education, health, housing and culture.

Interchange

Interchange is a registered charity which links the three Liverpool universities with the local voluntary and community sector. Community groups and voluntary organisations can come to **Interchange** to discuss issues which require further research; **Interchange** then works to identify undergraduate and postgraduate students with the right skills to take on the project.

Regeneration and development programmes

The University has provided input for a range of public initiatives, both in Liverpool and the region. Recent projects have included external membership of the North Liverpool Scrutiny Panel, convened by Liverpool City Council to advise on regeneration of the area, and involvement in the Foresight Group, formed with the Merseyside Transport Partnership to consider radical solutions to issues including congestion and climate change.

The University makes a major contribution to the health and wellbeing agenda not only via the training of medical staff, but also through representation on key bodies such as the Strategic Health Authority. In 2007, the University helped to establish the Health is Wealth Commission, charged with addressing the growing disparity between the Liverpool city region's fast-growing economy and the long-term poor health of its population. Since the Commission's recommendations were published in 2008, the University has been working with Liverpool Primary Care Trust to establish a dedicated institute to research health inequalities and inform policy.

Schools

The University has well-established relationships with a broad network of schools across the city and beyond. Its internationally-renowned commitment to widening participation has improved the life chances of pupils in some of Liverpool's most deprived areas. The University has supported North Liverpool Academy and supports a National Challenge Trust School in Liverpool, as well as sponsoring two new Wirral academies.

Influencing Public Policy and Improving Public Services

The University has a key contribution to make in improving public policy-making and quality of life in the city-region, nationally and internationally.

The University's contribution to critical issues such as energy, climate change and sustainable cities will only be of value if this input is embedded within broader policy communities.

Public policy advice and expertise

As a producer of impartial guidance, perfectly placed between consultancy advice and pure research, the University can respond to the growing demand for evidence-based policy at all levels of governance.

Our expertise spans a broad range of disciplines and provides a multi-perspective approach to many of the interconnected 'grand challenges' of the 21st century.

Consultancy

As part of its drive to improve health and reduce health inequalities, the University has played a pioneering role in developing Health Impact Assessment (HIA) methodologies and tools, which are now widely used around the world. In response to the burgeoning demand for its expertise, the University set up a dedicated HIA consultancy and training service, **IMPACT+**.

IMPACT+ has subsequently undertaken consultancy for a wide range of organisations – including Birmingham International Airport, the States of Jersey, the European Food Safety Agency and the World Health Organisation.

Learning and development opportunities

Building upon the University's strengths and longstanding reputation in public management, the practitioner-focused Master in Public Administration and Management (MPAM) is an in-company programme which allows organisations and individuals to address the fundamental changes which are taking place in the public and voluntary services.

The programme combines formal classroom sessions with emphasis upon action learning, helping practitioners to explore the consequences of change for the role, purpose and nature of governance, public policy, leadership and management. It will develop staff, raise performance standards, transform the sub-region and to make the learning organisation the standard. Current partners Merseytravel, Liverpool City Council Community Services and Liverpool PCT have worked with the University to deliver real service improvements and develop more effective future leaders in a changing and increasingly complex environment.

Promoting Public Understanding of Science

Our government is keen to rebalance the UK's economy by exploiting the country's knowledge base more effectively. As a result, it is increasingly important for non-experts to develop a better understanding of science and technology.

If individuals and organisations can gain greater insights into the nature of scientific methods, they will appreciate that high-quality research often requires significant investment in time, facilities and expertise. They will be less likely to draw premature conclusions about the results of individual studies, and they will be better equipped to engage with issues which developments in science and technology can trigger – such as the use of stem cells, or genetically modified crops. They will also gain a better understanding of the implications of scientific and technological developments, and the business opportunities which such developments may present.

The University of Liverpool has a substantial research community with a prodigious spread of expertise. Its researchers publish significant results in academic journals which may be inaccessible to non-specialists, so in 1998 the University launched a quarterly newsletter which communicates selected results to a wider audience.

Research Intelligence is available in print and online. Its numerous subscribers include bodies funding research, people carrying out research, businesses interested in exploiting innovative research commercially, organisations promoting economic regeneration, and the media.

www.liverpool.ac.uk/researchintelligence



Grants and funding schemes

The UK government and the European Union have established a wide range of schemes supporting collaboration between businesses and universities.

Schemes can be sector-specific, or operate more broadly. They can be regional, national or international and some are designed to help SMEs while others support large businesses.

Business Gateway is happy to discuss opportunities to apply for funding which could make benefiting from our expertise a reality for your organisation.

This directory provides an overview of some of the most popular schemes, consortium programmes, research grants, studentships and networks which may help you.

For more information, you can also visit:
www.businesslink.gov.uk

| Scheme | Applicants | Funded by |
|---|---|--|
| Case Awards | Also a PhD studentship, the difference is that the University makes the case for the award, thus reducing the burden on the company. Also, more research councils offer regular CASE Awards; with a broader range of available opportunities. | AHRC, BBSRC, ESRC, NERC, STFC |
| Collaborative research and development (R&D) competitions | Designed to assist the industrial and research communities to work together on R&D projects in strategically important areas of science, engineering and technology – from which successful new products, processes and services can emerge. | Technology Strategy Board (TSB) |
| Economic Challenge Investment Fund (ECIF) | Established to enable higher education to respond rapidly to the needs of employers and individuals during the economic downturn. | Higher Education Funding Council for England (HEFCE) |
| Industrial CASE Awards | Provides funding for PhD studentships where businesses take the lead in arranging projects with an academic partner of their choice. Projects should be in the areas of engineering and the physical sciences. | Engineering and Physical Sciences Research Council (EPSRC) |
| Industrial Partnership Award (IPA) | Science-led, responsive mode grants where an industrial partner contributes at least 10% of the full economic cost (FEC) of the project. Funding covers the remainder of the cost (at 80% of FEC rate). IPA projects are normally funded in preference to standard grants of equivalent scientific merit, because of the industrial contribution. | Engineering and Physical Sciences Research Council (EPSRC) |

| Scheme | Applicants | Funded by |
|---------------------------------------|---|--|
| Industry fellowships | Aims to enhance knowledge transfer in science and technology between those in industry and those in academia. It provides opportunities for an academic scientist to work on a collaborative project with industry, or for someone employed in industry to work on a collaborative project with a university department or a not-for-profit research organisation. It is anticipated that fellows will establish personal and corporate links between the two sectors in the UK as a foundation for their long-term future development. Fellowships can run for two years full time, or up to four years part-time, where fellows maintain a working relationship with their home institution throughout. During the length of the fellowship, the fellow remains employed with their home institution with salary costs covered by the fellowship. Research expenses may also be claimed up to the value of £2,000 per year. | Biotechnology and Biological Sciences Research Council (BBSRC), the Royal Society, Engineering and Physical Sciences Research Council (EPSRC), Natural Environment Research Council (NERC), Rolls-Royce plc and Astra Zeneca |
| Industry Interchange Programme | Supporting the flow of researchers, in either direction, between the university science base and industry. The scheme supports short term exchanges that provide strategic advantage to the UK science base and industry, arising from reciprocal access to facilities, expertise and/or knowledge, and an increased understanding of scientific issues of common concern. The interchange may be full- or part-time, or taken in tranches. | Biotechnology and Biological Sciences Research Council (BBSRC) |
| Innovation Vouchers | Business Gateway is an approved supplier for this business development scheme, designed to help business owners, entrepreneurs and social enterprises in the North West of England to purchase an academic's expertise to develop innovation and enhance business. A wide range of departments across all areas of the University are involved in providing quick knowledge-based responses to small businesses with identified immediate business issues. | Northwest Regional Development Agency (NWDA) |
| Innovative Medicines Initiative (IMI) | The Innovative Medicines Initiative is a unique Public-Private Partnership (PPP) between the pharmaceutical industry represented by the European Federation of Pharmaceutical Industries and Associations (EFPIA) and the European Communities represented by the European Commission. Its overall goal is to reinvigorate the biopharmaceutical sector in Europe; through collaborating, competitor pharmaceutical companies are invited to work together to find solutions in order to overcome the research bottlenecks in the drug development process. Conditions to be arranged. | European Union (EU) and the European Federation of Pharmaceutical Industries and Associations (EFPIA) |

| Scheme | Applicants | Funded by |
|--|--|--|
| Invention for Innovation (i4i) | i4i funds translational research, extending between basic research and pre-clinical trials or health technology assessments to provide investment in, and improved identification of, promising healthcare technologies. Its aim is to accelerate the development of new healthcare products for the 21st century. | National Institute for Health Research (NIHR) |
| Knowledge Transfer Partnerships (KTP) | KTP is a UK-wide programme enabling businesses to improve their competitiveness, productivity and performance. It is part-funded by a government grant and involves recruiting a high calibre graduate, who is then based in the company, to deliver the plan with support from an academic expert who will mentor the project from start to finish. KTPs can vary in length from one to three years (classic KTP) and from 10-40 weeks (shorter KTP), depending on the needs of the business and the desired outcomes. A small to medium-sized enterprise (SME) would be expected to contribute about a third of the costs involved in the project. | Technology Strategy Board |
| LINK scheme | Involves collaborative research with at least one company and one science-base partner with the aim of developing a new treatment/intervention. Projects with SMEs are particularly favoured and overall government support can be up to 50% of total eligible costs. | Biotechnology and Biological Sciences Research Council (BBSRC) |
| Modular training for industry | Funding to establish Continuing Professional Development (CPD) courses in industry-relevant areas. | Biotechnology and Biological Sciences Research Council (BBSRC) |
| Grants for Research And Development (GRAND) | Aims to help entrepreneurs and business owners introduce innovative products and processes including research trials and product testing. | Northwest Regional Development Agency (NWDA) |
| Science Bridges Awards | Funding to stimulate academic collaboration between the UK and either the USA, China or India. | Research Councils UK (RCUK) |
| Young Investigator Grants and Programme Grants | Novel cross-disciplinary, international collaborations. | Human Frontier Science Program (HFSP) |

Please note: This overview shows a selection of programmes that are available at the time of publication. This does not necessarily mean that you will be eligible for the programmes identified.

Useful websites

Research Councils

Arts and Humanities Research Council (AHRC) – www.ahrc.ac.uk
Biotechnology and Biological Sciences Research Council (BBSRC) – www.bbsrc.ac.uk
Engineering and Physical Sciences Research Council (EPSRC) – www.epsrc.ac.uk
Economic and Social Research Council (ESRC) – www.esrcsocietytoday.ac.uk
Medical Research Council (MRC) – www.mrc.ac.uk
Natural Environment Research Council (NERC) – www.nerc.ac.uk
Science and Technology Facilities Council (STFC) – www.scitech.ac.uk
Research Councils UK (strategic partnership of the UK's seven Research Councils) – www.rcuk.ac.uk

UK Charities

Association of Medical Research Charities – www.amrc.org.uk
British Academy – www.britac.ac.uk
British Heart Foundation – www.bhf.org.uk
Cancer Research UK – www.cancerresearchuk.org
Leverhulme Trust – www.leverhulme.ac.uk
North West Cancer Research Fund – www.cancerresearchnorthwest.co.uk
Royal Society – www.royalsociety.org
Wellcome Trust – www.wellcome.ac.uk

UK Government Departments and Agencies

British Council – www.britishcouncil.org
Department for Business, Innovation and Skills – www.bis.gov.uk
Department for Environment, Food and Rural Affairs (DEFRA) – www.defra.gov.uk
Department for International Development (DfID) – www.dfid.gov.uk
Department of Health (DH) – www.dh.gov.uk
Government Office for the Northwest (GONW) – www.gonw.gov.uk
Higher Education Funding Council for England (HEFCE) – www.hefce.ac.uk
Ministry of Defence (MOD) – www.mod.uk
Northwest Regional Development Agency (NWDA) – www.nwda.co.uk
Office for Strategic Co-ordination of Health Research (OSCHR) and the National Institute for Health Research – www.nihr.ac.uk
Technology Strategy Board (TSB) – www.innovateuk.org

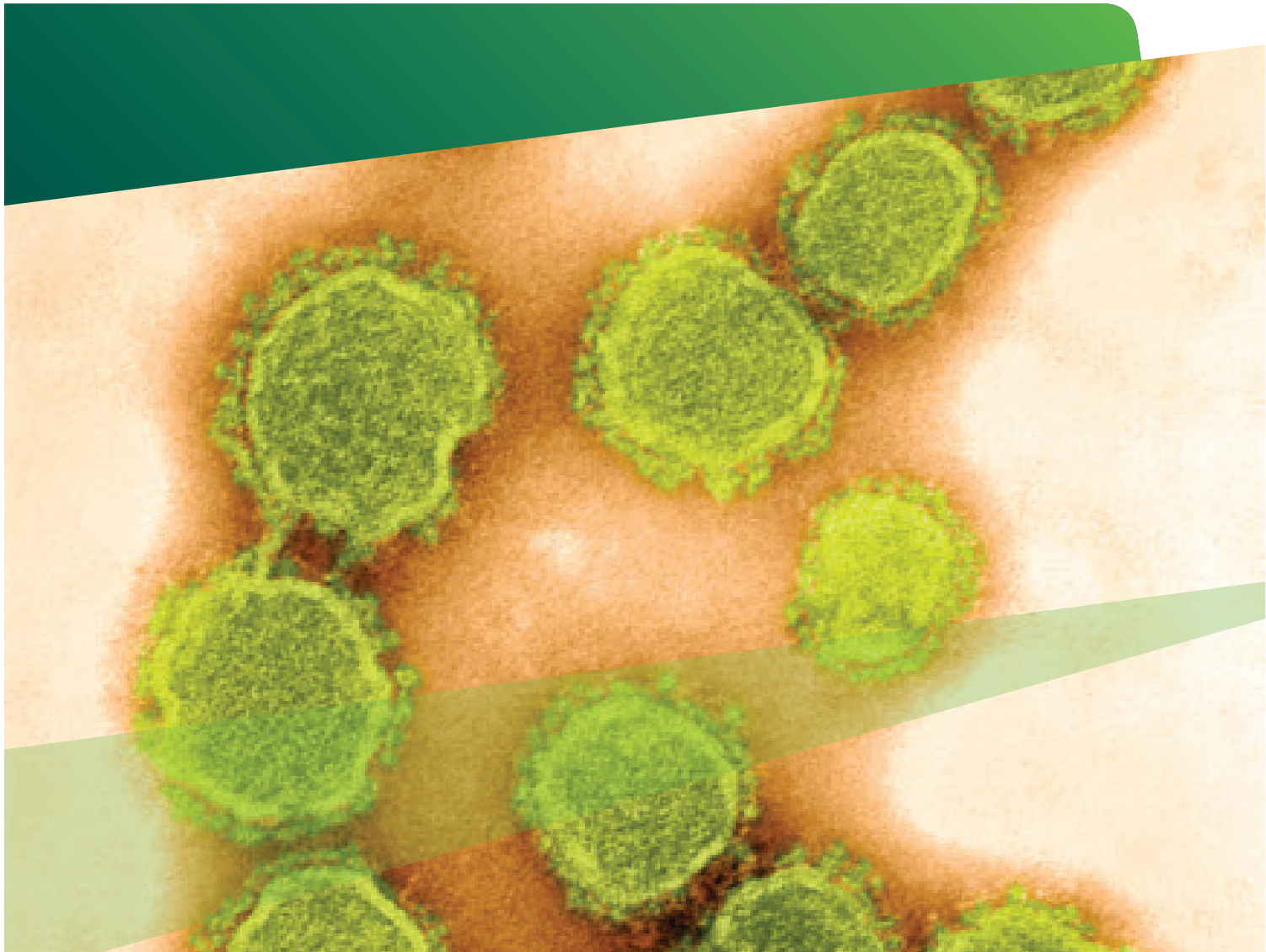
European Commission

EU Community Research and Development Information Service (CORDIS) – www.cordis.lu
European Research Council (ERC) – <http://erc.europa.eu>
Framework 7 – www.cordis.europa.eu/tp7
UK Research Office (UKRO) – www.ukro.ac.uk

Other useful sites

European Federation of Pharmaceutical Industries and Associations (EFPIA) – www.efpia.org
Community of Science (COS) / Funding Opportunities – <http://fundingopps.cos.com>
Ulive Enterprises – www.ulive-enterprises.com

Health & Wellbeing



Overview

Breadth of Expertise

- Diagnosis
- Therapy
- Monitoring
- Experimentation
- Models/modelling
- Design & development
- Clinical trials
- Epidemiology
- Disease prevention
- Training

Focus of Expertise

- Translational research
- Patient benefit
- Child health
- Human health
- Animal health
- Infectious diseases
- Zoonoses
- Tropical diseases
- Cancers
- Drug safety

Approaches

- Population/organism /cell/molecular biology
- Biobanking
- DNA/gene/genome sequencing
- Bioinformatics
- Microarrays
- Imaging & microscopy
- NMR
- Pharmacogenetics
- Materials & materials chemistry

Application Areas

- Supranational bodies (WHO, UN)
- Health authorities
- Food industry
- National/regional government bodies
- NHS
- Petfood industry
- NGOs
- Biotech industry
- Pharmaceutical industry

Key Capabilities

1.0 Drug Safety and Personalised Medicines

2.0 Combatting Infectious Diseases

3.0 Oncology

4.0 Clinical Trials and Evidence Synthesis

5.0 Paediatric Medicine

6.0 Gastrointestinal Health

7.0 Appetite and Obesity

8.0 Ophthalmology

9.0 Veterinary Science and Zoonoses

10.0 Genomics and Bioinformatics

The University of Liverpool has one of the largest biomedical communities in the United Kingdom and is the only higher education institution with education and research spanning the biosciences, medicine, dentistry, health sciences, tropical medicine and veterinary science. This gives rise to a rich synergy of research effort into a range of healthcare-related issues. The University is also integrated into the Royal Liverpool University Hospital and other research hospitals in the city, which augments its clinical research and trials capability.

For more than 100 years Liverpool has been at the forefront of fundamental advances in biomedical knowledge and practice, with outstanding highlights such as the first diagnostic X-ray, the discovery of the transmission of malaria by mosquitoes, the understanding of the electrical nature of nerve transmission and the introduction of neuromuscular blockers into surgical anaesthesia.

Increasingly the University's focus is on translational research, emphasising the opportunities presented by the unusual number of fertile interdisciplinary interfaces which exist in Liverpool within biomedical and health sciences, and also with colleagues in engineering and the physical sciences. These provide real opportunities for innovation and, in turn, support a wide range of knowledge transfer activities and engagement with industry partners, an important pillar of the University's forward strategy.

The University has strong links into the neighbouring biomedical industrial community and is itself active in providing accommodation and business incubation support services for the industry. The University's Merseybio Incubator was established as a state-of-the-art facility for developing biomedical businesses. With laboratory and office accommodation, the facility provides start-up and incubation services for up to 15 new companies at any one time.

The University aims to be a benchmark for the way in which a research-led university can work with partners to improve health and wellbeing in the population it serves. This capability is available to industrial and public sector organisations to help them solve problems by the application of its range of research excellences.

1.0 Drug Safety and Personalised Medicines

Keywords: *Drug safety; pharmacology; personalised medicine; stratified medicine; pharmacogenetics; adverse drug reaction; safe drug design; medicinal chemistry*

Overview

Adverse drug reactions (ADRs) are a major concern both to the pharmaceutical industry and to public health. A quarter of a million people are admitted to hospital in the UK each year following adverse reactions to commonly prescribed drugs, costing the NHS £0.5 billion. ADRs are also a major cause of failure of drug development programmes, and can result in withdrawal of approved drugs from the market. Further understanding is required of the underlying mechanisms of clinically important ADRs. In addition, advances in pharmacogenetics enable the prediction of a patient's response to a particular drug and open the way for stratified and personalised medicine. Liverpool is one of the very few centres worldwide with the integrated expertise required to make major advances in these important aspects of human disease.

Expertise

Drug safety research and pharmacogenetics are internationally recognised key strengths at the University of Liverpool.

The **Centre for Drug Safety Science** (CDSS), in partnership with the pharmaceutical industry and other organisations, is a world-leading centre for the investigation of fundamental mechanisms of clinically important adverse drug reactions. The Centre promotes cross-disciplinary collaboration between researchers, clinicians and industry to provide new knowledge that will inform the design and development of future medicines with the ultimate aim of making drug therapy safer.

Liverpool is also home to the **Wolfson Centre for Personalised Medicine**, which builds upon the University's leading research expertise in the area of pharmacogenetics – how an individual's genetic makeup influences their response to a given drug. The aim of the Wolfson Centre is to identify genetic predictors of adverse or ineffective response, and to develop the evidence base that will allow translation of laboratory findings into patient care. To complement the Wolfson Centre, the University has also been awarded the Department of Health-funded NHS Chair in Pharmacogenetics.

This critical mass in genetic marker research will help identify patients that are more likely to benefit from a particular drug, or experience an adverse reaction, and thereby enable matching of safe and effective drug therapies to specific patient populations (stratified medicine) and even to individual patients (personalised medicine). Pharmacogenetics and stratified

medicines allow pharmaceutical companies to save drug development programmes by targeting ADR-risk medicines at genetically defined sub-populations.

Together, the **Centre for Drug Safety Science** and the **Wolfson Centre for Personalised Medicine** create a world-leading centre for the investigation of fundamental mechanisms of clinically important adverse drug reactions, with the overall aim of preventing such responses using improved drug selection, drug design and more informed patient selection.

Complementary facilities

- Synthetic chemistry laboratories allied to the University's **Centre for Materials Discovery** high throughput robotics suite, for preparing novel molecular entities and libraries of compounds for biological evaluation
- The **NIHR Biomedical Research Centre in Microbial Diseases** and **NIHR Biomedical Research Unit for Pancreatic Diseases** are translational facilities engaged in developing new therapies against infectious and pancreatic diseases respectively
- A physiological approach to pharmacological problems is being developed through the establishment of the **Centre for Integrative Mammalian Biology**
- Clinical trials infrastructure – Liverpool is a major location for public and commercial clinical research and trials.

• Also see *Clinical Trials and Evidence Synthesis* on page 23.

Applications

With a focus on translation of drug related research for patient benefit, the University collaborates extensively with the pharmaceutical and biotechnology industries in all aspects of drug development. Industry partners within the **Centre for Drug Safety Science** include Merck, AstraZeneca, Pfizer, Novartis and GlaxoSmithKline.

University researchers have played a leading role in development of a genetic test which identifies patients at risk of severe adverse reaction to the HIV anti-retroviral Abacavir. In collaboration with industrial partners this discovery has been translated into the clinic.

Similarly, a therapeutic drug monitoring service for HIV drugs has been established by researchers in Liverpool and spun-out via a commercial partner, Delphic Diagnostics Ltd. Doctors use this service to guide them on safe and effective patient-specific prescribing of drugs.

2.0 Combatting Infectious Diseases

Keywords: *Tropical medicine; bacterial; viral; microbial disease; zoonoses; clinical trials; drug development; disease vectors*

Overview

Infectious disease research represents a major competitive strength in Liverpool, with R&D critical mass and established links with key partners providing a thriving, interdisciplinary network. This configuration presents a development pipeline via which excellent basic research can be translated through development and trialling into the generation of new products to improve patient health. Strong partnerships with industry from conception to commercialisation are critical to the success of this integrated translational approach. The University has broad research strengths in bacterial and viral microbial disease, respiratory and neurological infection and, in collaboration with the [Liverpool School of Tropical Medicine](#), is active in combatting HIV-related diseases, malaria and other vector-borne diseases.

Expertise

The University possesses a wealth of resources in infectious disease research, from vibrant schools of Medicine, Veterinary Science and Biological Sciences to the affiliated [Liverpool School of Tropical Medicine](#) and the [National Centre for Zoonosis Research](#). This gives rise to a rich and uniquely strong synergy of research effort into infectious disease.

The University is also integrated into the Royal Liverpool University Hospital and other research hospitals which strengthen the infectious disease clinical research and trials capability. Liverpool is a major location for public and commercial trials, supported by large and well-characterised patient registers and clinical excellence in key infectious disease areas such as HIV.

✚ Also see *Clinical Trials and Evidence Synthesis* on page 23.

Liverpool has been awarded the [NIHR Biomedical Research Centre in Microbial Diseases \(BRC\)](#), a translational facility for development of new drugs, vaccines and diagnostic to combat microbial diseases, in collaboration with industry partners. The BRC is completed by a Medical Microbiology facility, a Bioanalytical facility and a Sample Repository. Pharmacological aspects of infection control are engaged in collaboration with the University's [Wolfson Centre for Personalised Medicine](#) and the [Centre for Drug Safety Science](#).

The [National Centre for Zoonosis Research](#), represents the world's first interdisciplinary centre dedicated to the study of animal-borne human disease. Veterinary researchers are also investigating the ecology and epidemiology of infectious diseases in order to gain a better understanding of risk and management of future pandemics.

✚ Also see *Veterinary Science and Zoonoses* on page 28.

Applications

The University engages with a range of industry partners to develop new drugs, vaccines and diagnostics to address infectious disease healthcare needs which are not yet being met. Examples of this translational activity include:

- Longstanding collaboration with GlaxoSmithKline and other partners on development of new anti-malarial drugs
- Collaborative projects within the [NIHR Biomedical Research Centre in Microbial Diseases](#) include development of diagnostics for epidemic strains of *Pseudomonas aeruginosa* in cystic fibrosis, a simple test for early stage prediction and prognosis of severe sepsis, a new inhaled vaccine candidate for pneumonia and a new drug target for tuberculosis
- University researchers have developed improved ways of diagnosing Japanese Encephalitis (JE) viral infection and monitoring disease progression, allowing governments across Asia to more effectively control this disease.

The University has also established key strategic global relationships with other renowned centres of excellence in infectious disease including the US Centers for Disease Control and Prevention (CDC), and Washington University in St Louis.



3.0 Oncology

Keywords: *Clinical trials; experimental cancer medicine centre; good clinical laboratory practice; pancreatic; head and neck; haematological/blood; biobanking; pre-clinical testing*

Overview

The University is especially strong in a number of tumour-specific areas, notably pancreatic, blood, head and neck, as well as treatment strategies such as experimental radiotherapy and surgical oncology. Liverpool has the largest combined clinical and basic pancreatic cancer research group in the UK. Translational research activity is undertaken by all groups, with a strong focus on clinical practice and clinical trials, and extensive collaborations with biotech and pharmaceutical industrial partners.

Expertise

Liverpool has been awarded Cancer Research UK Centre (CR-UK) status in acknowledgment as a centre of cancer research excellence. This Centre will focus on development of treatments tailored to individual cancer patients based on an understanding of the biology of the disease and how it varies among different people. The Centre has a spectrum of research expertise from fundamental cancer biology to extensive clinical activity.

The **NIHR Biomedical Research Unit for Pancreatic Diseases**, awarded to the University in partnership with the Royal Liverpool University Hospital, is dedicated to the development of new drugs, diagnostics and preventative strategies for management of pancreatic diseases, particularly pancreatic cancer and pancreatitis. Outputs will be translated into the clinic for improved patient care. Collaboration with industry for commercialisation of developed products is implicit in the remit of the Unit.

Oncology clinical trials

Liverpool can deliver all phases of oncology clinical trials for industry and public sector partners in a broad range of different cancer types. Previous trials, such as the ESPAC1 pancreatic cancer chemotherapy trial, have led to fundamental changes in clinical practice. Ongoing trials include the use of novel therapeutic strategies, such as cancer vaccines (TeloVac) and gene therapy (MetXia). Oncology clinical trials resources include:

The **Liverpool Experimental Cancer Medicine Centre** (LECMC) has been awarded to the University and its NHS partners, the Royal Liverpool University Hospital and Clatterbridge Centre for Oncology. The LECMC is a translational research centre with both laboratory and clinical facilities and expertise. The resources available allow the safe, rapid and rational evaluation of new cancer treatments, and the development and application of novel biomarkers to facilitate late stage clinical trials.

The **CR-UK Liverpool Cancer Trials Unit** (LCTU) works closely with Cancer Research UK in the clinical research and trialling of new and existing products for the treatment of cancer. The LCTU manages all Liverpool oncology trials and ensures they are undertaken to the highest quality standards and meet all regulatory and International Conference on Harmonisation (ICH) / WHO Good Clinical Practice (ICH-GCP) requirements.

The **Pancreatic Clinical Research Facility** (PCRF) is the clinical facility of the **NIHR Biomedical Research Unit for Pancreatic Diseases**. The PCRF is located next to the pancreatic wards of the Royal Liverpool University Hospital to ensure that pancreatic patients participating in clinical trials receive ongoing NHS care from the specialist pancreatic clinical team.

➤ Also see *Clinical Trials and Evidence Synthesis* on page 23.

Biobanking

The University is a recognised centre of tissue banking expertise. In its **Liverpool Tissue Bank**, tissue samples collected from patients are banked together with associated clinical data to provide a valuable resource for research groups investigating the mechanisms of disease. University biobanking complies with the requirements of the Medicines and Healthcare products Regulatory Agency (MHRA) and the Human Tissue Act (England and Wales 2006). Subject to ethical approval, samples are made available to external groups, including industry.

Biomarker validation

With a combination of world-class research, Good Clinical Laboratory Practice (GCLP)-grade laboratories and biobanking capability, the University is in an ideal position to discover, test and validate markers for prognosis, screening, diagnosis and monitoring of cancer progression.

Applications

Liverpool groups are routinely engaged in collaborations with industry partners. Trials have been conducted with a wide range of companies including Oxford Biomedica, Pharmexa, Roche and Solvay. Links with other companies revolve around pre-translational, discovery-based activities, such as biomarker and target validation. These collaborators include Cyclacel, Incyte, Epigenomics, Sequenom, Oxford Gene Technology, AstraZeneca and Boehringer-Ingelheim.

4.0 Clinical Trials and Evidence Synthesis

Keywords: *Clinical trials; adaptive trial design; trials methodology; trial monitoring; clinical trial regulations; medical statistics; systematic reviews; meta-analysis*

Overview

Clinical trials are undertaken to evaluate whether a new intervention is safe and effective. Successful clinical trials, both in the public and private sectors, are highly dependent upon using valid, appropriate trial design and statistical methodology, combined with the highest standards of data management, administration, communication and quality control.

The University has built a strong critical mass of clinical trials resources and specialised related activities. This is aligned to recognised international expertise in diseases areas such as epilepsy, cancer, infection, obesity, perinatal, dental and neurology – a high proportion of which are particularly prevalent in the regional population with large, well-characterised patient populations.

Liverpool is expert in undertaking systematic reviews of research to identify areas where new trials are required. These can form the basis for decision-making by governmental bodies such as NICE, the National Institute for Health and Clinical Excellence.

Expertise and applications

This area is multidisciplinary, involving statisticians, clinicians, informaticians, social scientists and health economists. Capabilities include:

- Trial design and methods, including adaptive designs and paediatric trials
- Selection of appropriate trial outcome measures
- Clinical trial regulations and legislation
- Risk-based trial monitoring
- Patient recruitment and retention strategies
- Statistical analysis of trial data
- Cochrane methodology for systematic reviews, to assess evidence and inform trial design
- Overviews of multiple treatment comparisons
- Individual patient data meta-analysis
- Patient risk stratification to inform trial design
- Training programmes for clinical trialists, methodologists, Data Safety Monitoring Boards and clinical trial personnel.

The University has four centres which specialise in this area:

The **Clinical Trial Research Centre (CTRC)** is a centre of excellence in clinical trial design, management and analysis, accessed by both the public and private sectors, and one of only a small number of units in the UK awarded Full Clinical Research Collaboration registration status. The CTRC incorporates the Medicines for Children Research Network Clinical Trials Unit, the Liverpool Cancer Trials Unit, the Epilepsy Trials Unit and other groups in infection, oral health, obstetrics and gynaecology.

The Liverpool-based **North West Hub for Trials Methodology Research (NWHTRM)** provides a focus for research around trials methodology, developing a world-class centre where methodological issues facing the clinical trials community can be investigated – enhancing patient care by improving the validity and relevance of the healthcare evidence base.

The **Centre for Medical Statistics and Health Evaluation** provides innovative statistical analysis support and advice to clinical researchers, and delivers a number of CME-accredited courses that are designed to provide healthcare professionals with research skills. Areas of expertise include survival analysis, meta-analysis, joint modelling of longitudinal and survival data, pharmacogenetics and stereology.

Based in Liverpool Women's Hospital, which houses the busiest maternity and neonatal units in the UK, the University undertakes a range of randomised controlled trials and systematic reviews both nationally and internationally around reproductive and developmental medicine.

Applications

A wide range of organisations collaborate with the University to access these specialist clinical trial resources. Public sector partners include UK and international governments, public health bodies and research institutions. Companies which have engaged clinical trialling of new interventions include Johnson and Johnson, Eisai Ltd and UCB on the trialling of new anti-epileptic drugs.

5.0 Paediatric Medicine

Keywords: *Medicines for Children Research Network; paediatrics; child health; translational medicine; adverse drug reactions*

Overview

Liverpool is at the forefront of translational research and development in children's health and paediatric medicine. Internationally-recognised expertise spanning the University's Institute of Child Health and the Alder Hey Children's NHS Foundation Trust has been augmented by the award of coordinating centre of the **NIHR Medicines for Children Research Network** (MCRN). The importance of moving forward research into paediatric medicines has placed Liverpool in a unique position to support the pharmaceutical industry in development of interventions for children.

Expertise

The **NIHR Medicines for Children Research Network** (MCRN) was established in Liverpool to co-ordinate and galvanise paediatric research across the UK. The MCRN improves the efficiency and quality of randomised controlled trials and other well-designed studies of medicines for children and adolescents, including those for prevention, diagnosis and treatment. The associated **Clinical Trials Unit**, has a national responsibility for organising and implementing clinical trials of paediatric medicines. The MCRN works in close partnership with industry to maximise the development of safe and effective medicines and formulations for children.

Interdisciplinary translational research

- The award of the MCRN has been paralleled by progress in other areas of translational research that have a clinical impact directly on child health, both in the UK and globally
- The University leads a new initiative to examine adverse drug reactions in children (the ADRIC programme)
- Liverpool is a recognised centre of excellence in research and development of childhood airway disease, with ongoing studies into viral and bacterial respiratory disease, lung development and nasal airway ion transport
- National studies, based in Liverpool, are examining the impact on families of conditions such as cystic fibrosis and Systemic Lupus.

Applications

The **NIHR Medicines for Children Research Network** supports pharmaceutical and biotechnology companies and contract research organisations (CROs) through all research and clinical stages. This includes development of paediatric clinical trial feasibility studies, trial site identification, trial implementation, costing, ethics approval, staff training, patient recruitment, data collection and addressing of new paediatric regulatory requirements.

The MCRN has adopted large numbers of paediatric clinical trials in a wide range of indications from companies such as Abbott Laboratories, MedImmune, Shire Development, GlaxoSmithKline, Wyeth, Merck, AstraZeneca, Pfizer, Roche and Novartis.

6.0 Gastrointestinal Health

Keywords: *Pancreas; inflammatory bowel disease; gastrointestinal; microbial disease; cancer; clinical trials; endoscopy; experimental models*

Overview

Gastrointestinal research in Liverpool is interdisciplinary in nature, encompassing biomedical research groups within the University and their clinical colleagues in the gastroenterology and surgery directorates at the Royal Liverpool University Hospital. Activities range from basic science to translational projects and clinical trials. Diseases of particular interest include pancreatitis, inflammatory bowel disease, gastrointestinal microbial disease and gastrointestinal cancer. Staff are working with industry partners to address their clinical needs in gastrointestinal disease prevention and management.

Expertise

Pancreatic disease research

Pancreatic research is centred in the **NIHR Biomedical Research Unit for Pancreatic Diseases**, which specialises in pancreatic digestive diseases. The Unit has been awarded to the University in partnership with the Royal Liverpool University Hospital, and is undertaking translational research into pancreatitis and pancreatic cancer. It is pioneering the development of new drugs, diagnostics and preventative strategies to improve patient care. The Unit has strong links into industry for partnering in the development and commercialisation of these products.

Other translational research

Gastrointestinal translational studies also take place in the [NIHR Specialist Biomedical Research Centre in Microbial Diseases](#). Examples here include development of novel treatments for Crohn's disease, and the diagnosis of patients pre-disposed to *H. pylori*-associated gastric cancer.

Clinical trials

Liverpool has considerable experience of conducting clinical trials in benign (eg. inflammatory bowel disease) and malignant (eg. pancreatic cancer) gastroenterological diseases. Cancer trials are coordinated by [Liverpool Experimental Cancer Medicine Centre](#) and [Liverpool Cancer Trials Unit](#).

✦ Also see *Clinical Trials and Evidence Synthesis* on page 23.

Endoscopy

The Royal Liverpool University Hospital houses one of the UK's largest endoscopy units and is a national endoscopy training centre. It provides the whole range of diagnostic and therapeutic endoscopic interventions and novel endoscopic techniques, for example, confocal endomicroscopy. There are opportunities for development of endoscopic techniques, and for performing endoscopy and tissue acquisition as part of clinical studies.

Experimental models of gastrointestinal diseases

There is expertise in the use and development of various experimental models of gastrointestinal diseases. These include mouse models of cancer, colitis and pancreatitis, primary culture models of both gastric and colonic epithelium from humans and mice, and access to the [Liverpool Tissue Bank](#) with more than 11,000 samples linked to clinical outcome data.

✦ Also see *Oncology* on page 22.

Applications

The University has worked with a biotech company, Provoxis Natural Products Ltd, to develop a medical food product derived from a plant extract with demonstrated clinical efficacy against inflammatory bowel disease. Similarly, studies have been undertaken with Sanofi Pasteur on the dynamics of healthcare-associated rotavirus gastroenteritis infection in large hospitals. Clinical trials have been conducted with a number of companies to evaluate the safety and efficacy of new interventions in disease areas such as pancreatic cancer, ulcerative colitis and other forms of inflammatory bowel disease.



The Royal Liverpool University Hospital houses one of the UK's largest endoscopy units and is a national endoscopy training centre.

7.0 Appetite and Obesity

Keywords: Obesity; weight management; appetite; food interventions; health claims; drug development; clinical research; clinical trials

Overview

Activities in this area centre around the **Liverpool Obesity Research Network** (LORN), which comprises key research and clinical laboratories based across the University of Liverpool, Aintree University Hospital and the Royal Liverpool and Broadgreen University Hospitals. LORN specialises in:

- Pre-clinical and clinical studies of appetite control, diabetes, energy balance and weight management
- Discovery science focused on the role of the central nervous system, the gut and adipose tissue in energy regulation and appetite
- Biopsychology – the psychological, physiological and biological mechanisms that govern appetitive behaviour
- Public health epidemiology of obesity and evaluation of nutrition programmes
- Veterinary obesity research, with Europe's only clinical centre for weight control in companion animals.

Members of LORN work extensively with the food and pharmaceutical industries. LORN offers industrial collaborators an unrivalled knowledge and range of expertise in investigational methods of weight management.

Expertise

The **Liverpool Obesity Research Network** has a wide range of specialised biomedical and clinical research facilities, methodologies and techniques available to collaborators:

- Clinical study resources – the unit specialises in investigative medicine and clinical trials in diabetes and obesity, with extensive experience in phase 2 and phase 3 clinical studies, and has worked on the development of many novel treatments that act both peripherally and centrally. The unit has a dedicated Patient Assessment area and is staffed by a clinical trial co-ordinator, four research nurses, clinical research fellows and dietitians
- Dietary and drug induced pre-clinical obesity models, including a validated model of Olanzapine-induced hyperphagia and weight gain.

- Development of study methodologies for holistic investigation of weight management, including measurement of metabolism and energy balance, obesity modelling, eating behaviour, physiology of appetite expression, feeding psychology.
- The Kissileff Laboratory is a purpose-built suite of rooms for the experimental study of human eating fitted with a two-way mirror, cameras and video editing and analysis equipment, enabling observational analysis of eating behaviour in individual or group settings
- Universal eating monitors for the automated measurement of food intake and changes in appetite within a meal
- Indirect calorimetry techniques enable measurement of metabolic rate and energy expenditure in response to food consumption or drug treatments
- Psychophysical measurements of changes in sensory or hedonic evaluation of foods and fluids, such as the effects of drugs on taste and palatability thresholds.

Applications

The LORN Clinical Research Unit routinely engages with the pharmaceutical industry on the development and clinical trialling of new treatments for obesity and diabetes. Company collaborators include Sanofi–Aventis, Pharmacia, Takeda, Speedel Pharma, Novo Nordisk, Eli Lilly, Abbott Laboratories, Novartis, Roche and AstraZeneca.



8.0 Ophthalmology

Keywords: Age-related macular degeneration; diabetic retinopathy; retinal disease; screening; imaging; grading; biomaterials

Overview

Liverpool's **Ophthalmology Research Unit** (ORU) combines the University's ophthalmology research division and the clinical St Paul's Eye Unit in the Royal Liverpool University Hospital. The ORU performs basic science and clinical research into the control of eye disease and ocular tissue repair and regeneration. It is a centre of excellence for the teaching and training in the control and treatment of eye disorders, and is at the forefront of development of novel techniques to improve the understanding and treatment of ocular disease. The expertise and resources within the ORU and the applied nature of its activities have resulted in numerous collaborations with industry in technology and product development.

Expertise

Interests include age-related macular degeneration, corneal scarring, diabetic eye disease, ectodermal dysplasia, glaucoma, melanoma and proliferative vitreoretinopathy. The interdisciplinary activities of the ORU are carried out in partnership with the University's departments of Clinical Engineering, Orthoptics and Pathology.

Diabetic eye disease

The **Ophthalmology Research Unit** has pioneered the development of technician based screening for diabetic retinopathy. This approach has been adopted by the Department of Health as part of the National Screening Programme. Diabetic retinopathy is the commonest cause of blindness in the working age population.

Age-related macular degeneration (AMD)

AMD is the commonest cause of blindness in the developed world. **Ophthalmology Research Unit** staff have led the UK in introducing photodynamic therapy and, most recently, antiVEGF (anti-vascular endothelial growth factor) drug therapy, for the treatment of AMD. Models of care developed in Liverpool have now been adopted by the Royal College of Ophthalmologists and National Commissioners.

Grading of images of retinal disease

A national Screening and Grading Centre has been established within the **Ophthalmology Research Unit** for the delivery of retinal screening programmes. This Centre trains and accredits ophthalmic technicians on the grading of retinal images for diabetic retinopathy and AMD disease management.

Staff within the **Ophthalmology Research Unit** are developing new techniques for the assessment of retinal function, structure, retinal imaging and data analysis. These techniques assist early detection of retinal disease and measurement of intervention efficacy.

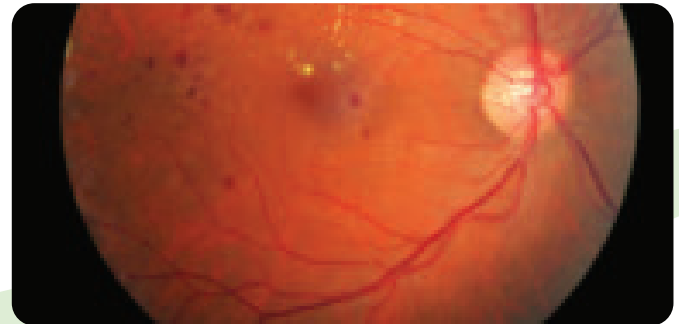
Biomaterials development

The **Ophthalmology Research Unit** studies the applications of new and modified materials for eye disease management. This includes use of tamponade agents in the treatment of retinal detachments, novel vitreous substitutes, surface modification of intraocular lenses to modulate ocular scarring following lens implantation, and the development of membrane materials suitable for transplanting retinal cells as treatment for AMD.

Applications

The **Ophthalmology Research Unit** has a strong track record of partnering with the pharmaceutical industry in the development of eye disease interventions. They have worked with Pfizer on the characterisation of effects of the ophthalmic solution Latanoprost (Xalatan®), a treatment for the reduction of elevated intraocular pressure in patients with open-angle glaucoma or ocular hypertension.

They have also collaborated with a number of companies in the development of new biomaterials, for example in the use of silicone oils as tamponades, and the preparation and transplantation of clinical grade membranes carrying retinal cells to treat eye disease.



9.0 Veterinary Science and Zoonoses

Keywords: *Disease epidemiology; mathematical modelling; climate change; zoonoses; continuing professional development; clinical hospitals*

Overview

With interdisciplinary collaborations across the wider University and access to state-of-the-art research and clinical facilities, Liverpool researchers are uniquely positioned to work with industry and address the key questions in veterinary science and medicine.

Expertise

Liverpool is a recognised centre for research into the pathogenesis, transmission and control of infectious disease, both in and between animal and human populations.

National Centre for Zoonosis Research (NCZR)

The **National Centre for Zoonosis Research** represents the world's first interdisciplinary centre dedicated to the study of animal-borne human diseases. As the hub of a dynamic network the NCZR undertakes world-class research into zoonotic infections, and is a catalyst for national and international collaborations, taking multidisciplinary and multi-institutional approaches to zoonosis research. The Centre provides scientifically-sound, evidence-based, relevant and timely advice and consultancy services to governments, businesses and other partners.

Epidemiology

The University has particular expertise in epidemiology, the research of transmission and control of infectious disease. Areas of study include the epidemiology of zoonotic infections (food-borne pathogens, MRSA, *Clostridium difficile*), and modelling the dynamics of disease spread. These models, which take into account variables such as climate change, disease emergence and evolution, and infection processes, are critical for exploring the efficacy of mitigation and control strategies of possible future epidemic scenarios.

Continuing Professional Development

Liverpool is a leading UK centre for student training and the continuing development of veterinary professionals, delivering a range of courses in veterinary science and medicine.

Facilities

- First opinion and referral hospitals in all three disciplines of horses, small animals and farm animals
- Philip Leverhulme Equine Hospital and associated Leahurst Equine Practice
- Small Animal Teaching Hospital with advanced facilities for small animal medicine and surgery
- Two working farms on site, the Wood Park dairy farm and the Ness Heath sheep and pig farm
- Farm Animal Hospital & Practice
- Small Mammal Unit, a unique facility to study disease dynamics in free ranging rodent populations
- The Behavioural Isolation Unit for behaviour, zoonosis and infection research
- Kinetic and kinematic gait analysis systems
- Establishment of the UK DNA archive for companion animals.

Applications

Veterinary researchers have a proven track record of commercial activity and working with business. There are real strengths in diagnostic assay development, some of which are provided as a commercial service and others which have been exploited by commercial partners.

Long standing relationships exist with livestock, animal health and pharmaceutical industries. Companies engaged with include Pfizer, Mars UK, Novartis and Schering-Plough in areas such as autoimmune disease, weight management and infection control. Merial Animal Health has a well-established collaboration with the University on the development of avian pneumovirus vaccines for poultry.

The **Tesco Dairy Centre** is a national resource centre for farmers, set up as part of the Tesco Sustainable Dairy Group, offering expertise in cattle lameness, fertility and calf health. The Centre aims to help farmers in enhancing the commercial benefits of their work, as well as offering advice on animal health and welfare.

10.0 Genomics and Bioinformatics

Keywords: *Microarray; gene expression analysis; DNA sequencing; sequence assembly; statistical analysis; single nucleotide polymorphism (SNP) discovery*

Overview

Liverpool's **Centre for Genomic Research** is one of the most advanced laboratories of its kind in the UK. The Centre possesses a range of state-of-the-art DNA sequencing technology, while its microarray facility offers the full range of high-density technological platforms for microarray design, fabrication and image analysis. With access to the latest computational tools the Centre can apply expertise in sequence assembly, genome annotation, metabolic analysis, gene expression analysis and statistics. The Centre provides genomics services for the entire UK including undertaking contract and collaborative research with industry partners.

Capabilities

Genome sequencing

- 454 GS FLX Titanium Pyrosequencing – a long-read sequencing technology, can be used for sequencing genomes *de novo*, cDNA sequencing for gene discovery and metagenomic analysis of, for example, microbial populations
- ABI-SOLiD 3 sequencing – a high capacity, short-read technology ideal for whole genome re-sequencing and expression analysis
- Expression analysis – both SOLiD and 454 platforms can be used for genome wide expression analysis without the need for microarrays – millions of cDNA tags can be sequenced in parallel for highly sensitive analysis
- Single nucleotide polymorphism (SNP) discovery and detection – Sequencing with both platforms can be used to identify SNPs *de novo*. Due to the extremely high throughput nature of the platforms, SNPs can be found at very low frequencies, such as in cancer tissue.

The Centre possesses a range of state-of-the-art DNA sequencing technology, while its microarray facility offers the full range of high-density technological platforms for microarray design, fabrication and image analysis.

Microarrays

The **Centre for Genomic Research** provides access to all of the major commercial microarray platforms, including Affymetrix, Agilent, Nimblegen and Illumina. It can construct custom arrays either by in-house *in-silico* design from online sequence resources followed by commercial fabrication, or by in-house fabrication using ink-jet or contact printing robots from cDNA amplicons or synthesised oligonucleotides. Full service provision is offered from receipt of RNA through to provision of fully analysed expression data.

Bioinformatics

- Genome annotation – automated genefinding software and search tools can be applied to genome sequence to give a complete gene list with annotation
- SNP discovery – high confidence SNPs can be identified from raw sequences taken from either of the Centre's sequencing platforms. Data includes flanking sequences for downstream assay design
- Statistical analysis of gene expression data – to identify genes which are responding to experimental treatment or disease. Analysis techniques used include functional profiling and network description.

Applications

In addition to public sector clients, the **Centre for Genomic Research** provides high-value commercial services to both SMEs and large companies (eg. Shell Global, Unilever) operating in as diverse fields as DNA diagnostics and the biotechnology, pharmaceutical and environmental sectors. Services include sequencing and identification of microorganisms from field samples, generation of bespoke genotype arrays for species and strain specific applications, and sequencing of genomes to identify presence of particular genes.



Health & Wellbeing

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those which exploit and/or contribute to the development of Health & Wellbeing include:

- Biomedical Electron Microscopy Unit
- Centre for Cell Imaging
- Centre for Drug Safety Science
- Centre for Genomic Research
- Centre for Integrative Mammalian Biology
- Centre for Materials Discovery
- Centre for Medical Statistics and Health Evaluation
- Clinical Trial Research Centre
- CR-UK Liverpool Cancer Trials Unit
- Functional Proteomics Facility
- Liverpool Cancer Research Centre
- Liverpool Experimental Cancer Medicine Centre
- Liverpool Microarray Facility
- Liverpool NMR Centre for Structural Biology
- Liverpool Ophthalmology Research Unit
- Liverpool Tissue Bank
- North West Hub for Trials Methodology Research
- National Centre for Zoonosis Research
- NIHR Medicines for Children Research Network
- NIHR Biomedical Research Centre in Microbial Diseases
- NIHR Biomedical Research Unit for Pancreatic Diseases
- Tesco Dairy Centre
- Ultra Mixing and Processing Facility
- Wellcome Trust Centre for Research in Clinical Tropical Medicine
- Wolfson Centre for Personalised Medicine

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Case Studies

Oncology

A study at the University of Liverpool, sponsored by Oxford Biomedica Ltd, which has been completed successfully, tested the use of a novel gene therapy, MetXia, in combination with a chemotherapy drug, in patients with pancreatic cancer. Conventional chemotherapy agents are non-specific in that they will target both normal and cancer cells, leading to the side effects that can limit their use. The advantage of MetXia is that the chemotherapy is nearly all limited to the tumour cells, which means it is much more effective in killing the cancer and has fewer side effects.

MetXia comprises a highly engineered retrovirus that contains the gene for the P450 enzyme. P450 turns the inactive chemotherapy prodrug cyclophosphamide into the active form. MetXia is injected into the cancer so that it enters the cancer cells; the carried P450 gene is transferred into the cells which then start to generate the enzyme. The inactive form of cyclophosphamide can then be given into the bloodstream near the cancer, this is converted into its active form when it reaches the tumour, and then destroys the cancer cells. This was the first trial in the UK using this type of agent in pancreatic cancer.

Gastrointestinal disease

University researchers have collaborated with a biotechnology company in the development of a potential treatment for inflammatory bowel disease. They have identified specific *E. coli* bacteria in the lining of the bowel which are thought to be a causative factor in Crohn's disease. Subsequently they have demonstrated that the binding of these bacteria to the lining of the bowel can be inhibited by the soluble fibre extracted from plantain (large, green bananas).

This work has progressed in partnership with Provoxis Natural Products Ltd to develop a medical food product derived from plantain extract. A clinical trial to demonstrate the clinical efficacy of plantain fibre in human patients with Crohn's disease is currently being conducted as part of the NIHR-funded Biomedical Research Centre in Microbial Diseases at Royal Liverpool University Hospital and research into further applications of the fibre is supported by the Biotechnology and Biological Sciences Research Council.

Environment & Climate Change



Overview

Breadth of Expertise

- Experimentation
- Sampling on land/ in freshwater/at sea
- Data collection/synthesis
- Mapping and survey
- Computer/physical modelling
- Analysis
- Management/control
- Prediction/forecasting
- Monitoring
- Future-proofing

Focus of Expertise

- Rivers and lakes
- Oceans, shelf & coastal seas
- Wetlands
- Coastal protection/ sea defences
- Climate change
- Ecosystems
- Biodiversity
- Pollution
- Sustainability
- Engineering solutions

Disciplines

- Anthropology
- Applied chemistry
- Applied mathematics
- Applied physics
- Biological sciences
- Civil engineering
- Complexity science
- Earth & ocean sciences
- Economics
- Geography
- Planning

Application Areas

- Supranational bodies
- National/regional government bodies
- Aid agencies and other NGOS
- Regulators
- Health authorities
- Local authorities
- Planning
- Resource allocation
- Civil defence
- Construction
- Insurance
- Utilities
- Environmental consultancies

Key Capabilities

1.0 Understanding the Big Picture

- 1.1 Climate change science
- 1.2 Environmental science

2.0 Addressing Regional and Local Concerns

- 2.1 Water sustainability and integrated management
- 2.2 Water and coastal engineering
- 2.3 Environmental radioactivity
- 2.4 Economics of ecosystems and biodiversity

It is critical that we extend and enhance our understanding of the way the Earth's systems work – and how these might change in the medium to long term due to global warming and the impact of human activities like logging, fishing, farming, manufacturing, building towns, roads and airports, driving and flying. Otherwise we risk being unprepared for change, ill-equipped to address strategic issues and slow to prevent foreseeable problems that threaten life on Earth.

This requires fundamental research at scales ranging from global to local, into environments extending from the uplands to the open oceans and the atmosphere, over timescales ranging from geological to historical and the present. Addressing problems such as desertification and the sustainable use of ecosystems demands the knowledge and skills of experts in disciplines as diverse as geography, Earth and ocean sciences, biology, anthropology, ecology, engineering and applied elements of physics, chemistry, mathematics, planning, society and economics – working in collaboration rather than isolation.

The University of Liverpool is making valuable contributions to this fundamental global research endeavour – helping to advance our understanding of the big picture and plan for a sustainable future.

The knowledge, expertise and technologies gained through this fundamental research also help to address regional and local concerns; guide the policies and practices of public, private and voluntary sector organisations; inform planning and resource allocations; solve problems; provide services; and generate intellectual property which underpins innovative commercial products.

1.0 Understanding the Big Picture

The University is helping advance our understanding of 'the big picture' by exploiting its own, very wide-ranging expertise; by fostering collaborative, multidisciplinary approaches to uncertainties about climate change and other environmental challenges; and through close working relationships with key institutions adjoining the University.

The University set up the [Centre for Marine Sciences and Climate Change](#) to capitalise on its many environmental strengths. It does this by providing a forum for researchers from Earth and ocean sciences, geographical, biological, mathematical and social sciences and civil engineering to reach a consensus on their research priorities, develop an integrated plan and initiate fruitful collaborations.

Centre members are currently focusing their efforts on fundamental research into climate change, carbon and nutrient cycling; ocean biogeochemistry; ocean warming; sea level change; and shelf sea dynamics. They are also pursuing applied research into sea defences and electricity generation from new renewable sources such as wind and tides.

The Centre's associate members include researchers from the Natural Environment Research Council's [Proudman Oceanographic Laboratory](#) (POL), which is located on the University campus. POL is renowned for its world-class research into the physics of estuarine, coastal and shelf sea circulation; wind wave dynamics and sediment transport processes; global sea level science and geodetic oceanography; and marine technology and operational oceanography. It also hosts the Permanent Service for Mean Sea Level (PSMSL) and the British Oceanographic Data Centre (BODC).

POL collaborates with the University on a wide range of environmental projects, extending from better understanding of ocean circulation and the interaction between the atmosphere and the oceans in regulating climate change to 'fingerprinting' the sources of sea-level rise detected in instrumental and sedimentary records.

The [Liverpool Institute for Biological Complexity](#) is another cross-disciplinary resource which focuses on the interface between biosciences, mathematics and complexity science. This is an important aspect of climate change research in being able to accurately predict impacts on ecosystems that support human populations.

For further information see 'Specialist centres, facilities & laboratories' on page 142.

1.1 Climate change science

Keywords: *Warming; orbital forcing; oceans; carbon cycling; biogeochemistry; ice; sea-level; coastal & shelf seas; rainfall; river styles; human activity; geological timescales; historical timescales*

Overview

There are many signs to suggest that our climate is changing: records reveal rising global temperatures; a rising snowline; Summer sea ice shrinking in the Arctic; upper ocean warming; and sea-level rise. Alongside these physical changes, there are also biological and chemical changes – ranging from earlier bird migration and changing vegetation patterns and ecosystem dynamics to coral reef damage through warming.

These changes need to be placed in their proper geological, historical and contemporary contexts. Indeed, it is through this understanding that human impacts on the climate system can truly be detected. Further, we need to uncover interrelationships and trends in order to predict likely global and regional impacts on societies and economies in an accurate and timely way to enable effective budgeting and resource allocation.

The University of Liverpool is therefore contributing to this important endeavour, which is a prerequisite to the development of sustainable global, regional and local strategies and actions to mitigate the impacts of climate change and adapt to them.

It is also working with local authorities, downscaling predictions of climate change from global climate models, to help them develop their adaptation strategies.

Fundamental research

Geological and global-scale research

The University is researching the link between tectonics, Earth surface weathering and climate; the orbital forcing of climate change; carbon cycling and the biogeochemistry of the atmosphere and ancient oceans; the strength of the Asian monsoon; and the Earth systems' response to ice ages and sea-level rise.

It is investigating sea level history and sediment supply to the world's coastal and deep ocean basins in order to decipher the effects of climate change on sedimentary basins over geological time; and exploring – through fieldwork in Europe, Africa, China, South and North America – the relationship between changes in river style and sediment flux over time and patterns of climate change. Current projects include the deep ocean drilling project (DSDP) cores offshore of the Congo, the Black Sea, the Mediterranean and the Yangtze.

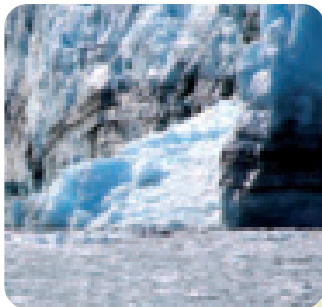
Oceans and coastal seas

The University is a key player in research into the relationship between the climate and the oceans – confirming recently, for example, that oceans play an important role in the Earth's climate system by storing heat and carbon and redistributing it over the globe.

It also researches continental shelf and coastal seas, where signals of climate change appear to be amplified. It recently found a clear signal of coastal warming in shelf seas which could lead to rapid changes in the ecosystem – for example, changes to fisheries, which links in to the University's expertise, and track record in the management of marine ecosystems and resources. Coastal warming could also endanger health by enabling new species and diseases to invade. Since sea-level changes in coastal seas can be much larger than in the open ocean, research into coastal systems over the last 10,000 years and at the present time is helping to understand how rising sea levels and storms could threaten threat to the physical security and economic sustainability of some coastal communities.

The human dimension

University researchers are identifying and distinguishing the impacts of humans and climate change on coastal waters, river catchments, lakes, mires and bogs, arid lands, slopes, glaciers and wetlands with a view to establishing early impacts (as far back to Neolithic times) of land-use and fuel consumption on atmospheric carbon and climate. This is a far from trivial issue, requiring careful analysis and interpretation of records that are regarded as 'proxies' for changes in the climate, Earth surface and biological systems, yet it underpins our understanding of long term climate change. The use of biological proxies for climate change research, coupled with accurate and innovative ways for determining the age of given sediment records, also provides a means for resolving climate and human drivers of soil erosion, sediment flux, desertification and changes in ecosystem dynamics.



Techniques

The University uses a wide range of techniques to uncover vital evidence from the past and the present:

- Geophysical investigation techniques:
 - Seismic and acoustic profiling
 - Geomagnetism and remote sensing
- Offshore survey techniques:
 - Spatially- and vertically-resolved trends in temperature, Nutrients and biological productivity
 - Sea bed habitat characterisation and sub-bottom structure
- Sedimentology and stratigraphy for the identification of depositional environments, extreme events and erosion regimes:
 - Core logging and correlation
 - Particle size analysis
- Sediment supply characterisation:
 - Sediment geochemistry (inorganic and organic)
 - Environmental and rock magnetism
 - Mineral composition and structure
- Data on past vegetation patterns, human impacts and water quality:
 - Palaeontological and palaeoecological techniques (analysis of pollen, algae, foraminifera etc)
 - Stable isotopic investigation of carbon and oxygen
- Chronological methods for sediment dating:
 - Low-background gamma spectrometry
 - OSL and U-series dating
 - PSV dating.

1.2 Environmental science

Keywords: *Human impact; climate impact; Earth surface processes and landforms; geomorphology; natural hazards; soil erosion; pollution; environmental impact assessment; environmental management; spatial planning; ecosystem-based management*

Overview

Environmental problems take many forms – from natural hazards like earthquakes, volcanoes, tsunamis, flooding and pests to manmade problems like heavy metal and organophosphate pollution, nuclear waste, toxic manufacturing by-products, soil erosion, water shortages and over-reliance on oil and gas. They range from local phenomena like extreme rainfall to the disruption of whole ecosystems to global phenomena, such as the circulation of greenhouse gases arising from human activities.

Environmental science provides a holistic, inter- and transdisciplinary quantitative approach to acquiring knowledge and understanding of the natural environment and its multifaceted interactions. It is a well-established field encompassing the physical, mathematical, life and social sciences. It enables us to improve our ability to understand, predict and manage natural hazards and promote sustainable development.

Expertise

The University of Liverpool has recently established the School of Environmental Sciences, bringing together a spectrum of expertise to underpin transdisciplinary research that is of considerable relevance to society. This is achieved by assembling teams whose members are drawn from numerous disciplines according to the demands of individual projects. Whilst the core of the School lies in Geography, Earth and Ocean Sciences, Civic Design, Environmental Management and Marine Biology, the full range of disciplines extends right across the University – from the physical and life sciences to the mathematical and social sciences and engineering.

Fundamental research

Natural hazards

Complementary research is focusing on the practical and theoretical issues of sustainable societies in the inter-related contexts of climate change, natural perils and human health. It is contributing to the understanding of human vulnerability and response to natural perils, in particular, improving understanding of flood magnitude and frequency in relation to climate change, informing hazard assessment and management from the study of past volcanic and seismic events, and developing practice for hazard evaluation and assessment. Predictive modelling of coastal environmental response to climate change is also providing effective support tools for decision-making and resource allocation to mitigate vulnerability to coastal flooding and erosion.

Environmental change

The core scientific interest here is the evidence for and forcing of environmental changes within varied depositional and geomorphic settings – lacustrine, riverine, glacial, coastal, hillslope, aeolian and montane – and on varied timescales. Reconstruction of past environments considers the relative importance of gradual and catastrophic processes; past evidence of climate- human interaction; Earth system modelling – particularly in relation to the causes of soil erosion and desertification; and the development of advanced analytical techniques for improved understanding of cause and timing.

Ecosystem research

Understanding ecosystem function and dynamics is currently a key focus of environmental management. This requires fundamental research not only in relation to the current health and status of ecosystems, from upland peat bogs to those of the marine environment, but how these have changed through time in relation to internal dynamics and external forcing. Bringing together expertise in ecology and palaeoecology provides the University with a key strength in this area, thus better informing the understanding of ecosystem response to climate change and human impact, and providing a sound basis for the management of resources.

Human health and wellbeing

Cutting across the physical, natural, social and biomedical sciences is research into the linkage between the environment and human health. Together with the [Liverpool School of Tropical Medicine](#), the University provides key answers to the impacts of climate change on disease, health and wellbeing. Climate and human health research has examined the integration of impacts models with the prediction of climate variability from ensemble prediction systems, the downscaling of climate models, and prediction of disease, in particular malaria and meningitis.

Environmental science provides a holistic, inter- and transdisciplinary quantitative approach to acquiring knowledge and understanding of the natural environment and its multifaceted interactions.

Facilities

The University is well-equipped with facilities to support environmental science. These include:

- Low-background hyper-pure germanium gamma spectrometry and associated alpha spectrometry
- Metal chemistry and mineralogy by electroanalytical chemistry, scanning electron microscopy, atomic absorption spectroscopy (AAS), X-ray diffraction (XRD) and X-ray fluorescence (XRF)
- Organic chemistry by liquid and gas chromatography mass spectrometry (GC-MS) and Fourier-transform infrared spectroscopy (FTIR)
- Stable isotope geochemistry (carbon, oxygen, nitrogen, hydrogen)
- Greenhouse gas emissions (carbon dioxide, methane, nitrous oxide)
- Carbon and nitrogen dynamics in peat and soils (dissolved organic carbon, enzymes)
- Seawater aquaria and mesocosms
- Geomagnetism, mineral and palaeo-magnetic research
- Numerical modelling and computing
- Palaeoecology and microscopy
- Laboratory-based sedimentology and field instrumentation
- GIS and decision-support systems
- Research vessel, and a full range of equipment for environmental sampling and monitoring.



2.0 Addressing Regional and Local Concerns

Although the University's climate and environment research is essentially fundamental in nature, some of its findings can be applied directly to improve human health and wellbeing. They have led, for instance, to improved understanding of monsoonal climate patterns, the prediction of rainfall and the onset of malaria and spread of meningitis in Africa. They have enhanced our understanding of animal and wildlife disease in Africa and Europe. Outcomes like these are of considerable importance to aid agencies and health initiatives, which are able to utilise their limited resources more effectively.

The University's environment research programme includes strategic and applied projects which address particular regional or local environmental concerns, some of which are carried out on behalf of public or private sector clients. In this respect, the University's research is underpinning the adaptation and mitigation strategies of local authorities, regional government, national regulatory authorities, as well as business activities with links to the environment – for example, the production of drinking water, water treatment, waste disposal and renewable energy.

The University has long-standing strengths in different aspects of water sources and their management; in the 1990s, it developed the plan for cleaning up the Mersey, helped to implement the plan and supplied the Chair of the award-winning Mersey Basin Campaign. It also has extensive expertise in the design and management of seawall defences. Detecting and interpreting environmental radioactivity is another long-standing strength.

It is also cultivating new strengths and is currently leading pioneering work on the economics of ecosystems and biodiversity.

2.1 Water sustainability and integrated management

Keywords: *Water sources; water quality; biogeochemistry; biodiversity; ecosystems; wetlands; sustainability; policy compliance; environmental economics; ecosystem services; carbon economy; poverty alleviation*

Overview

Water is one of the 21st century's most valuable assets. We cannot survive without it; it is also a source of food and energy; it is involved in a wide range of industrial processing; it plays a key role in ecosystems; supports transport; provides opportunities for recreation and sport; and it is the foundation of numerous businesses.

Managing and protecting water resources is one of today's most significant challenges. Doing this effectively requires complementary expertise from a wide range of disciplines – from the natural sciences to the social sciences, public health and engineering.

Expertise

The University can draw on expertise from all these disciplines. To ensure it harnesses this expertise coherently, it has created a specialist institute:

The **Institute for Sustainable Water, Integrated Management and Ecosystem Research (SWIMMER)** is the gateway to expertise in the natural science of water (extending from biogeochemistry and radioecology to wetlands and biodiversity); social and economic requirements of water (cleanliness, restoration and environmental management); and environmental economics (eg. the sustainable delivery of ecosystem services, developing a low carbon economy, poverty alleviation, cost-benefit analysis).

The University's expertise in the assessment of ecosystem services and their economic valuation underpins decision-making at a variety of scales. Examples range from the management of peat bog and wetland resources (by authorities such as Natural England and United Utilities) to the integrated planning of river basins and coastal seas (by DEFRA, the Countryside Council for Wales and the Association of Rivers Trusts). They extend to the impacts of climate change on human health and wellbeing in different regions of the world.

SWIMMER facilitates the provision of a range of services to businesses – for example, guidance on policy compliance, decision-making, resource management and future-proofing. These services are used by industry, regulators, governments and non-governmental organisations in the UK and around the world.

For further information on SWIMMER see 'Specialist centres, facilities & laboratories' on page 142.

Applications

Through SWIMMER, the University is helping the Environment Agency to implement the EU Water Framework Directive, harnessing its understanding of river hydrology, water quality and wetlands.

Managing and protecting water resources is one of today's most significant challenges. Doing this effectively requires complementary expertise from a wide range of disciplines – from the natural sciences to the social sciences, public health and engineering.

2.2 Water and coastal engineering

Keywords: *Coastal processes; estuarine processes; data capture; computer modelling; beach erosion/accretion; seawalls; wave overtopping; electricity generation; tidal barrage; hydroinformation; environmental hydraulics; flood risk; river channel dynamics*

Overview

A major strand of the University's environmental expertise is focused on emerging and predicted problems afflicting our coasts, river channels and floodplains – for instance, pressures on shorelines due to sea level rise and storm surges and on riverside developments at risk of flooding and bank erosion; on the increasing demand for water and the environmental protection of water bodies; and on water as a renewable energy source.

The University's engineering and geomorphology expertise in this area derives from research encompassing a mix of laboratory experimentation, field data collection and computational modelling studies – and from real-world implementation of engineering, land and land-use management solutions. This includes the development of novel flood defences, numerical models to predict overtopping of defences during storms, fundamental research to gain a better understanding of historical flood risk and channel dynamics during high river flows, and the provision of eco-hydrological solutions for reducing flood peaks and providing buffer zones for flood waters.

Expertise

Maritime and coastal engineering

Research in this area has focused on capturing data relating to coastal and estuarial processes and developing computer models capable of predicting the behaviour of coastal and estuarine regimes under different conditions. These will allow the diverse effects of climate change on particular maritime areas to be predicted and planned for – and the effects of man-made alterations tested in a virtual environment before resources are committed.

Models developed to date cover phenomena such as sediment transport, which can lead to beach erosion and accretion; the formation and morphology of sandbanks; waves and tides' potential to overtop sea defences; and their effect on the behaviour of estuarial barrages, breakwaters and other harbour structures.

The University has also responded to the UK's emerging interest in marine sources of renewable energy. To date, its modelling expertise has been targeting the potential for tidal barrage and tidal stream electricity generation, and the appraisal of environmental issues likely to arise from such developments. Much of the work relies upon accurately modelling fundamental fluid mechanics processes and has been carried out in collaboration with the **Proudman Oceanographic Laboratory (POL)**.

Water sourcing, flows and supply

The University has expertise in water sourcing and in the collection, treatment and distribution of water; the collection and treatment of wastewater; and the civil engineering aspects of pollution control in the water environment.

A special area of interest is the development of new hydro-information systems, remote sensing, geographic information systems (GIS) and related computational methods. These can be harnessed to assist in the management of water within natural catchments, and the design, performance and operational control of water distribution and sewerage systems.

Research in this area also links to expertise in the geomorphology and dynamics of river channels, and how they change over time in relation to hydrological processes, land-use and climate. The Environment Agency has been particularly interested in the University's work on slope-stream coupling, channel connectivity, monitoring and modelling channel response to extreme events, improving knowledge on the magnitude and frequency of extremes using historical data, and in the hydrogeomorphic function of riparian and perimarine wetlands and woodlands as means for environmental management.

Pollution control

Environmental standards set within legislative frameworks are designed to minimise the pollution of water sources and pollution from wastewater. Meeting these standards requires good engineering design.

The University has expertise in the environmental hydraulics of water bodies located inland and in coastal regions. Its expertise derives from studies involving physical models at laboratory scale; field investigations; and the development of computer models. Using this approach, it has advanced our understanding of the mixing zones near wastewater outfalls and the subsequent pollutant dispersion. It has harnessed this to rehabilitate water bodies by means of artificial mixing systems.

Its environmental hydraulics expertise has also been deployed to simulate the transport of sediments and the dispersal of pollutants which might be in flow conduits or surface waters, in sediments or soil; and to assess the performance of hydraulic control structures. The University has also worked on engineering solutions for the protection of freshwater environments in tide-affected locations. In addition, research into ecosystem services for coastal and riverine wetlands has considered the development of natural eco-hydrological solutions to waste treatment and the management of nutrient fluxes in the environment.

Applications

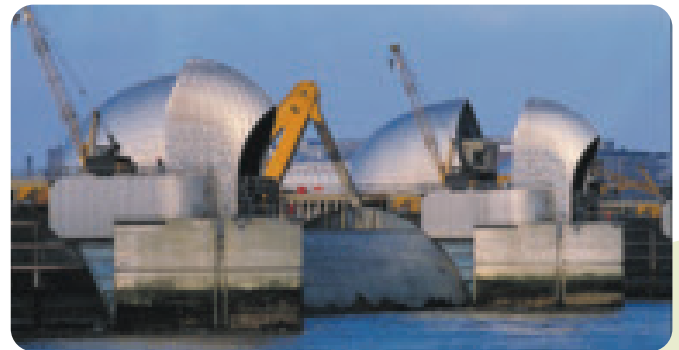
Enhancing the National Flood Forecasting System

Seawalls are intended to contain waves in normal conditions and limit the amount of wave overtopping during high seas. Wave overtopping can be limited by manipulating the slope, shape and surface characteristics of the seawall and its 'freeboard' – its height above the normal level of still waters.

Engineers have relied on mathematical models published 10-20 years ago to predict the mean rates at which seawalls of different shapes and heights would be overtopped by random waves. However, University of Liverpool research revealed that these models overestimated risks to the safety of passing pedestrians and vehicles – leading to unnecessarily high seawalls. Since then, the University has created a better computer model, based on sound theoretical principles and a clear physical representation of the processes involved.

Linked to the operation storm surge forecasting model run by POL, the new model enables seawall designers to achieve a much better balance between effectiveness, cost and environmental impact. It can also be used to predict how existing sea defences would cope with waves and surges of different magnitudes. In 2006, when Black & Veatch – one of the UK's leading consultants on flood and coastal defence appraisal and design – was helping the North East Region of the Environment Agency configure the National Flood Forecasting System to its specific requirements, it chose to harness the University's model.

It is now protecting the coastline from Berwick-upon-Tweed to the Humber estuary and estimates, using data supplied by the Meteorological Office on waves and surges which should reach the coastline 36 hours later, where and to what extent the water will overtop sea defences along the coastline.



2.3 Environmental radioactivity

Keywords: Nuclear power; nuclear fuel reprocessing; radioactive materials; detection; remobilisation; pollution monitoring; radioecology; radiometric dating

Overview

Environmental radioactivity is the study of radioactive materials in the human environment. Some of these materials are present as a result of natural processes; some are found purely as a result of human activities. Others can arise from both natural processes and human activities, and the location and concentration of some natural isotopes – for instance, uranium-238 – can be affected by human activity.

Radionuclide pollution can arise from nuclear fuel reprocessing, nuclear weapons tests, nuclear accidents and the theft of nuclear materials or equipment containing nuclear materials. Once these materials are released into the environment, they can reach and affect the health of humans and animals via the food chain (radioecology), or by direct exposure to the air, the water or the soil.

We need to detect such materials to minimise public health risks. We also need to understand how these materials can be remobilised in our environment and incorporated into the food chain via wildlife, birds and livestock.

Expertise

The University of Liverpool has a research centre which specialises in different aspects of environmental radioactivity research, and provides a service to archaeologists, government agencies and businesses.

The **Environmental Radioactivity Research Centre** researches radionuclide pollution arising from nuclear fuel reprocessing and nuclear accidents. It has developed state-of-the-art radionuclide detection methods. It investigates the ways in which radioactive materials can be remobilised in the environment; and it helps us to gain a better understanding of the dangers to human and animal health which result from ingestion of such materials or exposure to them.

It deploys its detection methods in a range of non-destructive industrial inspection and monitoring applications, and it provides radiometric dating services.

The Centre also carries out complementary research in the area of environmental pollution. Its achievements include improvements in the methods and instruments used to detect persistent organic pollutants and heavy metals in sediments and waters. This work links directly to the requirements of the Environment Agency, amongst other environmental protection agencies, in providing quantitative assessments of the impact of radionuclides in the environment on human health.

For further information see 'Specialist centres, facilities & laboratories' on page 142.



2.4 Economics of ecosystems and biodiversity

Keywords: *Ecosystem services; terrestrial biome; freshwater biome; marine biome; ecology; environmental economics; unit values; discount rates; certification; labelling; biodiversity offsets; policy impacts; production impacts; consumer impacts; toolkit*

Overview

The natural environment provides us with a wide range of 'ecosystem services': crop pollination; seed dispersal; waste decomposition; energy from biomass fuels, hydropower, tides and wind; pharmaceuticals derived from nature; seafood and game – and, of course, water. Due to the impact of human activities, the capacity of ecosystems to deliver some services is seriously compromised. Could such services be rationed or simply unavailable to our grandchildren – and what would be the consequences?

Expertise

We can assess this with confidence thanks to an ambitious study co-ordinated by a University of Liverpool economist, and soon it will be possible to weigh up the cost-benefits of 'business as usual' versus alternatives which would help safeguard our ecosystems for current and future generations.

The creative use of certification and labelling is an established example – for instance, the Forest Stewardship Council logo, and the certification scheme run by the Programme for the Endorsement of Forestry Certification, which guarantees that timber has come from a sustainable source. Emerging initiatives include biodiversity offsets and biodiversity markets – allowing developers whose projects damage habitats to purchase biodiversity credits from third parties who commit to maintaining similar habitats or ecosystems in the surrounding area.

The idea is to establish unit values for biodiversity and ecosystem services in all three biomes – terrestrial, freshwater and marine. These will be informed by evidence on everything from events happening from one second to the next at the molecular level to changes at the level of the biome that take place over years, decades and centuries. The values must be workable in a variety of socio-economic contexts.

The work was commissioned by the European Commission, the United Nations Environment Program (UNEP) and Germany's environment ministry and is scheduled for completion in 2010. The University of Liverpool is co-ordinating the development of a conceptual framework which integrates ecological and economic considerations. This is essential in order to compare the costs and benefits of 'business as usual' with those of alternative approaches.

Applications

This ambitious project is designed to help nations predict the consequences of international and national policies on ecosystems and biodiversity; provide a toolkit to guide public sector decisions made at local levels; give businesses a framework for assessing the impact of production on ecosystems and biodiversity and the risks and benefits of alternative approaches; and empower consumers.

The natural environment provides us with a wide range of 'ecosystem services': crop pollination; seed dispersal; waste decomposition; energy from biomass fuels, hydropower, tides and wind; pharmaceuticals derived from nature; seafood and game – and, of course, water.



Environment & Climate Change

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those which exploit and/or contribute to the development of Environment & Climate Change include:

- Centre for Marine Sciences and Climate Change
- Environmental Radioactivity Research Centre
- Institute for Sustainable Water, Integrated Management and Ecosystem Research (SWIMMER)
- Liverpool Institute for Biological Complexity
- Proudman Oceanographic Laboratory

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Case Studies

Intellectual property at heart of novel testing kit

A decade ago a University of Liverpool oceanographer set out to research 'metal speciation' – a phenomenon which can arise naturally or result from man-made pollution. When metals dissolve in water, the resulting ions may bind to dissolved organic matter, forming variants following reactions influenced by light or bacteria ... or remain 'free'. High levels of 'free' metals can have a drastic effect on local flora and fauna, but plants are 'immune' to the effects of metal ions as long as they remain tightly bound.

At the time it was difficult to measure very low concentrations of dissolved metals and their speciation in natural waters, but key problems were solved by harnessing an electrochemical technique. The resulting device had many strengths – most notably its ability to measure arsenic in drinking water at concentrations of 0.1 parts per billion, distinguishing between highly toxic reduced arsenic (arsenite) and less toxic oxidised arsenic (arsenate); and its portability and autonomous operation.

The patented technology attracted the interest of Wagtech International, a Queen's Award for Enterprise-winning water and environmental testing specialist. The technology was licensed to Wagtech, which commissioned the University to optimise the methodology, enhance the software and embed it in the hardware, instead of running on a laptop. Then Wagtech designed the instrument at the heart of the apparatus and a sonde assembly with a full set of electrodes and protective cover. Neatly packed into a protective hard-shell carrying case with a sample beaker, consumables kit, digital pH meter, micro-pipette, cable clamp, USB lead and mains and vehicle cigarette lighter adapters, this novel environmental test kit was launched in Summer 2009.

United Utilities develops breakthrough technology

The treatment of waste using chemicals recovered from the treatment process is a key goal in developing a sustainable future. To help achieve this, United Utilities Water (Uuw) developed the 'enzymic hydrolysis' (EH) process, which manages waste arising from the treatment of sewage. Installed nationally, it recovers valuable resources like bio-gas and high quality soil conditioners and fertilisers as part of the treatment process.

Sewage sludge has been digested for 60 years but the fundamental microbiology was not understood. To enhance its understanding, enabling this breakthrough technology to be applied to other waste sectors, Uuw joined forces with the University of Liverpool, whose microbiologists have an international reputation. Their expertise in understanding complex microbiological processes using cutting-edge molecular ecology analytical techniques made them the ideal partner to help develop Uuw's technology.

Through a Knowledge Transfer Partnership (KTP) project, Uuw and the University developed a programme aimed at optimising the EH digestion process – enabling Uuw to improve its operational performance, exploit the technology commercially and grow its business.

"The KTP with Liverpool is one of a cluster that we have carried out and provides access to world-class research knowledge and facilities that we alone just couldn't access. It's a real win-win-win for the company, for the University, and for the Graduate Associate, who all get huge value from working together."

Steve Whipp
Standards and Innovation Manager at Uuw

Energy & Sustainability



Overview

Breadth of Expertise

- Auditing
- Data sampling/collection/synthesis
- Mapping
- Modelling
- Analysis
- Interpretation/display
- Prediction/forecasting
- Control/management
- Monitoring

Focus of Expertise

- Hydrocarbon reserves
- Carbon capture & storage
- Oil vulnerability
- Carbon footprint minimisation
- Renewable energy sources
- Power conversion/maximisation
- Grid stability
- Uninterrupted power supplies
- Nuclear waste

Disciplines

- Geology
- Geochemistry/Geophysics
- Electrical engineering
- Civil engineering
- Marine science
- Automation
- Nuclear physics
- Management

Application Areas

- Electricity generation/distribution
- Nuclear energy sector
- Oil & gas
- Renewable energy sector
- Policy-making
- Planning

Key Capabilities

1.0 Locating Hydrocarbon Reserves

2.0 Minimising Businesses' Reliance on Oil

3.0 Generating and Distributing Energy from Renewable Sources

3.1 Wind power

3.2 Tidal power

4.0 New Approaches to Electricity Markets

5.0 Smarter Electricity Distribution

6.0 The Nuclear Option

The use of energy has played a key role in the development of human societies – helping them to adapt to their environments and exert ever-increasing control. Early energy sources like wood, animal/vegetable oil and peat, water and wind were gradually replaced by coal and gas, which could also generate electricity, and by petroleum, which could power internal combustion engines.

In the industrialised world these new energy sources transformed transportation, agriculture and manufacturing and facilitated a domestic revolution. In the 20th century we learned how to generate electricity and power submarines, ships and satellites from nuclear energy.

Today, the developed world still runs on energy derived largely from fossil fuels. Most vehicles use derivatives of oil or gas and a vast range of manufacturers are utterly reliant on petrochemicals. Our information and communications technologies depend on electricity – most of which comes from coal or gas-fuelled power stations.

We cannot continue to rely on fossil fuels: supplies are dwindling and, in any case, burning fossil fuels is contributing to global warming. We don't know whether our efforts to generate energy from novel sources, such as nuclear fusion or hydrogen, will bear fruit. We do know that it will take time to ramp up the amount of power we generate from nuclear energy – and we still need to solve the problems posed by nuclear waste.

This means that in the short-to-medium-term it is essential to develop technologies and lifestyles which consume less energy; minimise the damage caused by fossil fuels; identify new reserves of oil and gas and extract more from existing reserves; enhance our ability to generate and distribute energy from renewable resources; and manage all our energy sources more effectively.

The University of Liverpool is helping to address many of these challenges – drawing on its expertise in the physical, environmental and social sciences, and in electrical, electronic and mechanical engineering.

1.0 Locating Hydrocarbon Reserves

Keywords: *Basin analysis; basin modelling; plate tectonic reconstruction; sequence stratigraphy; deepwater reservoirs; reservoir quality; carbon capture and storage; diagenesis*

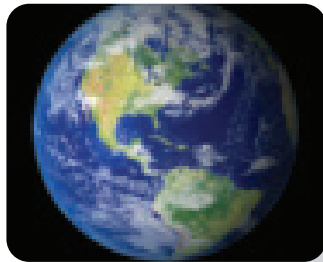
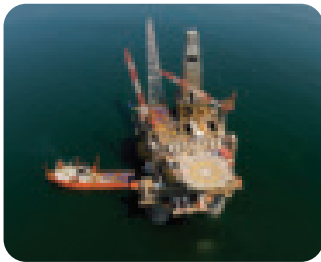
Overview

Nine of the world's 10 largest oilfields have 'entered depletion', to use oil industry jargon, and oil companies are publicly acknowledging that there is no more 'easy oil'. In other words, they are unlikely to uncover massive reserves below shallow, off-shore seas. Instead, they will need to locate deep-sea reserves and develop the capacity to exploit them – generating a whole new sub-sea industry.

The University carries out fundamental research whose results can help the oil and gas industry to locate new hydrocarbon reserves. These results are being applied around the world by multinational and state-owned oil companies, which have spent millions of pounds supporting the University's work in key areas. These include the development of:

- New geophysical techniques using satellite gravity anomaly inversion to map crustal thickness, micro-continents and the ocean-continent transition at rifted continental margins – and its application to refine plate tectonic reconstructions
- New models for the delivery of sand to deepwater submarine slope and basin settings and the positions and shapes of resultant reservoirs
- New models for the burial-related physicochemical changes to the reservoir rocks and prediction of the sealing capacity of shales, with a view to re-injection of CO₂.

This work also has application in the growing area of carbon capture and storage (CCS).



Expertise

The University's strength derives in part from its ability to integrate its expertise in geology, geochemistry and geophysics. This enables it to:

- Synthesise and interpret geophysical data (gravity/seismic) at rifted continental margins and map ocean-continent transitions
- Model sedimentary basin formation, subsidence and heat flow history
- Predict reservoir geometries and 3D architecture/connectivity
- Carry out stratigraphic and sedimentological analysis of sub-surface data, integrated with outcrop analogues
- Model tidal circulation and sediment transport in estuaries (also applicable to tidal sandbody reservoirs)
- Predict and model the diagenetic history of sandstones
- Model the role of biogenic processes in sandstone diagenesis and permeability behaviour at depth
- Predict the suitability of different reservoir types for carbon capture and storage.

Facilities and services

The University offers:

- The development and application of bespoke software for synthesis and display of geophysical data
- Seismic interpretation and reservoir modelling expertise
- Digital outcrop analogue data collection expertise involving differential global positioning systems (DGPS), light detection and ranging (LIDAR) etc
- Shallow borehole drilling and sediment sampling expertise
- State-of-the-art geochemical laboratories including X-ray diffraction (XRD)
- Expertise in modelling the financial implications of an organisation using the Environmental Resilience Audit
- Training on using the Environmental Resilience Audit tool.

2.0 Minimising Businesses' Reliance on Oil

Keywords: *Peak oil; oil vulnerability; direct/indirect oil price impacts; resource efficiency; sustainable procurement; sustainable business practices; competitive advantage*

Overview

Fifty years ago, an American geoscientist introduced a concept now known as 'peak oil' – a point in time when oil production rates reach their highest level before going into terminal decline. It's not clear when global oil production will reach a peak. Some estimates suggest that point won't arrive until the 2020s; others indicate that peak oil is imminent, and some commentators believe we may have reached that point already.

Whether it happens five, 10 or 20 years from now, rising demand from emerging nations, combined with the possibility of falling production, are expected to have a growing impact on prices. They may fall back in the short-term, as they have in the past; in the medium-to-long term they are more likely to rise inexorably.

Oil price rises have already had a discernible effect on transportation and energy costs, but they are also impacting on many other aspects of business operations. Businesses need to reduce their 'oil vulnerability' and the University of Liverpool has developed a methodology and a set of tools to help them do this.

Expertise

The University's expertise in this area fits into its wider work on auditing (for example, resource usage, carbon footprint) and gaining competitive advantage through greater resource efficiency, sustainable procurement practices and sustainable business processes.

It started to address oil-related problems by modelling the behaviour of oil prices under a range of foreseeable circumstances. It then turned its attention to organisations' potential to respond strategically to oil-based turbulence in their business environment.

Limiting the impact of rising oil prices can be very challenging: businesses may need fuel to transport their goods and energy to power their production processes. They may use raw materials derived from crude oil, they may produce man-made materials or assemble products with man-made components, or they may utilise a lot of man-made products.

Before they can figure out the most effective and appropriate ways to minimise the impact of oil prices on their 'bottom line', businesses need to understand the direct and indirect contribution that oil makes to their day-to-day operations.

The methodology developed by the University helps organisations to determine which particular business entities to prioritise – anything from product ranges to individual products or services, from market segments to individual customers, from particular plants to specific production lines. It comprises a five-stage process encompassing business activities/process modelling; resource auditing; mapping; data capture and analysis.

Since the overall aim is to assess the business entity's vulnerability to changing oil prices, oil-specific costs are expressed as a percentage of total costs. This is done by means of resource-tracking flags which identify costs like energy, liquid fuels, petrochemicals, man-made materials and components made from man-made materials. These flags indicate where the resource is situated in the oil supply chain; the further down the supply chain, the smaller the impact of oil price increases in the short-term – but the flags provide early warning of price increases in the medium term.

At the end of the exercise, potential interventions can be identified and prioritised.

Applications

The University's methodology and tools were tested on a range of businesses and refined with the help of the 'Transition Town Totnes' initiative; Totnes was the first town in the UK to set itself the objective of preparing for a carbon-constrained, energy-lean future.

This exercise demonstrated that oil vulnerability is not simply an issue for large companies and multinational giants; businesses of all sizes can benefit – including farms and restaurants (see case study on page 53).



3.0 Generating and Distributing Energy from Renewable Sources

3.1 Wind power

Keywords: *Forecasting; optimal control strategies; power maximisation; grid stability; synchronverters*

Overview

In principle, the wind offers a vast and inexhaustible source of energy which is freely and widely available – and ‘green’. In 2005, the potential of wind power on land and near-shore was estimated to be 72 terawatts – equivalent to 54,000 MtoE (million tons of oil equivalent’ per year), or over five times’ the world’s current energy use in all forms.

In practice, individual countries’ ability to generate electrical energy from the wind depends on a wide range of factors – environmental, political, economic and technical. So, although more than 80% of wind power installations are in the US and Europe, the picture varies from one state to the next. Thanks to Denmark’s 30-year commitment to wind power, it already generates around 17% of its total energy requirements using this method – although it exports much of this to Norway; in the UK, it’s less than 2%, despite its reputation as the windiest country in Europe.

Even if political and economic issues are resolved, numerous technical problems remain to be solved before wind power can start to realise its potential. Wind is unpredictable: wind speeds vary from hour to hour, and the wind can die down completely for extended periods.

To maximise the electricity generated from wind power, generators need to operate at varying speeds so as to cope with the variable wind input. At present the power industry does not have a cost-effective means of storing energy from renewable sources like wind, so it has to use it in real-time, as it is generated. However, energy from renewable sources cannot be connected directly to national grids.

The University of Liverpool helps to address some of these technical problems.

Wind turbine technology has advanced significantly over the past 20 years thanks to the development of large-scale doubly-fed induction generators and small scale permanent magnet generators (PMGs).

Expertise Forecasting

The University is investigating the potential for forecasting wind power generation – estimating the expected power production of one or more wind turbines using computational intelligence techniques.

Control

Wind turbine technology has advanced significantly over the past 20 years thanks to the development of large-scale doubly-fed induction generators and small scale permanent magnet generators (PMGs). In collaboration with industry, the University has developed a robust optimal control strategy for varying-speed maximal power point tracking of the outputs of small-scale PMGs.

Power maximisation

In addition, dedicated power electronics converters have been designed to maximise power outputs from PMGs, and field tests are planned involving three sets of wind generation systems.

Grid stability

Some renewable sources – most notably solar power – can only produce direct current (DC) rather than the AC on which today’s power systems are based. Some can produce AC, but not at the constant frequency which the national grid demands. Engineers get round these problems by converting all power inputs to a DC voltage and using inverters to convert this to a standard AC with a constant frequency.

At present, Britain’s national grid has relatively few inverters connected to it; they number in the hundreds, rather than the millions which would be required to obtain a high proportion of our energy needs from renewable sources. However, no-one knows whether the national grids could accommodate millions of inverters, which are less controllable than synchronous generators; it is possible that they could destabilise it, or make it less reliable.

Several research groups have hit on the idea of creating an inverter which mimics grid-friendly synchronous generators. University of Liverpool engineers are confident that the ‘synchronverter’ they have co-devised has distinct advantages over approaches being pursued elsewhere. In principle, an inverter could mimic a synchronous generator in terms of its internal dynamics – that’s to say, its internal processes – or in terms of input and output characteristics like frequency and voltage. The University’s approach is unique in that it addresses both internal dynamics and external properties at the same time. It is also distinctive in that it controls the voltage, rather than the current.

It takes the form of a mathematical model of a synchronous generator which is implemented in the software controlling the inverter. The model should work with any inverter and can operate in grid-connected mode or in island mode. When it is deployed in grid-connected mode, the real power and the reactive power sent to the grid can be regulated in two ways: it can respond to instructions from the grid operator or it can change the real and reactive power by responding to variations in the grid frequency and voltage on the basis of pre-set frequency/voltage 'drooping' co-efficients.

The technology has many other selling points, has been patented and is available for license (see case study on page 53). It could also be harnessed for the distribution of solar power to electricity grids.

3.2 Tidal power

Keywords: *Tidal stream systems; tidal barrages; tidal lagoons; Mersey; Dee; Solway Firth; Morecambe Bay*

Overview

Although not in widespread use around the world, tidal power has considerable potential as a source of renewable energy because tides are more predictable than wind power and solar power.

Tidal power can be harnessed in different ways. Tidal stream systems make use of the kinetic energy of moving water to power turbines, just as windmills exploit moving air. Barrages, which involve damming across the full width of tidal estuaries, make use of the potential energy in the difference in height between high and low tides. Tidal lagoons are similar, but can take the form of self contained structures and can be configured to generate electricity continuously.

The UK is estimated to have realisable tidal power of around 50 terrawatt hours, which equates to around 13% of the country's electricity demand. As in many other countries, the UK government has been reluctant to exploit the potential of tidal power because of concerns about the cost and the environmental impact.

However, the UK risks failing to meet its EU target for generating energy from renewable sources (15% by 2020), so interest in tidal power is currently growing. Since some methods of harnessing tidal power are cheaper than others and could have smaller environmental impacts, there is now interest in evaluating the generating potential of the different methods in specific areas.

Expertise

In conjunction with the **Proudman Oceanographic Laboratory**, the University of Liverpool recently evaluated the scope for generating electricity from tidal sources in the eastern Irish Sea.

Using 0D and 2D computer modelling, the team investigated the potential for reliable electricity generation from a combination of estuary barrages or lagoons and tidal-stream energy devices.

It reached the conclusion that building estuary barrages across the Solway Firth, Morecambe Bay and the Mersey and Dee estuaries could meet around half of the North West's electricity needs and contribute more than five per cent of the UK's electricity requirements. This is comparable to estimated figures for the electricity which might be generated by a barrage across the Severn Estuary. Moreover, since tides reach the North West some hours after they reach the Severn Estuary, electricity generated by tidal power would not be restricted to two narrow windows in time every 24 hours.



4.0 New Approaches to Electricity Markets

Keywords: Supply; demand; price; least-cost design; conventional power generation; renewable energy generation

Overview

Since renewable energy sources are relatively clean and inexhaustible, in principle they offer a sustainable solution to the rising global demand for energy demand which doesn't contribute to global warming.

In practice, at this early stage, the high cost of technologies which exploit wind energy, solar energy, tidal energy, energy from biomass – or coal and gas with carbon capture – is a major obstacle, limiting their penetration of electricity markets.

Expertise

An electricity market is a system for effecting the purchase and sale of electricity, using supply and demand to set the price. The least-cost design of electricity markets tends to favour conventional power plants using fossil fuels, rather than the costly renewable energy technologies. So, to enable renewable energy to compete with the conventional power plants, a number of countries have implemented financial support schemes.

However, research carried out recently by the University of Liverpool suggests that a green energy policy based on the least-cost technological development and efficient use of renewable energy is also feasible. This emerged from its use of advanced statistical and computational techniques to analyse current electricity market data.



5.0 Smarter Electricity Distribution

Keywords: Protection frameworks; relay co-ordination & operation; ultra-high-speed protection relays; system-on-a-chip technologies; renewables; optimal dispatch; interruptible load; multi-agent technologies; information management; condition monitoring; e-automation

Overview

In the UK the demand for electricity rose by more than 50% between 1970 and 2000 and it is still rising; in the US, demand rose by 26% in the 1990s alone. Some states are struggling to meet current demands because ageing transmission networks can't cope with the loads they are expected to bear. To get the most out of its ageing assets without putting them at risk, the power transmission industry needs accurate, intelligent, real-time monitoring and control systems.

It also needs to minimise the potential for disruption when electricity from renewable sources is channelled into electricity grids. Tides may be predictable, but tidal flows are not – and changes in the magnitude of tidal flows can result in variable power outputs. We know the sun doesn't shine at night – but we don't know how long or even whether it will shine from one day to the next. Wind speeds are even more unpredictable. This unpredictability impacts on the management of power systems because national grids were designed to transmit and distribute electricity generated in very controllable ways by conventional power plants.

The University of Liverpool is applying its expertise to both of these issues.

Expertise

Control of different energy sources embedded in power systems

The University is working on a new network-based protection framework to improve relay coordination and operation in distributed generation systems. This exploits multi-agent technology and is being developed in collaboration with National Grid plc in the UK.

See section 2.3 of Digital Technologies for further information, page 95.

It has also designed ultra-high-speed protection relays which can ensure reliable power system operation in case of high penetration of distributed generation by renewables. This work has been done in collaboration with Siemens using 'system-on-a-chip' technologies.

To facilitate and optimise the combined use of wind, tidal, solar and coal-fired generation power, the University has also worked on the optimal dispatch of various generation capacities using an approach involving interruptible load.

Intelligent, real-time monitoring and control

'e-automation' is shorthand for a new generation of automation systems for information management, condition monitoring and real-time control of distributed industrial systems achieved by integrating the latest networking and agent technologies.

The **National Instruments e-Automation Laboratory** was established at the University of Liverpool to research and develop e-automation systems; the laboratory is also supported by National Grid plc. It has been working on network-based industrial automation, investigating advanced control techniques, computational intelligence, machine learning, information processing and management, software intelligence, computer network and digital signal processing (DSP) system technologies.

It has applied its expertise to electricity grids, making aged systems 'smart' by harnessing information management and condition monitoring techniques more effectively

See section 2.3 of *Digital Technologies for further information*, page 95.

6.0 The Nuclear Option

Keywords: *Fission reactor; ²³²Th cycle; accelerators; transmutation; shorter half lives; modelling; waste characterisation; waste monitoring*

Overview

The UK government wishes to increase the proportion of energy generated from nuclear power and recently published a list of sites where new nuclear power stations could potentially be constructed. However, nuclear power will only be acceptable to the public if robust safety cases can be made, the production of new nuclear waste is minimised, and plans to deal with the existing waste are more persuasive than they have been to date.

The University of Liverpool has expertise which could be harnessed to explore new approaches.

The first challenge is to deal with waste that already exists; the second is to ensure that future waste is properly handled.

Expertise

New nuclear power solutions

Nuclear physicists and engineers at the University believe it should be possible to design nuclear power plants which will produce less waste – for instance, a fission reactor based on the ²³²Th cycle and reactors which are controlled by beams of particles from an accelerator.

It should also be possible to develop accelerators that produce beams of particles which can be used to induce transmutation. In other words, radioactive waste could be transmuted into different isotopes (with shorter half lives) using beams of protons or neutrons.

Nuclear waste

The first challenge is to deal with waste that already exists; the second is to ensure that future waste is properly handled. In both cases, it is vital for the radioactive waste to be fully characterised – enabling tailored solutions to be devised (for example, making the waste safe or moving it to appropriate storage).

The University has the requisite expertise to characterise the waste. It also has sensor technology which could be harnessed to monitor the waste – and has already worked in collaboration with the nuclear industry.

Safety cases

The University has extensive knowledge of nuclear physics and a great deal of modelling expertise. This could be harnessed to provide independent safety cases of designs proposed for Britain's new nuclear power stations.



Energy & Sustainability

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those most relevant to Energy & Sustainability include:

- **National Instrument e-Automation Laboratory**
- **Proudman Oceanographic Laboratory**

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Case Studies

Oil vulnerability audit

An audit undertaken for a wine bar focused on its à la carte operation. It identified the top three issues the business needed to address to reduce its vulnerability to oil price rises in the years to come.

At the time, energy represented a low percentage of the à la carte operation's costs, but modelling revealed that this percentage could rise rapidly, since energy costs appear to track oil price rises. By identifying the items of equipment which were guzzling the most energy, the audit showed how the operation could become more energy-efficient.

Energy isn't the only area in which a restaurant is vulnerable to oil price rises. The cultivation, processing, transportation and distribution of food all require oil-based resources. Food packaging may also consume oil-based resources if materials have to be sent abroad for recycling – a cost which may be passed on to businesses. The à la carte operation sourced all its ingredients from local suppliers, but most of these ingredients were produced outside the UK. The audit highlighted the potential benefits of alternative strategies – such as local sourcing, community-supported agriculture, buying direct and long-term contracts.

The staffing of the à la carte operation was the third area where rising oil prices could have a serious impact on the reputation and popularity of the business: the head chef and commis chef lived outside the town and couldn't walk to work or use public transport. If rising fuel prices consumed an increasing proportion of their salaries, they could opt to find a job closer to home.

Patented synchronverter

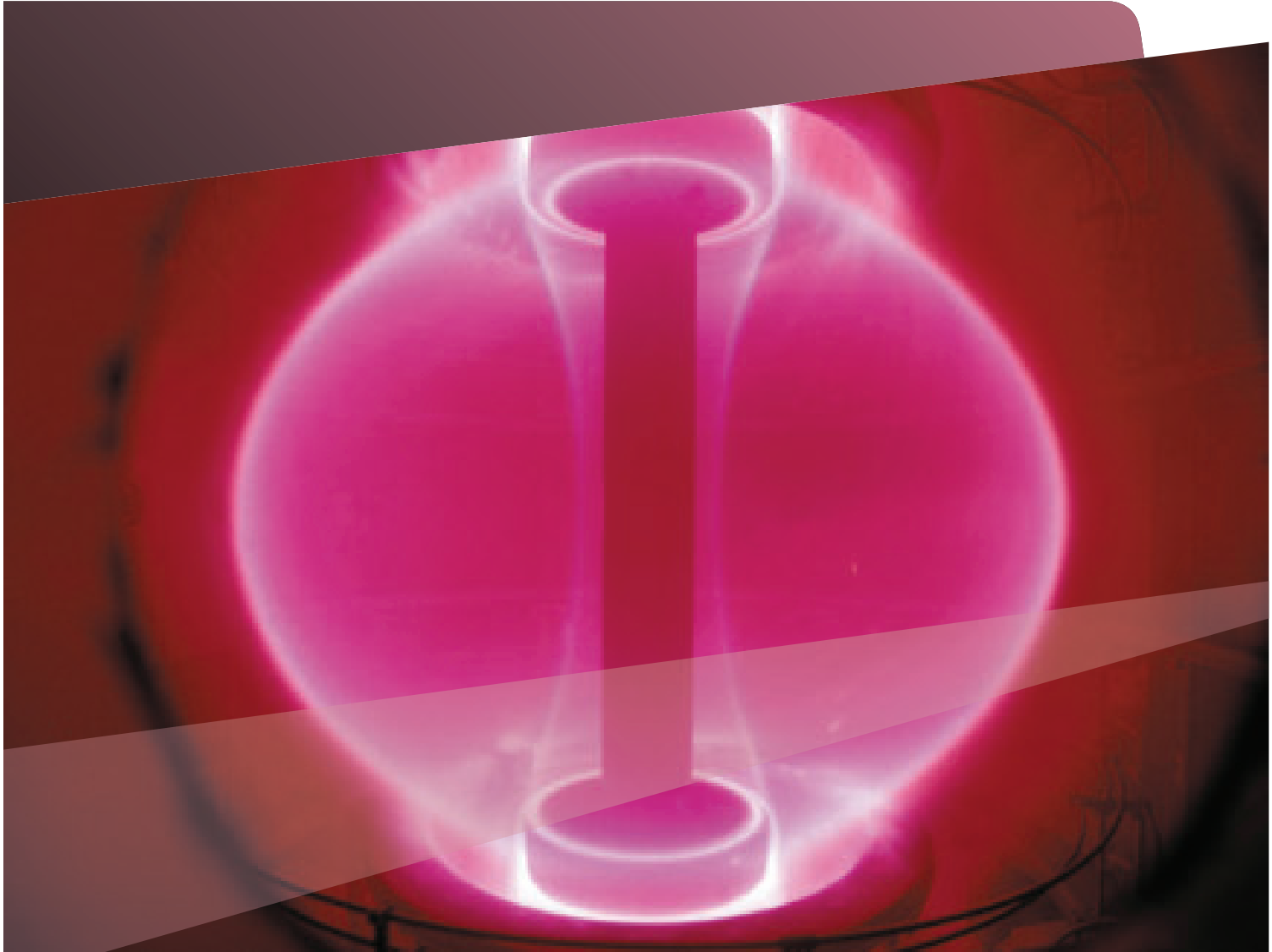
As yet there is no cost-effective way of storing energy from renewables, so it has to be used it as it is generated – but renewable energy sources can't be connected directly to national grids. Some produce only direct current (DC), rather than the alternating current (AC) on which today's power systems are based. Some produce AC, but not at the constant frequency which grids demand. Engineers get round these problems by converting all power inputs to a DC voltage, and using inverters to convert this AC with a constant frequency.

The University of Liverpool has co-developed a mathematical model of a synchronous generator which can be implemented in any inverter control software. A laboratory demonstrator built at the University provided an initial proof of concept. This shows that the technology is grid-friendly, ensuring the correct voltage is maintained. It can operate in grid-connected or island mode. It is cost-effective, since there is no need to modify the inverter hardware. It is easily installed, requiring no more than an adaptation of the inverter software's control algorithms, and it is versatile: it can be used with any power source that needs an inverter to interface with the grid or the load, and there is no need for between-units communications to operate it in parallel.

The synchronverter could also be used to improve the performance of static synchronous compensators (STATCOMs), or for any isolated or distributed power supply which currently relies on rotary frequency converters. It would be particularly advantageous in uninterruptible power supplies (UPS). With the synchronverter algorithms incorporated into the UPS, there would be no need for communication between units.

Further proof-of-concept studies are currently underway using a small research turbine.

Advanced Manufacturing



Overview

Breadth of Expertise

- Design/virtual design
- Modelling/simulation
- Experimentation
- Prototyping/manufacturing
- Dynamics and control
- Technology roadmapping

Manufacturing Operations and Approaches

- Rapid manufacturing
- Micro-manufacturing
- High-value manufacturing
- Sustainable manufacturing
- Bio-manufacturing

Manufacturing Technologies

- Laser engineering
- Additive layer manufacturing
- Microsystems fabrication
- Technological plasma
- Solid state electronics
- Ultra high energy mixing

Application Areas

- Aerospace
- Automotive
- Electronics
- Food
- Defence
- Pharmaceuticals
- Paints
- Personal care products

Key Capabilities

1.0 manufacturing Operations and Approaches

- 1.1 Virtual design and manufacturing
- 1.2 Product design and prototyping
- 1.3 Microsystems design
- 1.4 Rapid manufacturing
- 1.5 Lean and agile manufacturing
- 1.6 High value manufacturing
- 1.7 Sustainable manufacturing

2.0 Manufacturing Technologies

- 2.1 Laser engineering
- 2.2 Freeform fabrication
- 2.3 Microsystems fabrication
- 2.4 Technological plasma
- 2.5 Solid state electronics
- 2.6 Catalysis
- 2.7 Ultra high energy mixing
- 2.8 Biological engineering
- 2.9 Technology roadmapping

3.0 Other Capabilities

- 3.1 Dynamics and control
- 3.2 Structural mechanics
- 3.3 Aerospace engineering

To remain competitive, manufacturers need to innovate continually. In the 21st century innovation requires input from many different disciplines.

The University of Liverpool is able to draw on expertise in biotechnology, control, design, electronics, industrial engineering, mechanics, materials, physics, mathematics, operational research, artificial intelligence and management – and an excellent range of facilities. This is relevant to all phases of the product or asset life-cycle across a range of industries. The University has a highly successful track record of harnessing its expertise and its equipment to help businesses meet the challenges entailed in innovation.

1.0 Manufacturing Operations and Approaches

Keywords: *Design; simulation; analysis; integration; visualisation; 3D modelling; dynamic modelling; thermal modelling; stress modelling; right first time; lead time compression; assembly; manufacturability; disassembly; mass customisation; high throughput; sustainability*

Overview

The modern concept of manufacturing stretches from product design, manufacturing planning and processing, to supply chain and end-of-life considerations. The University of Liverpool has the capabilities and experience required to devise and develop innovative and cost-effective manufacturing solutions and can also offer manufacturing performance analysis, system optimisation and product design.

Expertise

1.1 Virtual design and manufacturing

Virtual reality offers a powerful and human-centred approach to product design and is used by all world-class car manufacturing companies.

In conjunction with BAE Systems and Airbus, the University has recently embarked on a large scale design and manufacturing initiative in conjunction with Daresbury Laboratory. This new **Virtual Engineering Centre** will apply state-of-the-art design, simulation, analysis, integration and visualisation tools for concurrent product and process design. Supported by a cluster of super-computers, this resource is second to none in the UK. By facilitating 'right first time' it can ensure a step improvement in product lead time compression.

1.2 Product design and prototyping

The University has first-class facilities to support product design, modelling, analysis and prototyping, and can demonstrate extensive experience of exploiting innovative techniques to support new product development.

These facilities include two complete suites of software: CATIA and Pro-E. CATIA is a leading product design and innovation tool which is used by thousands of companies in a wide range of industries, while Pro-E supports 3D modelling, kinematic and virtual reality applications. In addition, Abacus is available for thermal, dynamic and stress modelling. At the component level, DFMA software provides detailed assessment on assembly and manufacturability, while DFE provides a similar assessment of disassembly, which is essential for recycling. For plastic parts, Mouldflow is an effective tool to identify defects caused by uneven flows.

Rapid prototyping is fully supported by 3D printing, Helisys systems and MCP vacuum casting equipment.

1.3 Microsystems design

The University has state-of-the-art femtosecond laser and Wyco surface measurement systems which make it possible to customise an entire new spectrum of nano and micro surface properties.

Completed microsystems design projects include the application of Coventor, a powerful software package, to the modelling and analysis for an innovative wireless implantable pressure sensor. Current projects include the design and performance evaluation of a novel micro-fluidic system, as well as the design and modelling of a micro ultrasonic system based on axiomatic design principles.

1.4 Rapid manufacturing

High throughput manufacturing is a key factor for competitive performance and the University has expertise in a range of rapid manufacturing methods. These include high-speed machining, which can impact directly on shop floor productivity, if applied correctly, and additive layer manufacturing processes, including 3D printing, Envision systems and laser scanning equipment for product digitization. In addition, the University itself has devised and developed two new rapid manufacturing methods, Selective Laser Melting (SLM) and Spiral Growth Manufacturing (SGM) (see 2.2 for further information).

1.5 Lean and agile manufacturing

In order to survive in a highly turbulent business environment, manufacturers have to be efficient and responsive to customer needs, while maintaining a degree of resilience to change. This requires them to strike a balance between becoming leaner – cutting waste and reducing operational costs – and becoming agile – by being flexible and ready to deal with change. The University of Liverpool works closely with companies in developing new ideas in this area.

It has expertise in the application of traditional approaches to the implementation of lean manufacturing, for example, waste reduction, Six Sigma, visual management and mass customisation, but it specialises in helping companies become more agile.

The University's **Agility and Supply Chain Management Centre** has developed a tried and tested, staged approach. The first step makes companies less vulnerable to dynamic changes in their business environment by identifying and addressing weaknesses in key systems and operations. The second makes companies more responsive to market needs by integrating improved business processes and operations. In the third stage, companies are helped to think proactively and strategically to seek new opportunities for growth. In order to become agile, a company needs to become ready. To become ready, it has to anticipate how future market trends could impact on its business.

The services offered by the **Agility and Supply Chain Management Centre** encompass:

- Training and implementation of lean techniques
- Agility diagnostics and implementation tools
- Simulation and modelling tools for optimising of manufacturing systems
- Strategic agility development and implementation.

1.6 High-value manufacturing

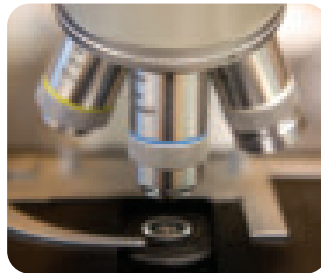
Moving up the value chain is imperative for manufacturers which compete with companies from countries with a low cost base. Formulating a high-value manufacturing strategy requires a holistic approach which draws on the latest concepts and deploys innovative methods.

Following extensive research into manufacturing performance evaluation, the University of Liverpool has devised a user-friendly framework. It also has a library of case studies which illustrate the pros and cons of different approaches to moving towards high-value manufacturing.

1.7 Sustainable manufacturing

Government directives aimed at minimising energy use, reducing waste and diminishing the UK's carbon footprint are increasingly demanding. As a result, businesses need to maintain a balanced 'triple bottom line', taking account of environmental, economic and social performance.

The University's research in sustainable manufacturing has focused on design for sustainable development, substitution of processes and process re-design. This has enabled it to uncover the intrinsic weaknesses of many eco-design tools and provided a firm basis for designing better methods which are acceptable to product designers. Since all relevant issues are considered at the earliest possible design stage, there is no longer any need for a piecemeal approach.



2.0 Manufacturing Technologies

Manufacturers subject a wide range of materials to a wide variety of processes – for instance, casting, moulding, forming, machining and joining. Advanced manufacturing involves the identification and effective deployment of contemporary technologies which can add value and improve performance.

The University of Liverpool is equipped with the facilities required to support a number of contemporary manufacturing technologies, and expertise acquired in the course of fundamental, strategic and applied research – much of which was undertaken in collaboration with industry.

2.1 Laser engineering

Keywords: *Deposition; forming; structuring; surface treatment; drilling; cutting; welding; micromachining*

Overview

Lasers are used to join, cut, form and surface-texture engineering components, to measure, analyse and diagnose, and to build multimaterial structures with novel properties and uses. Laser-engineered components are used in the automobile, aerospace, biomedical and general engineering sectors, and laser processes are widely used in medicine and art conservation. Laser systems are also used to monitor atmospheric pollution and undertake in-situ elemental analysis.

New laser types with new capabilities – for instance ultra short pulse length or high beam quality – are being introduced all the time, creating new applications and providing new processes to power the innovation that is so essential in a highly competitive, globalised world market.

Facilities and expertise

The University of Liverpool's facilities and expertise, combined with those of its dedicated **Lairdside Laser Engineering Centre**, constitute an internationally significant resource. This includes:

- High power carbon dioxide laser systems for cutting, welding, surface treatment, laser forming and direct laser deposition from powder of prototype and functional metallic components
- Nd:YAG and low power carbon dioxide laser systems for laser cleaning, laser marking, laser peen forming, laser direct write of micro and nano based inks
- Picosecond laser systems for micromachining, plasmonic surface structuring, laser cleaning.

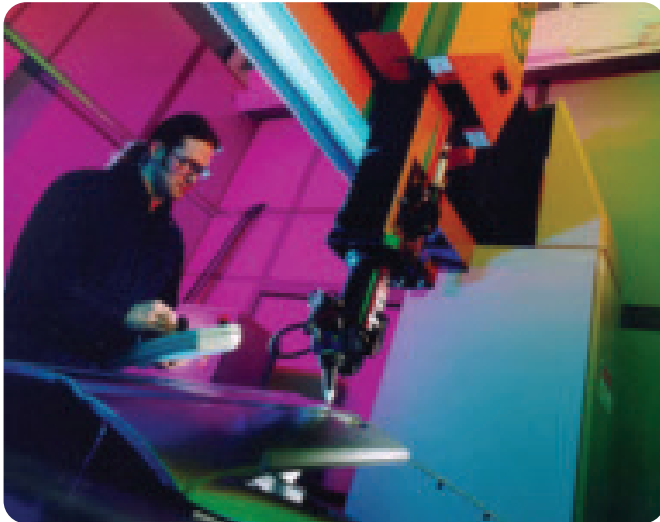
Advanced Manufacturing

- Femtosecond laser system for internal structuring of glasses and dielectrics, precision drilling and micromachining, including novel spatial light modulator technology for multiscale parallel processing
- Optical laser tweezer facility for biomedical and microengineering applications
- Atomic force microscopy and white light interferometry
- An established one year Masters programme; Engineering Applications of Lasers MSc (Eng).

Applications

The University's capabilities have attracted extensive interest from industry. Completed projects include an investigation, undertaken in collaboration with BAE Systems and Rolls Royce, of the potential for using laser bending to create on-board microactuators for the alignment of microelectronic components.

In addition, the **North West Laser Engineering Consortium (NWLEC)**, a joint initiative of the universities of Liverpool and Manchester, focuses on the development of novel, laser-based applications of microtechnology. NWLEC's KE-LAS programme is specifically designed to assist companies across the North West of England through knowledge transfer and exchange.



2.2 Freeform fabrication

Keywords: *Additive layer manufacturing; selective laser melting; spiral growth manufacture; selective laser sintering*

Overview

Freeform fabrication denotes manufacturing processes which translate 3D CAD data directly into 3D parts/entities by building up and fusing the chosen material layer by layer until the required geometry is attained. This can be achieved for a wide range of metals and plastics by means of stereolithography, selective laser sintering, 3D printing and a number of other processes.

These processes allow complex geometries to be created; they produce little waste and they are relatively energy-efficient. Since no special tooling is required, 3D parts can be built in days or hours, enabling products to be brought to market faster than traditional processes like forging and casting. Freeform fabrication is used to produce components for the aerospace industry and products for the dental and medical sectors.

Expertise

The University has extensive experience of Selective Laser Sintering (SLS), which fuses small particles of metal, ceramic, glass or plastic to create a 3D object. SLS offers a means of making complex geometries directly from digital CAD data. Increasingly, SLS is being exploited in short-run manufacturing to produce components for end-use. The University has devised and developed two new rapid manufacturing methods with strong industrial support from BAE Systems and EADS, and MCP Systems respectively.

Selective Laser Melting (SLM) is a solid freeform fabrication process that can be used to manufacture complex lattice structures which aren't achievable using conventional manufacturing techniques. This has enabled a series of innovative developments – for instance, the production of a new micro heat exchanger whose performance is 20% better than that achieved by existing technologies. Complex lattice structures manufactured in this way are already being earmarked for use in the aviation and automotive sectors as well as in environmental processing.

Spiral Growth Manufacturing (SGM) sidesteps the conventional stop-start, phase-change approach of conventional rapid manufacturing systems, providing a system which can work continuously. This method has huge potential in the health care sector. One example is the mass-production of complex pills in a single, continuous, high-output process which can also accommodate mass customisation.

2.3 Microsystems fabrication

Keywords: *Microscale components/devices; micro-reactors; micro-hierarchical structures; high-speed machining*

Overview

Microscale control and measurement devices have become a fact of modern life. These 'microsystems' manage the performance of our vehicles, machinery and plant, they protect our health and our environment, and they control a myriad of goods such as washing machines and DVD players.

Expertise

The University of Liverpool has an international reputation for its work on microsystem component technologies. It has developed micromachining and fabrication processes which will have a global impact on business for many years to come.

The extension of high speed machining to micromachining, using micro-cutters with 0.2 mm diameter, has opened up new opportunities for 3D micro-components, for instance, while the application of Selective Laser Sintering (SLS) for the free-form fabrication of micro-reactors and micro-hierarchical structures has led to major improvements.

Applications

The University has harnessed these processes to develop microscale devices covering a spectrum of applications – from biological and chemical analysis through to thermal management. These include nano-scaled functional materials, sensors, actuators, medical devices and implants – and the smallest quadrupole mass spectrometer ever reported, which is currently being developed as a state-of-the-art medical diagnostic tool.

✚ See also: *Materials*.

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2.4 Technological plasma

Keywords: *Plasma diagnostic/measurement tools; plasma discharge modelling/simulation; plasma surface interaction modelling; plasma processing system design; sputtering plasmas; pulsed RF plasmas; dusty RF plasmas*

Overview

Electrical plasma is known as the 'fourth state of matter' and its use as a materials processing tool underpins many multi-billion dollar industries. Microelectronics, telecommunications, aerospace, automotive, environmental control, packaging and textiles all make use of electrical plasma competencies.

The development of industrial plasmas has been product-led – driven by market demand – and has been largely empirical in nature. As a result, scientists and engineers are still striving to understand the fundamental physical and chemical mechanisms involved in plasma discharges so that their properties can be tailored for specific technological applications.

Expertise

The University of Liverpool is at the forefront of this activity in the UK, specialising in experimental and modelling studies of plasma discharges of relevance to industry. Through laboratory-based research and in-field measurement, it is gaining a better understanding of industrial processing environments for end users and plasma analytical tool suppliers.

The main thrusts of its research have been the study of reactive and nonreactive sputtering (PVD) plasmas for thin film deposition, pulsed RF plasmas for treatment and deposition of polymeric films for biocompatibility and cell growth, atmospheric pressure micro-plasma jets for materials modification, and the study of dusty RF plasmas. Much of the work concentrates on understanding fundamental plasma-surface interactions, including sheath physics and dynamics.

Areas of research currently being developed include:

- Plasma treatment and doping of carbon nanostructured materials
- High-pressure micro-discharges for biomaterials applications and graded chemical functionality of polymeric materials
- Atmospheric pressure plasmas (DBD) for modification of 3D materials.

Advanced Manufacturing

Facilities

The University has developed a wide variety of plasma diagnostics tools and associated electronics in-house, as well as computer models and plasma simulations to complement the experiments.

For plasma measurement, advanced plasma diagnostic and measurement tools (invasive electrical probes and non-invasive optical emission techniques) include:

- Langmuir and associated electrical probes
- Energy-resolved mass spectrometry (high mass resolution)
- Magnetic probes
- Current and voltage probes
- Ion and electron analysers
- Optical emission spectroscopy and Abel inversion reconstruction
- Laser probe diagnostics and laser photo-detachment techniques
- 2D 'fast' plasma optical imaging
- 3D laser tomography and velocimetry for particle diagnostics.

Plasma discharge experimental facilities encompass a range of physical and chemical vapour deposition rigs and process parameter control equipment, including:

- Complex – dusty plasma environments
- Pulsed magnetron deposition chambers for reaction sputtering of thin films and coatings
- Optically-based reactive deposition control equipment
- A range of discharge delivery power supplies, DC, pulsed DC (mid frequency) and RF
- Plasma polymerisation and plasma polymer treatment rigs (typically low pressure organic monomers)
- Water arc equipment for carbon nano-structured material synthesis
- Electron and ion beam sources.

Applications

The University has considerable expertise in fundamental plasma physics and plasma chemistry, the design of plasma processing systems, the development of plasma diagnostic tools, and the modelling of discharges and plasma surface interactions.

This can be harnessed for practical applications, such as the large-area pulsed deposition system developed in collaboration with Pilkington Technology.

2.5 Solid state electronics

Keywords: *Polymers; silicon; micro-electro-mechanical systems (MEMS); radio-frequency identification (RFID); metal oxide semiconductor field-effect transistors (vertical MOSFETs); Thin film transistors (TFTs); 3G neural networks; micropower SOI; high k dielectrics; characterisation; metrology; modelling*

Overview

The University of Liverpool is involved in the development of advanced Thin Film Transistors (TFT) and photovoltaic structures for high performance at low cost, as well as the development of high performance silicon structures and novel circuits for RF, micropower and 3G neural network applications.

The emphasis in both areas is on devices and sub-circuits with a strong materials underpinning. The University produces novel devices in both polymers and silicon, particularly vertical metal oxide semi-conductor field effect transistors (MOSFETs), but also has lengthy experience of device work in bipolar.

Activities span device design, realisation, trouble-shooting of anomalies and related modelling both theoretically and using numerical tools. The University has a history of engaging with industry, particularly in relation to trouble-shooting of anomalies, but also in joint programmes relating to reliability and other issues. More recently, the work is directed at new device physics models that are suitable for circuit simulation.

Expertise

The University works on materials characterisation, both electrical and optical, and also produces novel devices through full design cycle, modelling and theory.

It has longstanding expertise in semiconductor characterisation and device design, theory and modelling using bespoke commercial tools. The emphasis is on engineering, with materials work underpinning devices, and associated modelling directed at device optimisation and the realisation of compact models for circuits work.

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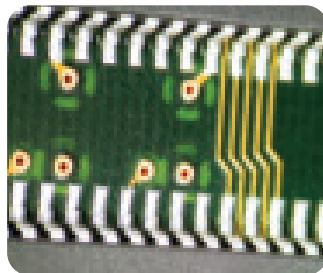
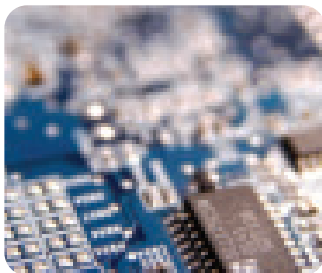
Current activities are focused on:

- Vertical MOSFETs for 'cheap' radio frequency applications
- Organic TFTs and ultra low cost radio frequency identification (RFID) and other circuits
- Modelling of organic diodes and fabrication
- Circuits for 3G neural networks and micro-power SOI
- Hi-k dielectrics
- MEMS
- Metrology for nanoscale materials – dielectric and semiconductor.

The University's expertise also spans the use and design of devices for utilisation in silicon VLSI and 3rd generation hardware neural networks. Emphasis in the VLSI area is on the use of newer materials and techniques in advanced technologies for improving the performance of existing logic families, and also in novel device and circuit cell architectures for neural computing. Higher performance at lower power consumption for bipolar transistors and CMOS is a key factor for electronic circuits for mobile phones and laptops whereas a trade-off between parallelism and speed is important for neural network hardware.

The University has a lengthy track record of successful research into the test and reliability of gate dielectrics for silicon based electronics. There is considerable activity around high-permittivity dielectrics for end-of-roadmap application and the University has excellent atomic layer deposition (ALD) facilities. New work is aimed at producing very high precision passive components, particularly capacitors for medical, RF and energy harvesting applications.

The University is also working on micropower analogue circuits for medical and other uses. Further circuit work is associated with the neuron devices activity whereby standard cell building blocks are under construction for potential use in large, brain-inspired electronic systems.



Facilities

The University offers basic test sample and device fabrication facilities together with an extensive suite of electrical and optical characterisation equipment. These facilitate evaluation of organic and inorganic semiconductors and composites of the former with nanotubes.

Facilities for semiconductor characterisation include:

- Current-voltage down to low-currents (sub pA)
- Multi-frequency capacitance-voltage
- Capacitance-time
- Charge pumping
- Photo IV
- State-of-the-art spectroellipsometer allows material characterisation from deep UV to far IR.

The electrical test equipment can be configured for automated stress measurements on devices and metal oxide semi-conductor (MOS) capacitors.

A comprehensive range of electrical and physical characterisation tools are available:

- Multi-frequency capacitance-voltage
- Low current-voltage including temperature dependence
- Spectroellipsometry
- X-ray spectroscopy (XPS)
- Medium energy ion spectroscopy (MEIS)
- X-ray diffraction (XRD)
- High-resolution transmission electron spectroscopy (XTEM).

Fabrication facilities

Clean room facilities allow the production of prototype field effect transistor (FET) devices in polymers and two-terminal test structures in silicon. There are also facilities for the fabrication of organic TFT devices, diodes and capacitors which can be integrated with antennas on to thin, flexible, transparent substrates.

✚ See also: *Materials*.

2.6 Catalysis

Keywords: *Design; exploration; mechanism; kinetics; development; homogeneous catalysis; heterogeneous catalysis; hydrogenation; oxidation; acid catalysis; carbonylation; C-C bond formation; asymmetric catalysis; green chemistry; renewable starter materials*

Overview

By facilitating chemical reactions without themselves being consumed, catalysts are the key to advanced chemical, pharmaceutical and agrochemical manufacturing and to energy production and conversion, as well as one of the most important tools in enabling sustainable development.

The University of Liverpool has expertise in designing and developing innovative catalysts and catalytic processes which can address problems currently faced by the chemical and pharmaceutical industries – and some of the grand challenges confronting society over the short, medium and long term. Its strength lies in homogeneous catalysis but it also has expertise in heterogeneous catalysis, enzymatic catalysis and catalytic mechanisms.

Expertise

Homogeneous catalysis

The University is particularly experienced in, and equipped for, hydrogenation, oxidation, acid catalysis, C-C bond formation, carbonylation, asymmetric catalysis, and tools for enabling green chemistry. It is actively searching for chemical manufacturing solutions which could start from renewable resources such as biomass, water, syngas and carbon dioxide, and from cheaper, nontoxic catalysts such as iron.

Such catalysts are made by design underpinned by atomic and molecular level understanding. They can take the form of discrete molecules, offering precise control over reaction pathways. They can be integrated with designer solid materials which are available at the University, creating immobilised catalysts for ease of handling. They may also take the form of highly dispersed nanoparticles when combined with materials of high porosity, affording stable catalysts for harsh conditions.

A significant feature of the University's research is the integration of design, exploration and development in catalysis with mechanistic studies, the latter informing understanding and directions of the former. In particular, the University specialises in in-situ high pressure NMR measurements, surface chemistry, catalytic kinetics and high level computer modelling.

The University has developed a thorough understanding of the mechanism and kinetics of the reaction of organometallic catalysts. This is relevant to the operation of many existing commercial processes and can also support the development of new, patentable processes: the results of mechanistic investigations carried out at the University have been used successfully in patent litigation to establish a new, patentable process which now dominates world manufacture of a particular pharmaceutical, for instance.

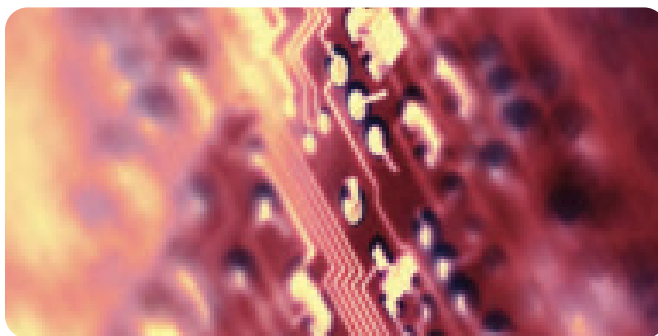
Heterogeneous catalysis

The University's research is focused on the development of new, highly efficient solid catalysts based on polyoxometalates, mixed oxides, layered hydroxides and other new functionalised materials for conversion of renewable feedstock and biomass-derived platform molecules into value-added chemicals and fuels.

Priority is given to multifunctional catalysts which contain two or more catalytic functions – acid, base, metal, etc – and can carry out multistep reactions in one pot – one catalyst bed – without separating intermediate products with high atom and energy efficiency.

Facilities

The University is an established centre of excellence in high pressure NMR (HPNMR) and IR methodologies. It has developed high pressure NMR gas flow cells and bubble column NMR reactors in which reactive gas is continuously passed through the reaction solution, eliminating the gas diffusion problems intrinsic to sapphire tube studies. This extends considerably the capabilities of HPNMR by allowing, for the first time for gas/liquid systems, the simultaneous acquisition of meaningful kinetic data and the structural characterisation and speciation of compounds present in solution by NMR.



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2.7 Ultra high energy mixing

Keywords: *Nanotechnology; nanomaterials; distributive mixing; dispersive mixing*

Overview

Mixing is at the heart of many manufacturing processes, producing emulsions and dispersions which form the basis of numerous medical, personal care and food products. The microstructure of such mixes can affect product performance and this is influenced by the mixing technology deployed.

There is a wide range of mixing technologies, for instance fluid division mixing, high stress mixing and controlled deformation dynamic mixing, but they all have their limitations. In a notional space with an X axis denoting distributive mixing and a Y axis denoting dispersive mixing, the capabilities of existing mixing technologies do not stretch far along either axis.

This could limit our ability to realise the potential of nanomaterials, but, working in collaboration with Unilever and Maelstrom, the University of Liverpool has addressed this problem by developing a unique, high pressure **Ultra Mixing and Processing Facility (UMPF)**.

There is a wide range of mixing technologies, for instance fluid division mixing, high stress mixing and controlled deformation dynamic mixing, but they all have their limitations.

Facilities and capabilities

The **Ultra Mixing and Processing Facility** can manufacture up to 25 litres of emulsion in a single cycle, accommodating inputs from between one and five process streams concurrently in batch or semi-continuous modes. It can cope with flammable materials, temperature regimes between 10°C and 250°C; pressure up to 5,000 bar, and flow rates ranging from millilitres to litres per minute for run-times ranging from six seconds to five minutes. It also plans to offer enhanced particulate dispersion from Spring 2010.

Businesses use the facility to explore the potential of ultra high energy mixing to deliver new products which benefit from process innovation as well as advances in formulation. After ascertaining the nature of the raw materials and the business's goals for a particular emulsion/dispersion, UMPF factors in its experience of working with similar materials and designs a series of experiments. Subject to contract, UMPF carries out the experiments and delivers samples of the mixed formulation and data resulting from its analysis of these samples.

2.8 Biological engineering

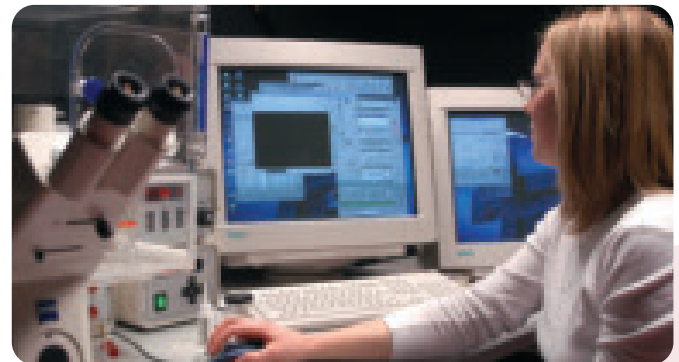
Keywords: *Biomolecules; cells; interactions; surfaces; micro/nano confined environments; micro/nano devices; bio-micro-electromechanical systems (bioMEMS); hybrids; semiconductor fabrication technology*

Overview

It is more than 60 years since engineers realised that biology might have the potential to suggest novel engineering solutions. This insight has already led to 'biomimetics' as diverse as cat's eyes reflectors and VELCRO®. Now that scientists can study how biological organisms work at the molecular level, it is inspiring biological engineering on micro and nanoscales.

Biological engineering borrows ideas, materials, structures and systems from biology with a view to solving engineering problems. These might be 'soft' problems, such as a need for more effective computing algorithms for particular applications. They might be 'hard', device-related problems which may be solved by taking biological elements with the functionality required and incorporating them into hybrid devices, or creating biomimetics which provide the same functionality.

Biological engineering is becoming a knowledge framework for entire new industries. For instance, the biochips industry benefits from collaborations between researchers with biomedical and agricultural backgrounds; who cover applications and sample preparation; specialists in biochemistry, photolithography, bio-micro-electromechanical systems (bioMEMS) and robotics, who cover fabrication; specialists in optoelectronics, physics and chemistry, who cover signal readout; and computer scientists, mathematicians and bio-informatics scientists who are responsible for data processing and management.



Advanced Manufacturing

Expertise

The University of Liverpool studies natural micro/nano-systems as a source of inspiration for hybrid micro and nano biodevices which may be static or dynamic. Examples include biosensors, genomics/proteomics micro- and nano-arrays, lab-on-a-chip devices and implantable medical devices – all of which use and depend on the optimum interaction of biological entities with micro/nanofabricated structures.

The University aims to target the market place emerging between biology and engineering, with an emphasis on nanotechnology aspects. A key research theme is the behaviour of biomolecules and cells in micro-/nano-confined environments – in particular in or on micro/nano structures fabricated using semiconductor manufacturing technology.

The University's expertise encompasses the modelling, simulation, design, fabrication and operation of micro/nano biodevices. Its research has focused particularly on the interaction of biomolecules (proteins and DNA) and cells (neuronal cells, bacteria, fungi) with flat, patterned or structured surfaces; on the interaction of biological objects with electric fields; and on dynamic devices based on protein molecular motors, advanced microlithography technology and scanning probe microscopy.

Areas presently developed include:

- Single molecule, extremely rapid bio-detection devices
- Novel computational devices based on biological algorithms
- Quantification of molecular surface properties for the design of bio-mimetic nano-structured surfaces.

Facilities

Nano-imaging, nano-fabrication and nano-manipulation facilities, including:

- Atomic force microscopy (AFM) accommodating all AFM imaging modes, eg. contact, tapping, lateral and vertical force microscopy, electric and magnetic mapping, liquid imaging
- Nanolithography and manipulation capabilities for molecular writing and nano-particle manipulation – including the ability to calculate diffusion constants, programme line lengths and dot dimensions.

Microfabrication facilities for bio-microdevices, including:

- Spin coating for a wide range of viscosities and film thicknesses
- Laser micro-ablation for microfabrication using a variety of materials, eg. polymers, thin metallic films
- Microlithography aligner for classical micropatterning.

Micromanipulation of biological objects:

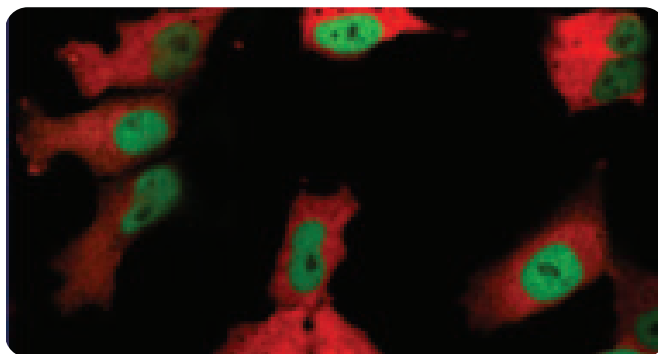
- Laser tweezers and laser scissors.

2.9 Technology roadmapping

Keywords: *Advanced manufacturing; micro/nanomanufacturing*

New technologies, whether incremental or disruptive, are emerging continuously. Technology roadmapping offers manufacturers a means of ensuring that they are up to speed with emerging developments and potential implications of these developments.

The University is well versed in conducting customised technology roadmapping exercises for industrial/research and technology organisations (RTOs). Its expertise extends from conventional manufacturing to advanced manufacturing as well as micro and nanomanufacturing.



3.0 Other Capabilities

The University of Liverpool has many other capabilities of relevance to advanced manufacturing. Some of these are particularly relevant to certain industrial sectors – most notably automotive, aerospace and defence.

3.1 Dynamics and control

Keywords: *Finite element modelling; non-linearity; variability; uncertainty; vibration; multi-physics problems*

Overview

The University has a reputation for innovative theoretical research coupled with application to industrial-scale engineering hardware.

Expertise

- Inverse problems, including finite element model updating and structural modification
- Active vibration control, especially pole/zero assignment
- Variability and uncertainty, due to modelling inaccuracies and manufacturing tolerances
- Moving-load problems, such as bridge vibrations caused by the flow of traffic and high-frequency vibration and noise in disc brakes
- Multi-physics problems such as the atomising disc – a device for producing metal powders by pouring molten metal onto a very high speed rotating disc
- Nonlinearity due to joints and connections between structures
- Robust performance nonlinear control of automotive engines and powertrains.

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Facilities

- A 64-channel LMS modal test system, among the best in UK universities and industry
- A Linux-Solaris cluster running MSC-NASTRAN, the aerospace and automotive industry standard finite element code, enabling research on industrial-scale structures
- A 120kW 1.2m diameter rolling-road vehicle dynamometer, a 120kW transient engine dynamometer, a 75kW clutch dynamometer and an electric low inertia (idle speed) engine dynamometer
- A disc-brake test rig instrumented for the measurement of disc vibration as well as torque, speed and temperature measurements.

Sample applications

Rolls Royce – The ‘correction’ of aero-engine casing finite element models. The casings, which are closely axisymmetric, have natural frequencies which appear in close pairs that need to be separated.

QinetiQ – Finite element model updating of a complete Lynx helicopter airframe. A new model updating method for large-scale structures based on ‘clustering’ of parameters having a similar effect on the dynamic behaviour was established, and the first 12 natural frequencies significantly improved.

Westland Helicopters – Predicting the dynamic behaviour of a Lynx tailcone when a large mass, equivalent to the tail-rotor gearbox and hub, was added to the baseline tailcone structure.

AWE-Aldermaston – Large surface-to-surface joints were modelled for the unclassified MACE structure. Elements with equivalent mechanical properties at the joint interfaces were identified from vibration tests.

Ford and MIRA – Development of a method to define the statistics of uncertainty in spot weld models and applied to spot-welded beam-like structures.

TRW Automotive – Development of a moving-load methodology for the analysis of squeal noise in disc brakes.

3.2 Structural mechanics

Keywords: *Lightweight structures; pressurised shells; composite sandwich structures; cellular core materials; impact behaviour; metals; polymers; foams; composites*

Expertise

The University has expertise in the performance of lightweight structures and materials under extreme loading conditions. This encompasses a wide range of materials including metals, foams and polymer composites, and it has particular strengths in pressurised shells, all aspects of buckling, and the use of advanced finite element techniques.

Its expertise extends to the structural impact behaviour of various composite sandwich structures, enabling it to work on issues like crashworthiness and the foreign object impact of composite fuselage structures for civil aircraft. Its skills encompass the manufacture and testing of components, and the analysis and optimisation of structures.

A major focus of study has been cellular core materials – for instance, the progressive collapse of polymeric and metallic foams, and the use of selective laser melting (SLM) to create bespoke cellular materials for optimised structural performance.

Facilities

The University has a specialist **Impact Research Centre**, with facilities including:

- Gas gun
- Powder guns
- Drop hammers
- Hyperbaric chamber
- Catapults
- Hopkinson bars
- High rate servohydraulic test machines
- Pressure pulse rigs.

The PPR is a differential pressure device capable of applying a repeatable uniform dynamic pressure load of the form that simulates a vapour cloud explosion (VCE) with a finite rise to peak pressure and finite decay to ambient pressure.

Applications

The **Impact Research Centre** has helped to address questions as diverse as energy absorption in aerospace composites and metal foams; the low velocity impact performance of glass reinforced plastic sandwich panels; and the dynamic response of optimised lattice structures manufactured by means of selective laser melting (SLM).

✚ See also: *Materials.*



A major focus of study has been cellular core materials – for instance, the progressive collapse of polymeric and metallic foams, and the use of selective laser melting (SLM) to create bespoke cellular materials for optimised structural performance.

3.3 Aerospace engineering

Keywords: *Flight simulation; handling qualities; aerodynamics; CF; vibration; impact; structures; aeroelasticity; materials; sensors; radar processing; infrared imaging; image processing; target tracking; missile guidance and control*

Overview

The University of Liverpool undertakes aerospace research in the areas of flight simulation, handling qualities and control, aerodynamics, aero-elasticity, structural dynamics, impact engineering and materials. The research involves a combination of numerical/analytic simulation and analysis (virtual engineering), backed up by extensive experimental and computational facilities.

Expertise

Flight science and technology

The University has a track record in successfully tackling problems previously considered beyond the scope of academia. It can draw on world-class researchers with expertise in flight science, aero-elasticity, structural materials and mechanics; and extensive research facilities – including full motion flight simulators, a 500 core computational fluid dynamics (CFD) cluster and structural dynamics, vibration and impact laboratories.

Its high-end flight simulator is considered the most capable in academia worldwide. It has been used to support international projects such as the European civil tilt rotor, flapped rotor systems, safety cases for wake vortex upsets; and corporate lift systems. Current projects include the alleviation of operational problems at the aircraft/helicopter-ship dynamics interface, utilising piloted simulation and CFD.

The CFD framework runs an in-house code and has been used to investigate the non-linear aerodynamics encountered in both fixed wing and rotary wing operations, including rotor dynamic stall and stall flutter, vortical flow, transonic cavity flow and fin buffet. Unique coupled CFD-structural model methods have been devised for predicting transonic aeroelastic stability and limit cycles, for example, developing active structures for drag and gust loads reduction, defining the uncertainty bounds of dynamic behaviour using probabilistic, stochastic and interval methods, aeroelastic tailoring for composite wing design, and flight flutter testing.

Avionic systems

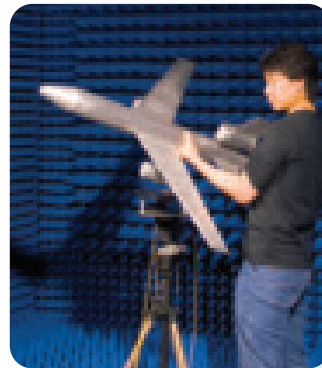
Electronic systems associated with flight are known as 'avionics'. Avionics encompasses the internal sensors and control systems within aircraft – from airborne communication and navigation systems to 'stealth' aircraft design and flight control systems.

The University has expertise in most aspects of avionic systems – radar and radar processing, aircraft data buses and data links, airborne imaging systems and target tracking. It has developed a range of simulation and processing tools that can be used for airborne radar and image processing – image stabilisation, target tracking, target recognition and 'smart' on-focal plane imaging systems.

It works closely with a number of large defence companies, with a variety of SMEs and with the Ministry of Defence (MoD). Projects undertaken include airframe simulation studies for QinetiQ-led/MoD-funded projects concerned with guidance and control for future precision guided missiles.

Facilities

- Two full motion flight simulators
- 130 node CFD cluster
- Areas for pilot briefings
- Substantial computational support
- CFD data visualisation.



Advanced Manufacturing

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those most relevant to Advanced Manufacturing include:

- **Agility and Supply Chain Management Centre**
- **Impact Research Centre**
- **Knowledge Exploitation Laboratory**
- **Lairdside Laser Engineering Centre**
- **Northwest Laser Engineering Consortium**
- **Ultra Mixing and Processing Facility**
- **Virtual Engineering Centre**

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Case Studies

Lairdside Laser Engineering Centre

Attiger is a young company which was set up to exploit proprietary diamond coating technology in new, high-volume applications. It was keen to base its business in a location from which it could easily service the whole of Europe. Despite offers from other areas, it chose to locate in Wirral because of the advantages conferred by close proximity to the Lairdside Laser Engineering Centre. The Centre provides Attiger with office space, access to lasers, expertise and business support.

“It has only been with the support of the Lairdside Laser Engineering Centre and the staff at the Laser Group in the University of Liverpool that we have been able to develop as we have. We look forward to a long and mutually beneficial relationship.”

Graham Downhill
Managing Director, Attiger

The Agility and Supply Chain Management Centre

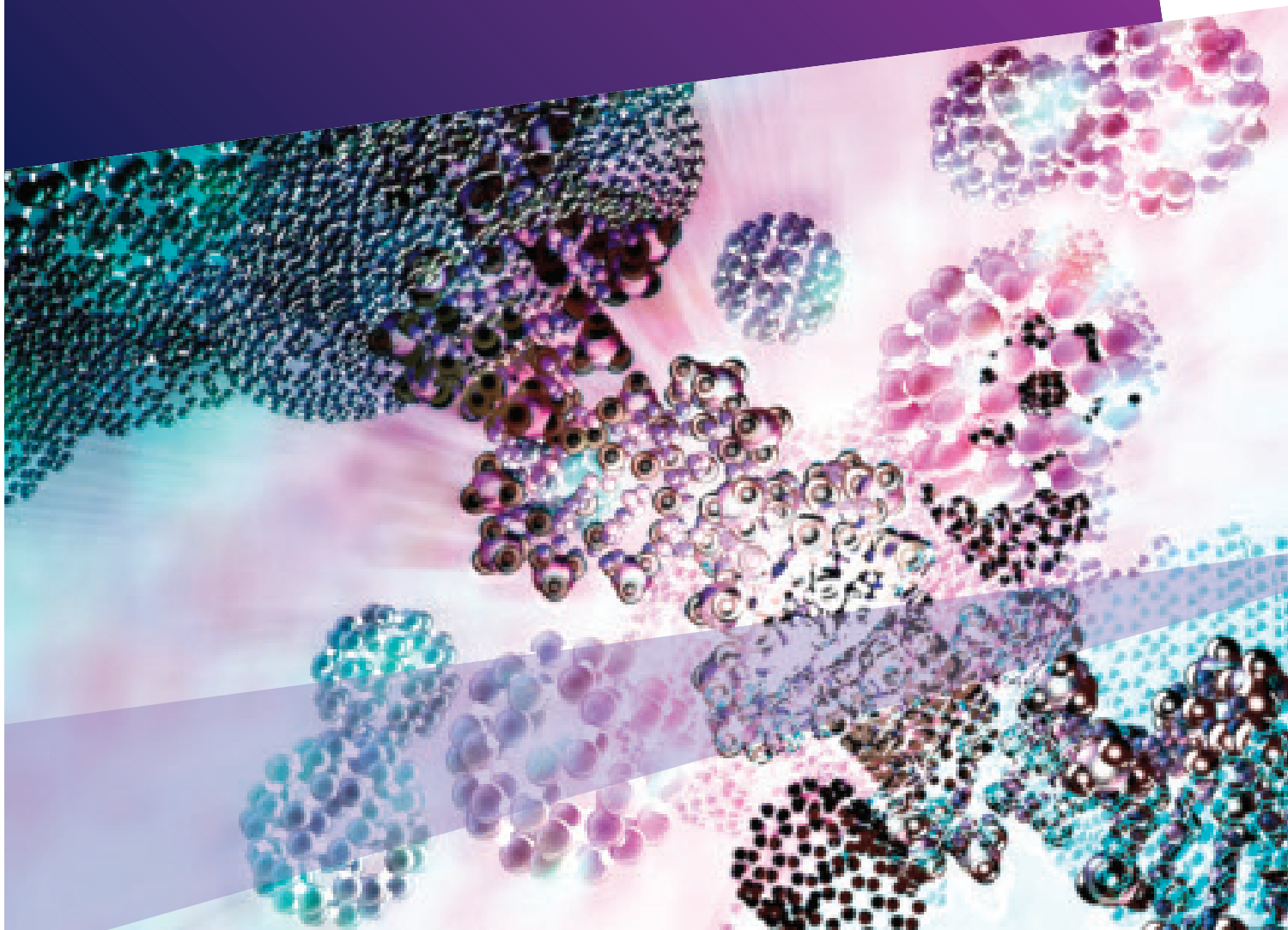
ICE is a marketing agency which started to build interactive kiosks for clients to use as part of their marketing communications strategies. The kiosks proved to be a winning formula, so ICE set up a new brand, AVI, to produce them. In 2004, ICE approached the Agility and Supply Chain Management Centre, hoping to draw on its expertise to enhance the company's manufacturing and stock control processes.

Since then, ICE has benefited from a series of collaborations with the Centre, which helped it to increase its turnover by becoming more agile, prepare for successful ISO 9001 accreditation by enhancing quality management, and strengthen its customer relationship management system.

“We were impressed by the scope of the Agility and Supply Chain Management Centre's expertise and its ability to identify Masters students needing to undertake real-world projects. Today we know from experience that the University has resources which have genuinely helped us in specialist areas, thereby supporting company growth.”

Steve Sherlock
National Business Development Manager, ICE

Materials



Overview

Breadth of Expertise

- Discovery/development
- Characterisation
- Functionalisation
- Experimentation/testing
- Modelling/simulation
- Device design/enhancement
- Theory

Materials

- Metals/alloys
- Polymers
- Composites
- Hybrids
- Functionals/multifunctionals
- Biomaterials

Types

- Bulk
- Surfaces/coatings
- Powders
- Foams
- Emulsions/dispersions

Scales

- Macro
- Micro
- Nano

Application Areas

- Aerospace & defence
- Biomaterials
- Construction
- Electronics
- High-performance engineering
- Household products
- Industrial diamonds
- Pharmaceuticals
- Sensors
- Smart coatings
- Speciality chemicals
- Waste disposal

Key Capabilities

1.0 Structural Materials

- 1.1 Construction materials
- 1.2 Other structural materials

2.0 Functional/ Multifunctional Materials

- 2.1 Dielectric and ferroelectric materials
- 2.2 Solid state electronics materials
- 2.3 Surface functionality and functionalisation
- 2.4 High throughput materials discovery

3.0 Biomaterials

- 3.1 Bionanotechnology
- 3.2 Biomaterials and tissue engineering

Many of the technological advances that have transformed our world over the last 20 years have been founded on developments in materials science and engineering. Materials are evolving faster today than at any time in history, enabling engineers to improve the performance of existing products and to develop innovative technologies that will enhance every aspect of our lives.

The University of Liverpool is at the forefront of materials science and engineering, which investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties. It includes elements of applied physics and chemistry, as well as chemical, mechanical, civil and electrical engineering. Its research also aims to understand materials so that new materials with the desired properties can be created. These can be harnessed to create novel applications in areas such as healthcare, electronics, energy storage, and biotechnology. It is also an important part of forensic engineering and failure analysis.

1.0 Structural Materials

1.1 Construction materials

Keywords: *Paving flags; pre-cast concrete blocks; ultra-high performance glass concrete (RGPC); recycled demolition aggregates; cementless concrete; fast-track construction; reinforcing steel corrosion*

Overview

The University of Liverpool carries out extensive research into concrete technology – focusing particularly on the development, characterisation and testing of innovative new materials and the evaluation of *in situ* concrete.

Materials discovery/development

Reactive glass powder concrete (RGPC) for paving flags

Since the mid 1990s, the UK has suffered from a growing surplus of green glass. This derives from an imbalance between the large quantity of green glass recovered for recycling, largely from bottles of imported beer and wine, and the low demand for green glass containers in the UK itself. This has led to a search for other uses for this surplus glass – for instance, using glass cullet to replace the quartz sand used to make ultra high performance concrete.

The University of Liverpool has developed a new material called Reactive Glass Powder Concrete (RGPC), which can be used to manufacture conventional concrete products such as pavement flags. RGPC offers real benefits over traditional products, producing a concrete flag which resists accidental damage and cracking, a problem which is prevalent with other paving flags. These new flags also weigh less, addressing health and safety concerns arising from handling injuries during placement, and require minimal pavement maintenance or repair during use.

RGPC also offers the potential to radically change the local economy of glass recycling since concrete paving flag manufacturers can absorb significant amounts of waste glass: a single factory fabricating conventional concrete flags requires 300 to 400 tonnes of aggregate every 12 hours and is likely to operate 22 hours per day.

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This ultra-high performance glass concrete is being developed with support from the Northwest Regional Development Agency (NWDA), the Northwest Opportunities Programme and industry.

Precast concrete products made with recycled demolition aggregates

Many structural walls are built using common pre-cast concrete blocks rather than reinforced concrete – thereby avoiding the danger of salts rusting the steel reinforcement and degrading the concrete. Transporting pre-cast blocks is extremely expensive, so manufacturers have to position themselves close to their market or their raw materials, which limits the geographic scope of their business.

Finding a way to break this link could reduce costs and increase competition in the industry. It could also deliver environmental benefits if natural aggregates in concretes could be replaced by recycled materials.

Construction and demolition waste has a relatively uncontrolled composition. Masonry buildings contain plaster, tile and glass as well as metal, wood and paper, while concrete buildings contain a small proportion of masonry. Nonetheless, the University has shown that significant proportions of both coarse and fine natural aggregate particles can be replaced by particles derived from crushed concrete and demolition waste (C&DW) without a detrimental affect on the compressive strength of the resulting material. It has also compared the availability and transportation costs of quarried and C&DW-derived aggregates.

The research was undertaken in collaboration with a demolition company, a demolition waste crushing company, two pre-cast concrete block manufacturers and a concrete producer. The results of lab-based research were promising, and factory trials have since revealed no practical problems with the use of recycled aggregates.

Cementless/geopolymer concrete products

Cement manufacture has undesirable environmental impacts ranging from scarring of the landscape to the production of greenhouse gases. Cementless concrete products made with waste materials would be advantageous, but are not currently available.

Previous research on cementless concrete used commercially available alkali solutions or powders and ground granulated blast furnace slag (GGBS) – but neither is commercially viable on grounds of cost. In view of this, the University has investigated the potential for using waste alkali solutions which cost money to dispose of, concentrating on waste ash sources rather than GGBS.

In order to facilitate their use in high-volume production, the University has focused on the reactions between siliceous ashes and waste alkalis. It has identified the most appropriate blending to deliver the required chemical and mineral composition, whilst enabling the ashes and alkalis to react and form a strong matrix which is equivalent to (if not better than) that achieved with the use of cement. Early results are promising. Research is now required to advance this promising technology to a point where it can be exploited by UK companies in full scale factory production.

Facilities

The University is exceptionally well-equipped for characterisation studies with two analytical scanning electron microscopes (SEM) and a new state-of-the-art X-ray diffractometer (XRD), as well as other relevant facilities such as infra-red spectroscopy and cathode luminescence microscopy.

It has expertise in a range of non-destructive testing techniques and is also well equipped for destructive testing thanks to its **Impact Research Centre**, which was set up to address problems involving the large dynamic loading response and failure of materials, and structures that occur throughout the field of engineering.

Materials characterisation/testing

Cementless/Geopolymer Concrete Products

The University has started to characterise the material properties of the starting materials and the different concretes produced by using ashes with different chemical and mineral compositions.

Its chemical analytical facility is facilitating the correct identification of minerals developed in the geopolymer cement. This type of analysis could provide key evidence for understanding the microstructure which develops in cementless 'geopolymer' materials as a result of using ashes from different sources. It could also inform the blending of different materials to produce geopolymer concretes with the desired engineering properties.

Fast track construction

The University's studies of early-age concrete maturity using temperature probes and temperature-matched cubes, together with strength assessment using the Lok test, have provided valuable information on how quickly formwork can be removed to speed up construction.

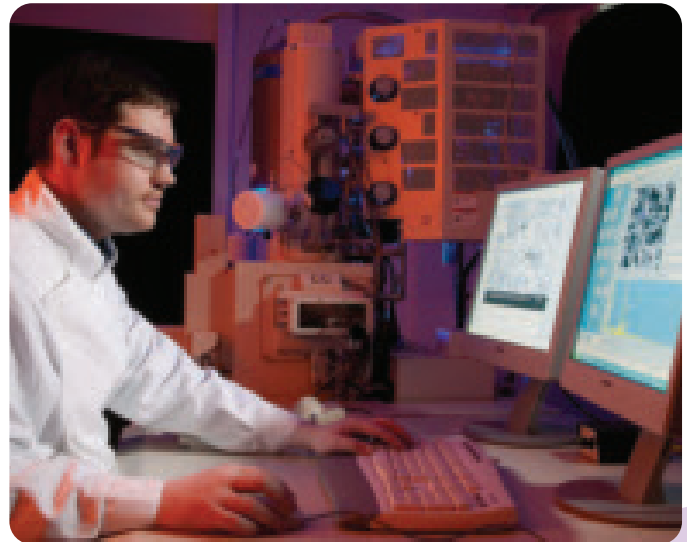
Corrosion of reinforcing steel

This is one of the biggest serviceability problems for reinforced concrete structures. Early warning of corrosion, before visible cracking or spalling is apparent, makes it possible to remedy this much more cost-effectively than leaving the problem to a later stage.

The University of Liverpool has assessed a range of electrochemical methods for evaluating corrosion.

Ground penetrating radar

GPR is a popular non-destructive investigative technique for detecting items such as reinforcing bars, pre-stressing tendons, voids and defects beneath the surface of the concrete. The University has assessed the capabilities of commercially available equipment and measured the radar properties of concrete for a wide range of constituents and conditions, producing guidelines for quantitative interpretation of results.



1.2 Other structural materials

Keywords: *Metallic shells; composite shells; strength; structural integrity; impact; blast; buckling; energy-absorption; fracture mechanics; computational mechanics; structural optimisation*

Overview

The University has carried out extensive research on lightweight materials and structures – independently and in collaboration with industry. It has a track record of developing and characterising novel materials and structures for use in high-performance engineering applications.

Materials development and characterisation

Porous metals

The University has developed and patented a novel technique for manufacturing a wide range of porous metals. The lost carbonate sintering method produces porous metals with open pores as fine as 100 microns. These new materials have exceptional mechanical, electrical, thermal, acoustic or biomedical properties.

Lattice structures

The University's selective laser melting facility has been used to manufacture a range of high performance lattice structures. These structures are capable of absorbing significant energy when subjected to impact loads. Their behaviour is now being modelled using finite element methods.

Hybrid materials

The University has developed a range of new thermoplastic-matrix fibre-metal laminates (FML) that can be manufactured in significantly shorter timescales than conventional FMLs. These hybrid structures offer an excellent resistance to continuous fatigue cycling as well as localised impact and blast loads.

Composite materials

The University is developing and characterising a range of new materials, including fully recyclable composite materials and environmentally-friendly composites based on natural fibres such as hemp, sisal and flax.

Materials testing

Blast resistance of safety critical components

A new test facility has facilitated important insights into the explosion resistance of safety critical components and, more importantly, structural systems – for example, FMLs and laser-welded aircraft panels.

The University's research has led to novel (small-scale) approaches to what has, to date, been considered a large-scale exercise only. In a significant advance, it has demonstrated the practicability of less than full-scale experimentation.

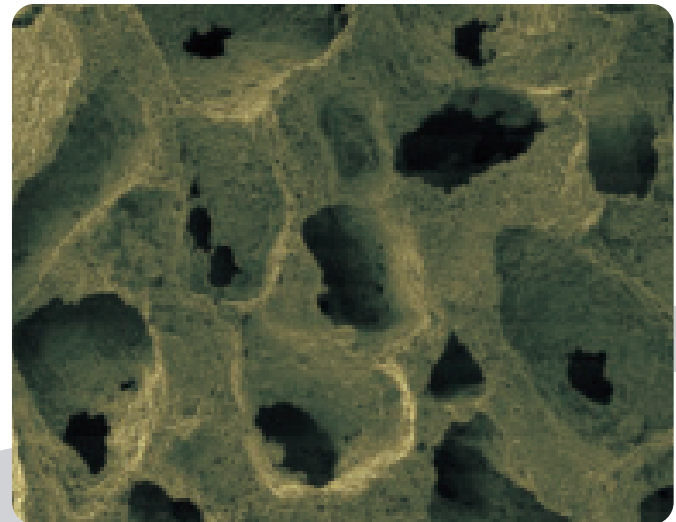
Foreign object and blast impact expertise

The University has expertise in impact testing a wide variety of structures and has studied a number of foreign object impact scenarios, including foreign objects impacting on tyre rubber on aircraft. Such studies are supported by numerical simulation of projectiles during impact using LS-DYNA.

Another area of expertise is in blast loading where a number of large air blast rigs are used to test panels up to one metre square, made in metallic and polymer composite materials. This experimental work is supported with numerical simulation (AUTODYN).

Fracture properties of composite materials

These are currently being investigated under extreme loading conditions, such as those associated with high velocity impact loading and blast.



2.0 Functional/Multifunctional Materials

2.1 Dielectric and ferroelectric materials

Keywords: *Thin films; nanostructured materials; semiconductivity; magnetism; refractive index; piezoelectricity; molecular beam epitaxy; chemical vapour deposition; growth monitoring/characterisation; structure-function relationships*

Overview

Advanced functional materials are an integral part of modern technologies. They are exploited in a wide range of applications such as IT, medical instruments, and sensors and actuators for the aerospace and automotive industries.

Functional materials can take the form of single crystals, ceramics, composites, nanocrystals, amorphous solids, liquid crystals, polymers and thin films.

Expertise

The University of Liverpool has expertise in a variety of thin film and nanostructured materials for electronic, optical and magnetic applications.

It deploys a range of techniques including molecular beam epitaxy, chemical vapour deposition, and optical growth monitoring and characterisation. These techniques can be applied to the study of epitaxial growth on semiconductors, on interfacial structures, and on structure-function relationships in nanostructured materials.

Materials discovery/development

The University's research has focused on the development of processes to assemble atoms or molecules systematically with atomic-scale specificity in order to generate materials with a desired property or function. It has world-class facilities to support the development of materials with a 'functional' property such as semiconductivity, magnetism, refractive index or piezoelectricity.

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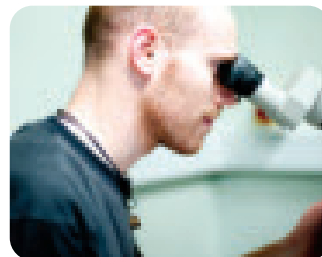
Facilities

- Royal Society – Wolfson class 1000 clean room
- Aixtron FE200L liquid injection chemical vapour deposition and atomic layer deposition reactor
- Cambridge NanoTechnologies 100mm atomic layer deposition reactor
- Polaron CVT TFS 4550 and VG80H molecular beam epitaxy
- Hitachi S-2460 scanning electron microscope
- Surface Technology Systems cluster tool comprising RF RIE reactive ion etcher, plasma enhanced CVD modules; and PVD sputtering chamber
- VG HB 601 scanning transmission electron microscope
- JEOL 2000FX transmission electron microscope
- Rigaku miniflex X-ray diffractometer
- HORIBA Jobin Yvon Ltd LabRAM Raman Microscope
- Millbrook desktop secondary ion mass spectrometer
- MCP Realizer selective laser melting equipment.

The class 1000 clean room contains an Aixtron 200FE metalorganic CVD reactor for the growth of nanostructured oxide thin films and a nitride-based molecular beam epitaxy system for nitride superlattice materials.

The clean room facility incorporates a class 100 UV photolithography unit and the equipment now provides a local facility for defining patterned structures with a $5\mu\text{m}$ pitch using a Karl Zuss MJ21 double-sided mask aligner, a resist spin coater, and a hotplate oven for curing photoresists.

The clean-room also houses a range of analytical facilities including a Jobin-Yvon LabRam Raman confocal microscope. The spectrophotometer can be employed for a wide range of applications such as surface enhanced Raman spectroscopy of single molecule adsorbates in vapour deposition processes or the analysis of new materials.



2.2 Solid state electronics materials

Keywords: *Silicon/silicon alloys; conjugated polymer electronics; bipolar devices; MOS devices; low-cost circuits/displays; microelectromechanical systems (MEMS); supercapacitors; sensors; solar cells/displays*

Overview

Solid state electronics encompasses circuits or devices constructed entirely from solid materials which may be crystalline, polycrystalline or amorphous. Some act as electrical conductors or insulators, others as semiconductors. Transistors, microprocessor chips and integrated circuits were early examples of solid state devices – more recent examples include liquid crystal displays and light emitting diodes.

Expertise

The University of Liverpool has expertise in materials characterisation (electrical and optical) and the production of novel devices – accommodating every stage of the design cycle, modelling and theory.

Materials

The institution also has a lengthy track record of semiconductor characterisation and device design, theory and modelling using bespoke commercial tools. Its work on inorganic semiconducting materials is mainly targeted at silicon and its alloys – most notably silicon-germanium for application in bipolar and MOS devices. Materials are assessed using a range of characterisation techniques, often in novel MOS capacitor test structures produced with low-temperature techniques.

Its work on organic semiconductors is interdisciplinary, encompassing chemists, physicists and engineers, and focuses on conjugated polymer electronics. This has the potential to impact on a range of applications – from general low-cost circuits and displays to power devices and microelectromechanical systems (MEMS), from supercapacitors and sensors to solar cells and displays. Its research into new display technologies covers vertical transistor structures using polymer materials where the film thickness can be used to define very small channel lengths.

✚ See also: *Advanced Manufacturing.*

2.3 Surface functionality and functionalisation

Keywords: *Materials surfaces; surface characteristics; surfaces processes/events; quantum effects; experimentation; theory; meso/nanoscale probing; structural properties; dynamical properties; physical properties; electronic properties; surface design; surface manipulation; complex alloys; quasicrystals; chirality in two dimensions*

Overview

Today's drive towards miniaturisation and nano-devices, with their attendant larger surface/volume ratios, means that events choreographed on surfaces hold the key to 21st century devices.

As industrial components like transistors for computer memories and magnetic particles for hard disks are pushed ever smaller and faster, they encounter unpredictable quantum effects: at meso and nanoscales, the bulk properties of matter give way to altered behaviour due to quantum mechanical interactions.

Basic research is an essential prerequisite to overcoming quantum limitations and opening the door to future discoveries. Surface scientists are pioneering in this respect, driving advances in sophisticated experimental and theoretical methods that will enable events at the nanoscale to be captured and decoded, and opening up new opportunities for industry to innovate.

The ability to design and probe collections of condensed atoms and molecules from the mesoscale (~microns) down to nanoscale (~nm) size scales is set to become key. The ability to manipulate molecular matter at the nanoscale will facilitate advances in catalysis, functional materials, electronics, biological interfaces, sensors and smart coatings.

The University of Liverpool was prescient in relation to surface science. Its [Surface Science Research Centre](#) was first established as a UK Interdisciplinary Research Centre in 1989 and quickly gained an international reputation as one of the leading surface science centres in Europe. It carries out fundamental research whose results are likely to inform future innovations.

Expertise

The **Surface Science Research Centre** fields an interdisciplinary team of scientists which brings together chemists and physicists. They have extensive experience of characterising materials surfaces and surface processes, and uncovering relationships between microscopic structure and composition and macroscopic behaviour.

The physicists have world-leading expertise in the surfaces of complex alloy materials. These materials have complex structures and can display combinations of physical properties not found in conventional simple alloys. Examples include quasicrystals and their approximants.

Facilities and services

The **Surface Science Research Centre** is outstandingly well equipped, with a wide range of instrumentation. It has a dedicated suite of state-of-the-art instruments for studying the structural, dynamical and electronic properties of clean and adsorbate-covered surfaces.

It offers surface spectroscopy using photons, ions or electrons and scanning tunnelling microscopy, which allows individual atoms and molecules to be imaged at surfaces, and has expertise in theory and modelling.



Applications

De Beers conjures up images of sparkling diamonds set in jewellery, but the company doesn't only mine natural diamonds; it also has an interest in synthetic diamonds for industrial use and is keen to improve their quality and the speed at which they can be grown. This requires a better understanding of diamonds' surface properties, and the ability to minutely monitor their growth.

These are two of the problems which the **Surface Science Research Centre** has tackled on behalf of De Beers in a series of collaborative studies which date back to the mid-1990s. In this project, **Surface Science Research Centre** the exploited reflection anisotropy spectroscopy (RAS) to monitor the growth of synthetic diamonds using chemical vapour deposition.

This is a rapidly developing optical technique which the **Surface Science Research Centre** helped to develop and apply – designing and building its own instruments. RAS can provide information about the electronic structure of a material and also the geometric structure at the nanoscopic or microscopic scale. As RAS can be carried out in a non-vacuum environment, this has the potential of expanding the applications of surface science into areas that have until now been forbidden by the restrictions of electron spectroscopy – principally the low mean free path of electrons in solid or liquid environments.

Today's drive towards miniaturisation and nano-devices, with their attendant larger surface/volume ratios, means that events choreographed on surfaces hold the key to 21st century devices.

2.4 High throughput materials discovery

Keywords: *High throughput techniques; robotics; automation; polymers; formulation; organic materials; porous materials; nanomaterials*

Overview

High throughput (HT) techniques involving automation and advanced robotics have the potential to revolutionise the discovery and exploitation of new multifunctional materials. They deliver fast, accurate results; enable speedy decision-making; and could potentially support broader patent claims. They can be exploited in energy, health, home and personal care and many other applications.

The number of sectors capitalising on this is still quite small. Some companies lack awareness; others have concerns about limited infrastructure; limited access to state-of-the-art equipment; lack of know-how, and lack of trained personnel.

The University of Liverpool's **Centre for Materials Discovery** was set up to get around such barriers to innovation. It is the only UK centre dedicated to helping businesses understand and reap the benefits of HT techniques.

Benefits

Traditionally, once you have postulated a hypothesis, your workflow involves manual synthesis of a single material; manual characterisation of the resulting material; and partial uncovering of structure-property relationships – which may or may not yield a lead material – and you do this over and over again.

HT materials discovery uses experimental design to assess a hypothesis rapidly and accurately. The aim is to gain the most information from the fewest experiments. This is achieved by using parallel synthetic protocols to map the relevant area, exploiting dedicated 'design of experiments' software. The results of the ensuing experiments are fed back into the software, enabling a predictive model to be produced which addresses the original hypothesis – for instance, elucidating structure-property relationships or the effect of a particular variable on the reaction.

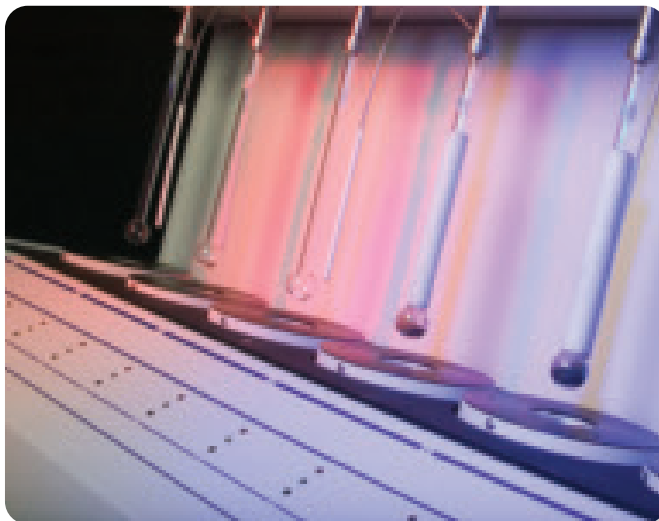
This approach delivers results much more quickly than traditional methods. It fosters real scientific understanding; advances an organisation's knowledge of materials properties; and could enable it to acquire broader patent coverage. Since it also facilitates speedier decision-making, it helps get to 'no' a lot faster.

Expertise and facilities

The **Centre for Materials Discovery** (CMD) is equipped with robotic synthesis, formulation and liquid handling platforms and more than 1000m² of laboratory space. It employs a multidisciplinary team of scientists with the skills required to facilitate the discovery and optimisation of new materials for commercial exploitation. It can undertake contract research on behalf of clients or foster knowledge exchange by working with clients. There may also be opportunities for clients to embed their own staff in CMD for extended periods.

Facilities at the **Centre for Materials Discovery** have been designed to provide a broad base of chemical synthesis and characterisation technologies, each focused on increasing throughput over and above that available in traditional laboratories.

The **Centre for Materials Discovery** works with clients from the private sector and with academics, utilising generic principles in methodology and practice to facilitate research across a range of sectors. Its work has encompassed new products, new material applications, and fundamental developments in materials synthesis.



3.0 Biomaterials

3.1 Bionanotechnology

Keywords: *Nanoparticles; metals; polymers; silica; ceramics; synthesis; sizes; structures; stabilisation; functionalisation*

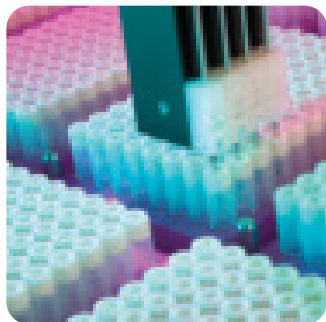
Overview

Bionanotechnology crosses the boundaries of chemistry, physics, engineering and biology, including biomedical and clinical sciences. It involves the manipulation of both the non-biological nanoscale materials of nanotechnology and of hybrid non-biological/biological nanomaterials.

In biomedical and clinical settings, applications of bionanotechnology should, in the near future, transform diagnostics and therapeutics, and provide platforms for personalised medicine. In the more distant future, applications in the fields of chemistry and engineering will exploit hybrid bionanomaterials to create, for example, smart environmental sensors and biological molecules with long-range self-assembly properties.

The University of Liverpool has a critical mass of research groups which are recognised leaders in various aspects of bionanotechnology. Their expertise spans biology, biomedical science, chemistry, clinical sciences, Earth and ocean sciences and engineering. They are brought together on a platform, the Liverpool Institute for Nanoscale Science Engineering and Technology (LINSET), which provides an efficient means to foster the vital interdisciplinary collaborations underpinning bionanotechnology, whilst maintaining core disciplinary excellence.

It is also part of 'NanoCentral' – an alliance of organisations whose members can provide access to a broad range of leading edge technologies, equipment and services.



Expertise

The University has particular strengths in:

- Chemical, biological and laser mediated synthesis processes
- Synthesis of different nanoparticle materials including noble metal, magnetic (pure metals, alloys, oxides), polymer, silica
- A wide range of sizes (1 nm upwards) with a tight control of dispersity
- Varied shapes – eg. spherical, cubed, tetrahedral, nanorods, wires and chains
- Different structures and compositions – eg. hollow, porous
- Polymer and self-assembling ligands as tool boxes for the stabilisation and functionalisation of nanoparticles.

Materials discovery/development

The University has pioneered a variety of methods for the nanoscale manufacture of polymer, metal and ceramic components which enable chemical control at the molecular level.

Stabilisation/functionalisation

It is recognised as a world leader in the development of functional nanoparticles as new tools for the analysis of biomolecular function. Its original developments in thiol-gold nanoparticle interactions remain the most commonly employed protocol world-wide for the preparation of ligand-stabilised metal nanoparticles.

More recently, it has pioneered the development of novel polymer and peptide-based capping ligands that uniquely allow independent stabilisation and functionalisation of nanoparticles with any biological macromolecule for innovative biological applications.

Applications

Due to their size, their physical, chemical and optical characteristics, and the potential to attach functional molecules to their surfaces, nanoparticles have a range of *in vitro* and *in vivo* biomedical applications. Biomedical applications being developed at the University include multiplex diagnostics; medical imaging; stem cell therapies and stem cell tracking *in vivo*; and single molecule imaging in live cells.

Facilities, equipment and/or services

- **Ultra Mixing and Processing Facility**, a unique tool for the creation of nanostructured fluids (emulsions, dispersions) by high pressure and high shear mixing
- Microwell library array platform, developed in-house, to screen for optimum properties of nanoparticles for particular applications
- Electron microscopy, including SuperSTEM aberration corrected microscope at the nearby Daresbury Laboratory for nanoparticle characterisation
- New imaging and detection platforms, including optical and photothermal microscopy for real-time detection of nanoparticle-labelled single molecules in live cells.

3.2 Biomaterials and tissue engineering

Keywords: *Biomaterial; biocompatibility; biointeractions; tissue engineering; medical devices; surface modification; cellular response; materials design; interface analysis; surface analysis; biocompatibility; stem cells*

Overview

Today, millions of people in the developed world are 'bionic' in the sense that they have some kind of implanted medical device: an artificial hip or knee, a heart valve, a 'stent', some kind of dental or facial implant, or another of the dozens of devices currently available. Our bodies recognise that these are foreign devices, no matter how inert the materials used to manufacture them – and this can sometimes result in rejection and failure well before a device's intended lifespan.

Biomaterials research aims to identify materials or coatings which can extend the lifespan of artificial or hybrid devices implanted in the body, while tissue engineers explore the potential for humans to 'grow' new body parts.

In 2001, the University of Liverpool joined forces with the University of Manchester, setting up the **UK Centre for Tissue Engineering** with the aid of £9.7 million of Research Council funding. This supported the most integrated and sustained research into tissue engineering in the UK for a six year period. Since then the University has expanded its facilities, creating the **UK Biomaterials & Tissue Engineering Centre** (UKBioTEC).

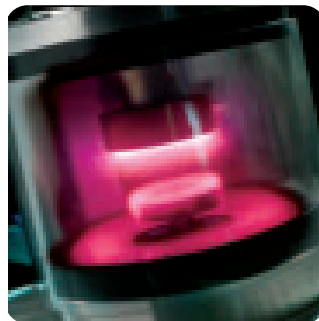
Alongside this, the University of Liverpool Stem Cell Consortium (ULSCC) provides a forum for scientists from different disciplines based in the University or at the Institute of Child Health, located at Alder Hey Children's NHS Foundation Trust. ULSCC is affiliated with the North West Embryonic Stem Cell Centre and is a member of the North West of England Stem Cell Network.

Expertise Biointeractions

A detailed understanding of biocompatibility and the interaction of materials with cells is a fundamental prerequisite to the enhancement and development of long-lasting implantable medical devices and tissue engineering products. Armed with this understanding, it should be possible to optimise the clinical performance of implantable devices by manipulating biointeractions at the molecular and cellular level.

By fostering collaborations between clinical engineers, biological scientists, physicists, chemists and materials engineers, the University offers an innovative environment for determining how the surfaces of materials and their modification can interact with and control biological systems.

This focus on cellular interactions at material interfaces has established many key indicators of bio- and blood compatibility.



Tissue engineering

The University's expertise in tissue engineering has been applied to the development of 3D functional scaffolds, the design of annular flow bioreactors, the isolation and enrichment of stem cell populations, and the control of stem cell phenotypes.

It has also been harnessed in large multi-partner R&D programmes led by the University – such as a £17 million project funded by the European Commission and Italian pharmaceutical company, Fidia. 'A Systems Approach to Tissue Engineering Products and Processes' (STEPS) aims to combat conditions like heart failure, diabetes, chronic ulcers and neurodegenerative diseases by making human tissue grown from stem cells available for transplant in the next few years.

Members of the University's Stem Cell Consortium (ULSSC) have played a key role in the development of substrates for the maintenance and self-renewal of embryonic stem cells.

Applications

The University's multidisciplinary team approach has facilitated the development of clinical applications for the treatment of a number of conditions – for example, Hirschsprung's disease. It has also provided the medical device industry with unique solutions to key business needs.

Capabilities and facilities

The [UK Biomaterials & Tissue Engineering Centre](#) (UKBioTEC) has a suite of biomaterials and tissue engineering laboratories which are complemented by additional facilities elsewhere in the University. These include:

- BioMEMS laboratories – providing access to 800m² of mainly class-100 clean room environment for fabrication, testing, measurement, analysis and modelling of bio-hybrid micro/nano structures
- Materials characterisation: dynamic contact angle, Fourier transform Infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy, secondary ion mass spectroscopy (chemical microscope), differential scanning calorimetry, HPLC, universal mechanical testing, atomic force microscopy
- Surface modification: gas plasma treatments, plasma polymerisation, design and discovery of functional materials using high throughput technology, preparation and application of nanoparticles, self-assembly of nanostructures, micro/nano surface structures using nanolithography and laser micro-ablation

- *In vitro* analysis: extensive cell culture facilities for established and primary cells including mesenchymal and embryonic stem cells, flow cytometry, light and fluorescent microplate spectroscopy, coagulometry, transmitted, reflected, fluorescent and confocal microscopy, scanning electron microscopy.

Biophysics

The University also works on the physical and electronic structure of interfaces which are important in biology and tissue engineering. Its research focuses on the interactions of biomolecules at metal-liquid interfaces, real-time measurements of conformational change in adsorbed proteins, hybridisation between adsorbed single stranded DNA and complementary strands, and the controlled growth of ordered collagen arrays by cells.

Capabilities and facilities

- High performance X-ray and Auger spectroscopy
- Scanning tunnelling microscopy (STM)
- Atomic force microscopy (AFM)
- Reflection anisotropy spectroscopy (RAS)
- Electrochemistry.

The University can access the ALICE accelerator at Daresbury Laboratory, which offers the most intense source of broad-band terahertz radiation in Europe and is the only accelerator equipped with a tissue culture facility for research on live human tissue.

Biomaterials research aims to identify materials or coatings which can extend the lifespan of artificial or hybrid devices implanted in the body, while tissue engineers explore the potential for humans to 'grow' new body parts.

Materials

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those which exploit and/or contribute to the development of Materials include:

- **Centre for Materials Discovery**
- **Impact Research Centre**
- **Knowledge Centre for Materials Chemistry**
- **Surface Science Research Centre**
- **Ultra Mixing and Processing Facility**
- **UK Biomaterials & Tissue Engineering Centre**

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Case Studies

Biointeraction

Biomer Technology is a young biomaterials company which aims to extend the working life of common medical implants by developing smarter biocoatings – exploiting proprietary polymeric surface coating technology.

Key to this is the ability to develop novel coatings which are capable of enhancing or inhibiting the body's natural reactions to implanted medical devices. Gaining an understanding of the cellular interactions between synthetic polymers and natural tissue is a prerequisite to this is – making it possible to identify chemical functional groups which will invoke a positive, negative or neutral response to their presence.

The company opted to collaborate with the University of Liverpool, in view of its significant expertise in bio-interactions and biocompatibility testing of novel materials.

“The University of Liverpool’s multidisciplinary approach and expertise has allowed Biomer to optimise the potential for our surface coating technology, and more importantly to identify future opportunities for collaboration and commercial exploitation of our technology.”

Simon Dixon

Managing Director, Biomer Technology Ltd

Lost Carbon Sintering (LCS)

LCS is a world-leading technology for manufacturing open-cell microporous metals, providing benefits of low cost production and accurate control over pore structure.

A project undertaken in collaboration with three companies – C-Tech, Thermacore and Ecka – tested the feasibility of using LCS to reduce product weights by 20-50% whilst achieving the same efficiency as current commercial products.

In the case of these particular products it proved possible to reduce weights by 50% through the use of LCS. The project also demonstrated that the application of microwave sintering enabled production times to be reduced by more than 50% whilst production energy consumption typically fell by 30%.

Digital Technologies



Overview

Breadth of Expertise

- Data acquisition
- Signal processing/classification
- Simulation/modelling
- Condition monitoring/fault diagnosis
- Non-destructive testing
- Software design/verification
- Systems design/prototyping
- Instrument design/prototyping

Focus of Expertise

- Biological entities/functions/processes
- Disease diagnosis/monitoring
- Non-biological materials/processes
- Computational devices
- Computer networks
- Computational markets
- e-Business processes
- e-Government

Technologies

- Microscopy
- Tomography
- Gamma ray & NMR spectroscopy
- Sensor technologies
- Ground penetrating radar
- Autonomous software
- Internet
- Semantic Web

Application Areas

- Aerospace
- Defence
- Logistics
- Automotive
- Electricity distribution
- Materials
- Security
- Biomedical
- Electronic trading
- Paints/coatings
- Telecoms
- Consumer electronics
- Environment
- Railways
- Waste management
- Robotics

Key Capabilities

1.0 Imaging and Detection

- 1.1 Imaging technologies
- 1.2 Image analysis
- 1.3 Detector technology for spectroscopic imaging

2.0 Signal and Information Processing & Communications

- 2.1 Signal processing and communications
- 2.2 Sensing and intelligent monitoring for complex conditions
- 2.3 e-Automation

3.0 Complex Software

- 3.1 Autonomous systems
- 3.2 Computational markets
- 3.3 Pervasive systems

4.0 e-Business

The UK's economy is significantly knowledge based and increasingly driven by research. By improving our collective understanding of the past, present and future across all academic disciplines, we can make an impact on the economy and society as a whole. Digital technologies are increasingly at the heart of this research, driving innovation forward and revolutionising the way we work.

With developments in digital technologies following each other up faster than ever, researchers at Liverpool are making progress in fields as diverse as imaging and detection; signal and information processing and communications; complex software; and e-Business.

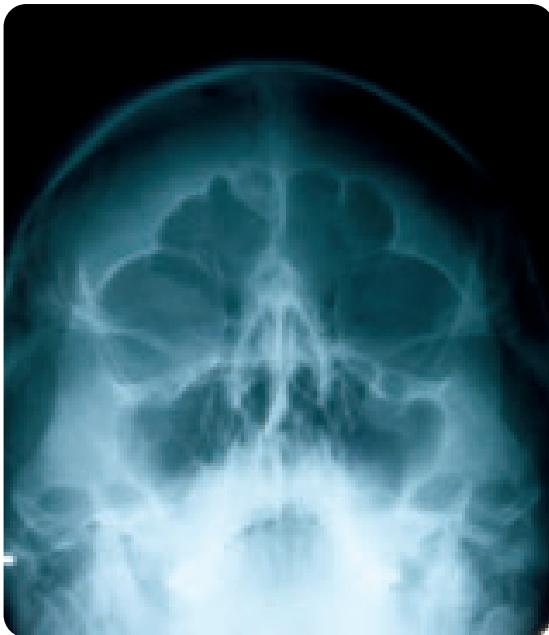
1.0 Imaging and Detection

There has been an explosive growth in imaging science recently due to continuing demand for ever higher resolution, rapid advances in vision research, new imaging technologies, the advent of multi-sensor data fusion and the increased sophistication of mathematical models and techniques.

As a result, imaging and image analysis are becoming increasingly indispensable in numerous fundamental and applied sciences, and in countless industrial applications.

The University of Liverpool has a wide range of imaging technologies at its disposal – including the ability to produce atomic-scale images unmarred by spherical aberration. Its multidisciplinary expertise is harnessed by defence contractors, by high-tech companies and NHS trusts, and by researchers working in the life and physical sciences.

The University's work on imaging and image analysis is designed to promote and support the use of a wide range of imaging technologies, enhance existing imaging technologies, and develop new ones and refine existing image analysis tools and develop new ones.



1.1 Imaging technologies

Keywords: *Microscopy; tomography; spectroscopic imaging; magnetic resonance imaging (MRI); dual energy X-ray absorptiometry (DXA); spherical aberration minimisation; thermal imaging*

Facilities and capabilities

- Microscopy
 - Scanning electron microscopy (SEM)
 - Transmission electron microscopy (TEM)
 - Scanning transmission electron microscopy (STEM)
 - STEM with no spherical aberration (SuperSTEM)
 - Scanning tunnelling microscopy (STM)
 - Atomic force microscopy (AFM)
 - Auger electron microscopy (AEM)
 - Confocal laser scanning microscopy (CLSM)
- Tomography
 - Computed (CT)
 - Electron (ET)
 - Positron emission (PET)
 - Single photon emission computed tomography (SPECT)
 - Optical coherence tomography (OCT)
- Magnetic resonance imaging (MRI)
- Dual energy X-ray absorptiometry (DXA) and CT for veterinary applications
- Spectroscopic imaging/mapping
 - Gamma ray spectroscopy
 - Nuclear Magnetic Resonance (NMR) spectroscopy
- Chemical imaging
- Geophysical imaging – in particular ground-penetrating radar (GPR).

There has been an explosive growth in imaging science due to continuing demand for ever higher resolution, rapid advances in vision research, new imaging technologies, the advent of multi-sensor data fusion and the increased sophistication of mathematical models and techniques.

Traditional light microscopes can magnify samples up to 1,200 times their actual size and are limited to a resolution of 0.2 micrometers. This means they cannot reveal fine details of specimens – for instance, the internal structures of cells. Electron microscopy was developed to overcome this problem. It works on a similar basis to light microscopes, but uses a focused beam of electrons in place of light to image the specimen. It enables samples to be magnified up to ~20 million times their actual size without loss of definition. It can reveal a sample's:

- Topography
- Crystallography
- Morphology
- Composition
- Electronic structure.

TEM microscopes cover the whole range of electron microscopy, from electron micro-diffraction – giving information on the crystallinity of the material – to high-resolution electron microscopy, which can display the atom columns of the crystal.

SEM is used to image the surfaces of solid samples at high spatial resolution (up to ~400,000 times actual size) and high depth of field. Biological samples have to be prepared for imaging, so it is not possible to image living material. SEM can be used to image microorganisms, or to magnify parts of organisms which can be seen with the naked eye.

STEMs are able to collect images up to a magnification of 10 million times by scanning a beam, focused down to the size of an atom, across the sample. At the same time, they collect chemical information associated with the same area of the sample. By using a high angle detector, it is possible to form atomic resolution images where the contrast is directly related to the atomic number of the chemical elements being imaged.

The images produced by STEMs are marred by the spherical and chromatic aberration which all lenses suffer from to a greater or lesser degree. SuperSTEMs overcome this problem by means of a computer-controlled system which corrects the inbuilt spherical aberration of the lenses. They can image a portion of a specimen at Angstrom or sub-Angstrom resolution and provide elemental and chemical analysis by means of electron energy-loss spectroscopy (EELS).

In a STM, an atomically sharp metallic tip is scanned at (sub) nanometer distances above a sufficiently conductive surface, where a 'tunnelling' current flows between the tip and the substrate. The tip is scanned across the surface either at a constant height or in tunnelling mode, allowing a profile of the (electronic) topography of the surface to be constructed, with resolution down to the atomic scale.

AFM is used to analyse and image the surface topography of specimens. It is well suited for the study of biological systems due to its high spatial resolution and its ability to image surfaces under liquids, offering nanometer scale resolution in images of biological samples under native conditions. It also has the potential for real-time observation of processes involving *living* biological systems.

AEM is based on analysing the energy of secondary (so-called Auger) electrons ejected from a solid surface on being radiated with accelerated electrons or X-ray photons. It can be used to measure the chemical composition of the top few layers of atoms on a solid surface and map the distribution of atoms across the surface at a lateral spatial resolution of <0.1 microns.

CLSM uses laser light of different colours to excite specific fluorescent probes and create a 3D image of their location and amount within an organism or organelles within cells. It is particularly suited for time lapse imaging of living cells and observing changes in the location or concentration of important biomolecules.

Tomography

Tomography offers a non-invasive means of imaging the inside of human or animal bodies. Tomographic imaging uses sensor information which is collected from number of different directions, relative to the patient. Clever reconstruction techniques are then used, enabling 2D or 3D images to be produced. The high-quality images produced are particularly important in the field of diagnostic nuclear medicine.

Different 'modalities' are available, providing information on a patient's anatomy – on structures such as bone or soft tissue, or the function of a patient's organs. Functional imaging can provide information on blood flow, for instance, or the uptake of glucose in different organs in the body, which is particularly helpful in aiding the diagnosis of cancerous tumours.

Digital Technologies

In Computed Tomography (CT), an external X-ray source is mounted on the opposite side of the patient to an X-ray sensor; this assembly is then rotated around the patient, yielding X-ray attenuation information from a large number of directions. CT provides 2D and 3D information on a patient's anatomical structure.

Some nuclear medical imaging modalities rely on measuring the uptake of a radioactive substance in a patient's body. Emission Tomography (ET) encapsulates a number of techniques that can provide functional information on a patient's organs. These techniques utilise a gamma ray sensitive detector system to provide the information necessary to form the image; this is sometimes referred to as gamma ray imaging. The gamma camera sensor is rotated around the patient to create a tomographic image.

The University of Liverpool has a wide range of imaging technologies at its disposal – including the ability to produce atomic-scale images unmarred by spherical aberration.

Single photon emission computed tomography (SPECT) utilises a gamma camera – consisting of a gamma ray sensitive detector coupled to a large collimator – to measure the location of a radiotracer in the patient's body. This gives the sensor directional position sensitivity, allowing an image to be formed. A gamma-ray emitting radionuclide is chemically attached to a radiopharmaceutical to form a radiotracer which is designed to target a specific function/organ in the body. The SPECT scanner is then used to image its location in the body by measuring the number of gamma-rays emitted as a function of position.

Positron emission tomography (PET) utilises a positron-emitting radionuclide and a gamma ray sensitive detector system to image the location of a radiotracer in the patient's body. The radionuclide and radiotracer used in PET produce 'back-to-back' gamma rays; this allows the sensor to determine the location of the radiotracer without the need for a collimator (unlike SPECT).

Optical Coherence Tomography (OCT) produces very high-quality, micrometer-resolution 3D images from within samples which scatter light, rather than reflect it (for example, biological tissue or certain plastics). It is able to penetrate significantly deeper into the sample – around three times deeper than confocal microscopy, and is used primarily for non-invasive medical imaging purposes such as detecting plaques in coronary arteries and examining the different layers of retinal tissue.

MRI

Magnetic resonance imaging (MRI) offers a non-invasive means of visualising internal structures of the body without incurring the radiation risks associated with CT and PET scanning. MRI is particularly effective at imaging soft tissue, and is used to diagnose and monitor tumours, cardiovascular and neurological conditions, as well as the skeleton and musculature. It can also be used to monitor functional activity such as brain signals, and can record signals from all regions of the brain – unlike EEG and MEG.

DXA

Dual energy X-ray absorptiometry (also known as DXA or DEXA) offers a means of measuring bone mineral density, and is the most widely used bone density measurement technology.

Spectroscopic imaging

Gamma spectroscopy can be used to generate images of areas inside the body by detecting the distribution of medically-administered radioactive isotopes. These can localise to specific organs or cellular receptors – enabling diagnosis or treatment on the basis of cellular function and physiology.

Nuclear magnetic resonance (NMR) spectroscopy can be used to determine the 3D structures of proteins. It is also the technique of choice for obtaining atomic-scale physical, chemical and 3D structural information on small molecules – whether these are produced naturally by the body, or by pharmaceutical companies in the form of new chemical compounds.

Chemical imaging

This is offered by imaging technologies such as TEM, STEM, SuperSTEM and AEM, which can simultaneously measure spectra and generate images.

Geophysical imaging

Geophysical imaging encompasses a range of imaging techniques which can visualise the sub-surface of the Earth non-invasively – for instance, ground-penetrating radar.

The University has four centres which specialise in particular imaging technologies for particular applications areas:

The **Centre for Cell Imaging (CCI)** is a world-class resource which enables researchers to measure multiple biological processes in real time, at resolutions only limited by the wavelength of the light used. Biological processes such as cell division, development, differentiation and cell death can be correlated with cell signalling through many different pathways. The activity and localisation of novel genes products can be monitored, and biophysical properties such as pH and membrane potential measured. Biological samples examined range from malarial parasites and bacteria to mammalian cells of many types, as well as plants, zebra fish and fruit flies.

The flexibility of the Centre's equipment and its array of biological tools have facilitated research into pituitary disorders, developmental disorders, blindness, diabetes, obesity, cancer, malaria, inflammation, asthma, and arthritis.

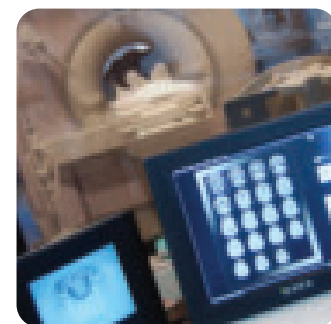
The University's **Magnetic Resonance and Image Analysis Research Centre (MARIARC)** has particular expertise in functional MRI (fMRI), diffusion tensor imaging (DTI), perfusion imaging, arterial spin labelling (ASL) and magnetic resonance spectroscopy (MRS). It has strong links with the Walton Centre NHS Foundation Trust which specialises in neurology and neurosurgery, and the Pain Research Institute, and with researchers in disciplines ranging from psychiatry and psychology to metabolic and cellular medicine. It supports world-class neuro-imaging research in cognitive and clinical neuroscience, and MR spectroscopy of human muscle *in-vivo*.

When the human genome was sequenced, it provided the information scientists needed to start exploring how our bodies work at the molecular level, and what exactly goes wrong when they don't function as they should. Since there is a relationship between form and function, it is vital to determine the three-dimensional structure of individual biomolecules and their variants, identify the properties associated with the different parts of their structure, and establish exactly how they interact with other biomolecules when carrying out particular, highly-specialised functions. The University's **NMR Centre for Structural Biology** facilitates this by providing state-of-the-art resources and access to scientists with an understanding of biology, physics, mathematics and chemistry.

The **SuperSTEM Laboratory**, based at Daresbury Laboratory, is equipped with two SuperSTEM microscopes – both of which minimise spherical aberration. SuperSTEM 1 produces images of a portion of a specimen with a sharpness measuring 1 Angstrom in diameter, and provides elemental and chemical analysis by means of electron energy-loss spectroscopy (EELS). SuperSTEM 2 provides sub-Angstrom resolution and accommodates a higher degree of tilt, allowing more control over the orientation of the specimen to be imaged; EEL spectra recorded within the same probe offer elemental and chemical data with atomic column specificity.

The Laboratory has undertaken studies for national research centres and companies as diverse as Qinetiq, Pilkington, Johnson Matthey and the Diamond Trading Company. Sample projects undertaken in collaboration with business include helping to resolve issues posed by the conversion of gases to liquid hydrocarbons, and ascertaining the source of colour in diamonds to inform the development of new methods of identifying their signature characteristics – tracing the origin of gem quality diamonds is becoming increasingly difficult using current methods.

For further information see 'Specialist centres, facilities & laboratories' on page 142.



Applications

The University's extensive imaging facilities and capabilities support research into a wide range of problems – for instance:

Biomedical applications

- Digital imaging and CCTV – used to study dental diseases and tooth morphology
- Fluorescence and confocal microscopic imaging – used to study cellular interactions and intracellular protein transport
- Nuclear magnetic resonance (NMR) spectroscopy – used to determine the complex 3D shapes of biomolecules and biopolymers at atomic resolution
- Electron tomography and STEM – used to study sub-cellular morphology of cells and characterise protein and lipid distributions
- Electroencephalography (EEG) – used to study visual perception/attention and the perceptual organisation of auditory environments
- Magnetic resonance imaging (MRI) and computed tomography (CT) – used to decode the relationship between brain form and function, to study tumours and monitor their treatment
- Positron emission tomography (PET) and single photon emission computed tomography (SPECT) – provide 3D visualisation of internal organs to aid medical diagnosis and monitor treatment
- Digital photography and confocal microscopy – used to study retinal morphology, diabetic retinopathy and age-related macular degeneration.

Other applications

- Radar and infrared imaging – used for image enhancement and feature simulation in defence and civil applications
- Electron tomography, STEM and SuperSTEM – used to study materials at the atomic scale and characterise their structures
- Electron backscatter diffraction imaging – used to investigate microstructures of rocks to understand solid-state grain-scale processes relating to earthquakes
- Photoelectron imaging – to understand fundamental properties of metals and alloys
- Computer vision and robotics.

1.2 Image analysis

Keywords: *Fast algorithms; resolution enhancement; noise removal; boundary detection; 2D to 3D; image comparison/matching*

Overview

Image analysis entails extracting meaningful images from the data captured by digital imaging technologies. Whichever technology is used, the images are captured using hardware and interpreted by software. The results are increasingly impressive, but they may not be adequate for some purposes.

Expertise

The University's expertise focuses on novel models and fast algorithms, encompassing:

- Restoration – removing 'noise' and/or enhancing resolution
- Edge detection – distinguishing boundaries of different objects
- Matching – identifying close matches of an image
- Feature extraction and segmentation – dividing images into regions of similar intensities and isolating areas/objects of interest
- 3D reconstruction and tomography – converting 2D image slices (from PET/CT/SPECT imaging) into 3D representations of an object
- Registration – mapping an image smoothly on to a related image, especially useful to compare images captured using different technologies.

In 2008, the University capitalised on its extensive facilities and its mathematical expertise by establishing the **Centre for Mathematical Imaging Techniques** (CMIT). This enables scientists, medics and engineers in the University – and businesses outside the University – to benefit from state-of-the-art mathematical techniques whilst giving applied mathematicians opportunities to tackle cutting-edge 'real world' problems.

For further information see 'Specialist centres, facilities & laboratories' on page 142.

1.3 Detector technology for spectroscopic imaging

Keywords: *Gamma radiation; charge collection in semiconductor devices; pulse shape analysis techniques; Compton imaging; medical imaging; multimodal imaging*

Overview

Radioactive isotopes which emit gamma radiation can be used as a diagnostic tool in medicine, helping clinicians diagnose or monitor cardiac and brain conditions and cancers non-invasively. An isotope is administered to the patient and the gamma radiation it emits is detected by external detectors. Radioactive isotopes are also present in radioactive waste and materials that could be used to make nuclear explosive devices, so the ability to detect their presence through their gamma ray emission is a vital tool for the security services.

The University of Liverpool has expertise in the development of the technology needed for gamma ray detection, gained through its nuclear physics research. Its expertise encompasses a wide range of radiation detector technology, in particular using sensors that have a position-sensitive readout.

Expertise

The University has one of only three laboratories in the world which can characterise position-sensitive semiconductor detectors (including germanium and cadmium zinc telluride) that allow gamma-ray interaction positions to be determined to millimetre accuracy with the aid of pulse shape analysis.

When gamma-rays interact with the detector material, charge is liberated in the form of electrons and holes. The process of collecting this charge takes tens or hundreds of nanoseconds, depending on the detector material and the geometry. By using digital techniques to record the time profile of the collection of this charge on the detector electrodes, exact information can be determined about the gamma-ray interactions positions. This technique is known as pulse shape analysis. This process needs to be characterised for particular detectors, and algorithms developed to convert the digital information from the detector into position information for later image determination. Algorithms can also be developed to determine the energy deposited in the interaction.

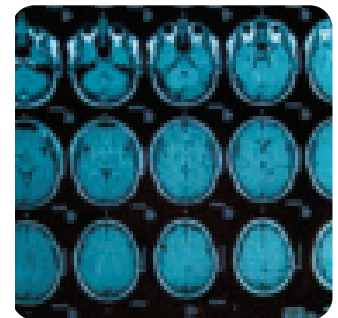
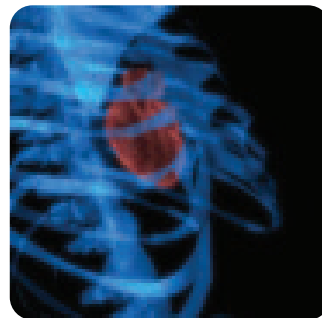
The spectroscopic imaging techniques used are mostly based on the Compton camera principle, where two detector elements are used with the algorithms developed above and the Compton scattering formula. The results identify gamma ray emitting isotopes and produce a spatial image that determines their size and location. Such an approach offers at least two orders of magnitude improvement in imaging sensitivity when compared with a conventional gamma camera.

Applications

The University has exploited its expertise in applications which provide enhanced medical imaging for diagnostics and monitoring purposes, and in applications designed to strengthen homeland security.

Medical imaging

Gamma-emitting radioisotopes are used for medical diagnostic purposes. Changes in normal physiological activity show up as a radiation hot-spot or cold-spot, as a result of radiation accumulating more than it would in healthy patients, or being blocked from accumulating. These effects are measured using a gamma ray spectrometer, which calculates how much gamma radiation the radioisotopes are emitting as they decay, and imaged using a gamma camera.



Conventional gamma radiation detectors are made from scintillation materials, which provide a very poor spectral response. Germanium provides a high quality spectral response – but it has to be cooled using liquid nitrogen, so it can only be used in large laboratories.

The University is working towards the development of two medical imaging systems based on semiconductor detectors. The first is aimed at imaging small animals using positron emission tomography (PET). The University has developed a system based on two position-sensitive germanium detectors which will give images with better spatial resolution and less background noise than can be achieved with conventional scintillation detectors.

The second is a gamma camera system using SPECT (single photon emission computed tomography). Conventional systems use a scintillation detector and a large collimator to give the image resolution. The University is developing a system based on a combination of position sensitive germanium, silicon and CZT sensors. A pair of these is needed for a successful spectroscopic imaging system and work is being carried out to determine the optimum combination.

Multimodality

Both systems have the potential to operate as multi-modality systems, where two imaging methods can be carried out simultaneously. The semiconductor detectors being used will work in magnetic fields, giving the potential for a combined SPECT/MRI system which will obtain anatomical and functional images simultaneously. As the semiconductor detectors used have excellent energy resolution, it will also be possible to use two isotopes simultaneously where there is a clinical need.

For the SPECT system, this new development will allow its use with a wider range of isotopes than the current systems where the mechanical collimator is optimized for specific gamma ray energies. This work is currently being carried out with advice from GE Healthcare and the current aim is to produce laboratory demonstration systems.

2.0 Signal and Information Processing and Communications

In the last 30 years the world has changed immensely. We now live in a digital age – consumers take mobile phones, digital cameras and televisions, CDs and DVDs, music downloads, emails and online social networking for granted. Businesses and hospitals rely increasingly on digital condition monitoring and fault diagnosis in place of routine checks carried out by humans, and on digital control.

Signal processing and communications lie at the heart of all of these developments – and many others. To be able to receive calls, emails, still or moving images, sound or data, we need sensors or receivers. To be able to communicate to the world we need some means of transmission. Signal processing is what happens between these two end points, enabling us to understand what we have received and respond or initiate actions.

2.1 Signal processing and communications

Keywords: *Information extraction; blind signal separation; machine learning for classification & clustering; meaning; channel estimation; equalisation; automated modulation recognition; antenna diversity; multiple input-multiple output (MIMO); electromagnetic/EMC measurement; computational electromagnetics*

Overview

The University's excellence in signal processing research has been achieved and is being maintained through fundamental theoretical developments, novel algorithms, sound radio frequency measurements and innovative and diverse applications.

Expertise

Core areas of theoretical developments are signal processing (including image processing), machine learning, and modelling. The University's strength in fundamentals is regularly demonstrated by its extremely strong international publication record and its well-known work on automated modulation recognition, blind signal separation and machine learning for classification and clustering. Much of the thrust is to extract information, to develop understanding and to generate meaning.

The University's excellence in signal processing research is being maintained through fundamental theoretical developments, novel algorithms, sound radio frequency measurements and innovative and diverse applications.

Applications areas:

- Audio – speaker separation and recognition
- Biomedical – breast cancer detection, retinal image processing, ECG, post-genomic micro-array data processing
- Communications – channel estimation, equalisation, and automated modulation recognition
- Non-destructive testing – railway inspection using ground-penetrating radar
- Vibration condition monitoring – fault detection, fault classification.

The University also carries out research studies in:

- Antenna diversity (including MIMO)
- Indoor radio propagation channel characterisation for wireless LAN
- Electromagnetic and EMC measurement techniques
- Computational electromagnetics
- Software radio.

The University's expertise has been harnessed in a number of radical applications. Examples include:

- Characterisation of indoor radio wave propagation for wireless personal communication – undertaken in collaboration with BT, this involved considerable work on wireless communications including layered space frequency equalization applied to MIMO multicarrier CDMA systems, multi-user detection of MIMO OFDM systems using blind source separation, and power and bit allocation for MIMO systems in frequency selective fading
- Pioneering work in the application of ground penetrating radar (GPR) and in automatic interpretation of non-destructive (NDT) data for utility detection and feature mapping. This was exploited for high-speed GPR rail track bed investigation in collaboration with site investigation specialist Zetica.
- Development of novel techniques for automated interpretation of ultrasonic TOFD data for weld characterisation and inverse models for the characterisation of buried unexploded bombs using borehole magnetometry

- Simulations of aerospace systems for the Royal Air Force's current generations of air-to-ground weapons, in association with the Ministry of Defence and QinetiQ
- Developing an image processing toolbox for the detection, tracking and identification of missiles for airborne missile warning systems
- Radio signal classification for the Ministry of Defence
- Maximising navigational information from marine radar returns in collaboration with industry.

Facilities

- The largest reverberation chamber in a UK university
- A computing cluster for CPU-demanding or memory-demanding applications.



2.2 Sensing and intelligent monitoring for complex conditions

Keywords: *Complex systems/processes; condition monitoring; sensor technology; telemetry; software; system integration; data collection; information; emergent behaviour; trends/patterns; fault detection*

Overview

Sensors and monitoring systems are essential to countless industrial, social and economical processes. However, conventional monitoring systems don't address the increasing complexity in such processes, which can lead to the collection of vast amounts of data which do not always provide insights into processes and potential problems/faults that may be of concern.

Expertise

Sensing expertise

The University has extensive experience in optical fibre and non optical fibre sensors for the monitoring of:

- Temperature
- Pressure
- Liquid flow, level, condition
- Movement and activity
- pH
- Electrical current and voltage
- Light
- Colour
- Sound
- Radio frequency
- Wear and corrosion
- Battery condition
- Driver fatigue.

In many applications the University harnesses a proprietary, patented approach based on chromaticity. In addition to more conventional sensors and optical fibre based sensors, it has extensive experience of remote CCTV scanning, acoustic and radiofrequency detectors.

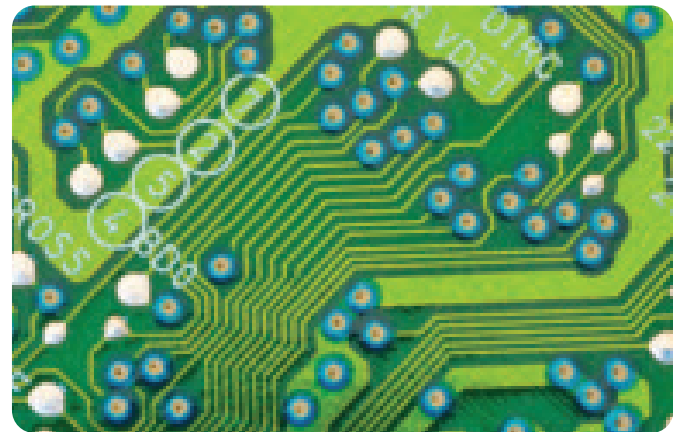
Sensing systems

The University designs systems which can be used to collect data in real time and telemetrically transfer *information* via the Internet or mobile phone. It is researching a range of sensing systems, including:

- Hybrid optical current transformer
- Optoacoustic measurements
- Fluid level, flow and quality
- Sizing and concentration of atmosphere-borne particles (PMIDS)
- Optical fibre temperature sensor
- Contamination of various environments
- Remote temperature and stress monitoring
- Linear and rotating displacement measurements
- Security and care systems.

The University of Liverpool's **Centre for Intelligent Monitoring Systems (CIMS)** is an applied research centre which addresses the need for information rather than data. It employs a generic approach – combining the strengths of sensor technology, software and telemetry to provide holistic, integrated and intelligent solutions to the monitoring of complex systems and the detection of emerging patterns.

For further information see 'Specialist centres, facilities & laboratories' on page 142.



Turning data into information

CIMS' approach permits outputs from different sensors positioned on complex processes to be combined to provide meaningful information, rather than a surfeit of data. This readily assimilated information can be used for condition monitoring and assessment and can identify unusual patterns of behaviour relating to fault conditions. In addition, by bringing together and using complex data from more than one source, the approach developed by CIMS provides systems that are self-evaluating and predictive – ie intelligent monitoring systems.

Research, design and prototyping

CIMS has the expertise and facilities required to develop concepts from research through design to prototype integrated systems which are commercially exploitable. It has extensive experience of working with business to commercialise products through technology transfer, technology licensing, technology manufacture and system demonstration/installation.

Applications

Applications areas include:

- Automotive, aerospace, rail
- Neonatal care and healthcare
- Domiciliary care
- Electrical generation, transmission and usage
- Environmental and pollution monitoring
- Fuel quality
- Bacteria growth
- Waste management
- Industrial processing
- Paints and coatings
- Security
- Semiconductor materials.

Typical applications range from monitoring the centre of gravity of aircraft in flight or the wellbeing of people in the living environment, to the monitoring of regulated airborne pollutants and tracking changes in complex industrial processes.

The University has particular expertise in the development of sensor and monitoring systems to reduce the environmental impact of high current electrical discharges – mainly in electrical switchgear. It is currently working on new mechanisms of current interruption.

Sensors and monitoring systems are essential to countless industrial, social and economical processes. However, conventional monitoring systems don't address the increasing complexity in such processes, which can lead to the collection of vast amounts of data which do not always provide insights into processes and potential problems/faults that may be of concern.

2.3 e-Automation

Keywords: Large-scale distributed complex systems; real-time control; information processing; condition monitoring; computer networks; agent/multi-agent technologies; ontology systems

Overview

'e-Automation' refers to a new generation of automation systems which use the latest networking and agent technologies for information management, condition monitoring and real-time control of large-scale, distributed, complex industrial systems. This concept has been developed and refined by the University of Liverpool and successfully applied to real-world problems.

Facilities

The University has a flagship research laboratory developed in partnership with National Instruments Corporation. The **National Instruments e-Automation Laboratory** is also supported by National Grid plc.

For further information see 'Specialist centres, facilities & laboratories' on page 142.

Expertise

The Laboratory's expertise encompasses advanced control techniques; computational intelligence; machine learning; and information processing and management. It extends to software intelligence, multi-agent and ontology systems, computer networks, digital signal processors and embedded system technologies.

Sample application Transformer monitoring

The power transformer is one of the most important and expensive components of power system plant. A large 400-kV unit can cost in excess of £2 million. With more than 700 power transformers currently operating in the UK's national grid, it is essential to closely monitor their in-service behaviour to avoid catastrophic failures, costly outages and loss of supply.

National Grid plc has been trialling an intelligent transformer monitoring system developed by the University's e-Automation Laboratory. Installed for pilot operation at one of the company's sub-stations, it has been run successfully on a supergrid transformer for more than a year.

Based on multi-agent and ontology technology, it comprises a series of modules including data acquisition, thermal model, data storage, load ability analysis and HTTP service. It has the potential to allow users to remotely monitor the working condition of all transformers in a network. National Grid plc plans to run simultaneous tests of the system in a number of substations.

3.0 Complex Software

Software is now everywhere. It is evident in our interactions with email systems and online stores, but less obvious, perhaps, in some of the devices we use every day: our cars, our boiler controllers, our washing machines and digital televisions.

As the ubiquity of computer software increases, its complexity is also rising. Contemporary software doesn't just follow a fixed list of instructions; it is expected to be intelligent, adaptive, autonomous, interactive and resilient, even in the most unpredictable environments. These requirements make contemporary software systems inherently complex – so much so that the breadth of its interactions may be beyond anyone's comprehension.

The University of Liverpool has expertise in two key types of complex software: autonomous systems, which allow a computational process to decide for itself what the best course of action is, and pervasive systems – networked processing devices and systems integrated into everyday objects and activities. It also has expertise in computational markets – in other words, using intelligent software agents to manage electronic market places, allocating resources to organise/streamline processes like finance and logistics.

3.1 Autonomous systems

Keywords: *Autonomy; autonomous systems; autonomous software; autonomic systems; agent-based systems; reliability; trust; security*

Overview

Autonomous systems are a response to the challenges associated with direct human control of computer systems operating in dangerous or complex scenarios. They are used in hostile environments, remote areas or computational scenarios where speed is vital – for instance, electronic trading systems, where following the market is tedious and difficult for human users.

The principle behind an autonomous system is that it can 'decide for itself' what its best course of action is in a given situation – and make these decisions without the need for human intervention. Can we be sure, however, that the system will indeed choose to do what it should do? Can we place our full trust in such systems? And what if the system learns new behaviour?

The University of Liverpool's expertise in autonomous systems encompasses both the practical construction of hardware for autonomous systems, the development of autonomous software to operate the relevant hardware, and detailed analysis of such software.

This kind of analysis has identified a key requirement: it is vital to understand and control not only what the system does – but also *why* it chooses to do this.

The University of Liverpool's expertise in autonomous systems encompasses both the practical construction of hardware for autonomous systems, the development of autonomous software to operate the relevant hardware, and detailed analysis of such software.

Expertise

The University is particularly strong in the development of techniques, tools and applications based on the 'agent' concept. An agent is a powerful abstraction capturing the core elements of an autonomous system – uncertain models of its environment, the goals it wishes to achieve and the ways it has for deciding between conflicting goals.

Based on this abstract notion a whole field of work has developed, providing improved programming methods for developing autonomous software, detailed analysis techniques for autonomous systems, and sophisticated mechanisms for effective collaboration and cooperation amongst autonomous entities.

The University of Liverpool specialises in:

- Programming tools for autonomous software, specifically sophisticated agent-based programming languages for developing autonomous applications, including tools for developing bespoke languages
- Software engineering methods for agent-based systems
- Mechanisms for ensuring co-operation, collaboration and negotiation between autonomous entities
- Mathematical and logical methods for the modelling and analysis of agent-based systems, specifically automated verification techniques for exhaustively analysing the potential behaviours of a multi-agent system.

Specialist laboratories

The **Liverpool Verification Laboratory** specialises in the formal analysis and automated verification of autonomous systems. It has developed world-leading agent verification tools and devised a route for the bespoke development of new agent languages which are both sophisticated and verifiable.

The University's **Semantic Web Technologies Laboratory** carries out research designed to support the development of the Semantic Web and the application of Semantic Web technologies.

Application areas

These currently range from aerospace, robotics and manufacturing to logistics, telecommunications and the Internet.

Information dissemination in public spaces

One significant application area has been the use of agents to support information dissemination within public spaces. The University's BluScreen project has shown how agents can determine the most suitable content for display on a digital signage screen by exploiting game-theoretic approaches, such as auctions and voting games, to detect multiple users in an open environment.

Domain-specific information dissemination

Since the preferences and information displayed can be domain-specific, ontological agreement between agents is critical. The University's evolutionary ontology project has demonstrated that agents can exploit argumentation to converge on ontological definitions of concepts to support communication and conceptualisation of the displayed content.

Plans are now underway to migrate much of this work onto small mobile computing platforms such as Apple's iPhone within the recently deployed **Liverpool Computer Science MacLab**.

For further information see 'Specialist centres, facilities & laboratories' on page 142.



3.2 Computational markets

Keywords: *Online markets; trading agents; computational economics; mechanism design; automated market design; alternative trading systems; dark pools; market modelling*

Overview

The rise of the Internet has led to many human activities moving online, particularly economic transactions. For instance, up to 70% of the shares traded (by value) on the New York Stock Exchange each week are traded by software programs which buy and sell shares automatically. Similar automated trading systems operate in other commodity markets – eg. foreign exchange markets and markets for commodities like oil and coffee.

Despite the proliferation of automated trading systems, auctions and online trading over the past decade, the science and engineering underpinning these systems is still very immature. Many challenging problems have yet to be solved. One set of problems concerns the design and assessment of effective trading strategies for automated software traders to use. What goals should the strategy seek to achieve? What historical market information should be used? What learning mechanisms should be adopted? Another concerns the design and management of the trading system itself. What overall goals should it seek to achieve? What rules should it follow? What behaviours should be encouraged or discouraged?

Expertise

The University of Liverpool brings cross-disciplinary expertise to such problems – from the application of ideas and concepts from economics, marketing and game-theory to the analysis and engineering of automated trading systems and participating trading agents.

Particular capabilities include:

- The design, operation and management of automated trading systems and online marketplaces
- The design and operation of automated trading strategies within such markets (trading agents)
- The development of linked online marketplaces, such as those in a supply chain or those for markets of complementary goods
- The development of models of consumer decision-making and trading
- The development of simulation models of marketplaces – for example modelling product diffusion over time, advertising effectiveness, word-of-mouth (WOM) impacts.

Facilities

- JASA software platform (Java Auction Simulation API)
- JCAT software platform (Java CAT Market Design Tournament platform).

Application areas

A key application in the medium term is the automated allocation of anonymous computer processing resources – the so-called 'Internet cloud'. This envisages the computer resources needed for large-scale business or scientific processing tasks being provided automatically and anonymously, in the same way that electricity is provided to most homes and businesses. If this vision is realised, managers would not need to negotiate use of the resources required for each new task, and businesses would not need to concern themselves with providing the necessary resources. Automated trading systems will be essential for the realisation of this vision.

The University is currently exploring this in collaboration with Hewlett-Packard and an Irish start-up company, Ripple Software.

The University of Liverpool brings cross-disciplinary expertise to such problems – from the application of ideas and concepts from economics, marketing and game-theory to the analysis and engineering of automated trading systems and participating trading agents.

3.3 Pervasive systems

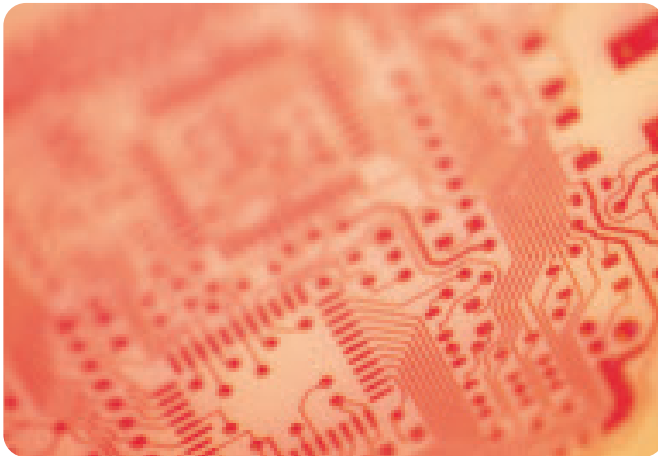
Keywords: *Pervasive systems; autonomic systems; ubiquitous systems; mobility; trusted computing*

Overview

As computational devices become smaller and faster, they are becoming more and more prevalent at work, in our homes and in the wider environment. They are embedded in our mobile phones and PDAs, in most electrical appliances, in our clothes, our cars, in houses and streets.

Some of these computational devices operate in stand-alone mode, detecting and measuring. Others are designed to exploit advances in wireless communication and sensing capabilities by collaborating with other computational devices – forming a large, dynamic network with capabilities ranging from sensing and computation to prediction and analysis. Such systems are known as 'pervasive systems' or 'ubiquitous systems' and can take very many different forms.

These systems present a number of challenges. In what innovative ways could they be harnessed? How should the software be constructed in order to achieve a particular system's goals – and how can we 'trust' such systems? Research undertaken by computer scientists at the University of Liverpool is helping to create solutions.



Expertise

Programming pervasive systems

Pervasive systems are distributed, dynamic and interacting. They exhibit three characteristics that are problematic from the perspective of traditional software development – they are autonomous, humans are an active and important part of the system, and they are truly mobile.

Engineering software for pervasive systems requires novel approaches, so the University is developing and applying sophisticated programming languages and development methods which combine autonomous computation with context-awareness.

Using pervasive systems

The modularity and mobility of pervasive systems necessitates run-time interoperability between different components. As new and diverse devices are deployed within the environment, or hitherto unseen services are discovered, these components need to determine how to communicate and exploit the available services autonomously.

To facilitate this, the University is developing mechanisms to resolve heterogeneities in terminology and assumptions in interface definitions. It is currently investigating this in the context of discovering location-dependent services using mobile devices within cultural sites such as museums and art galleries.

Creating trusted pervasive systems

Pervasive systems typically contain numerous sensors/computational devices which can acquire and provide access to a great deal of information and facilitate far-reaching computations. This raises questions about the reliability and security of such systems. If computational devices 'know' our status and our position and can track our route, for instance, can we be sure that they won't allow such sensitive information to be communicated to undesirable parties?

The University is developing techniques for the mathematical analysis of pervasive systems which will make it possible to assess the security and reliability of such systems before they are deployed.

Sensor networks

Sensor networks can incorporate a wide variety of devices, including sensors embedded in our immediate and wider environment – for instance, body sensors (eg. accelerometers, GPS and gyroscopes) concealed in clothes or mobile electronics and standard wavelength/infrared cameras.

This diversity could facilitate novel applications – for instance, the electronics industry might consider powering devices by scavenging biomechanical human body energy generated by movement.

Since context-awareness is key, electrical engineers at the University have used advanced signal/image processing algorithms, statistical data analysis and machine learning methods to combine and fuse different sensory signals, enabling the detection of the various movements and activities performed by humans.

Specialist laboratories

The **Liverpool Verification Laboratory** is developing techniques and tools for the modelling, analysis and security checking of designs for pervasive software.

The University's **Semantic Web Technologies Laboratory** is developing game-theoretic and argumentation-based techniques for autonomous resolution of semantic heterogeneity, and tools for the alignment of, and reasoning between, ontologies to support communication in pervasive environments.

For further information see 'Specialist centres, facilities & laboratories' on page 142.

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4.0 e-Business

Keywords: *e-Business, enterprise resource planning (ERP); management information systems; SAP*

Overview

The advent, growth and wide acceptance of software, local area networks and the Internet has made it possible for businesses to harness information and communication technologies to support business processes spanning the entire value chain. 'e-Business' now encompasses electronic tendering and purchasing, supply chain management, the electronic marketing, ordering and processing of orders, customer services, operations management and logistics.

The University of Liverpool was one of the first in the UK to grasp the full potential of e-business. It has been researching and developing innovative e-business solutions since the 1990s.

Expertise

The University's expertise extends from the fundamental technology through the construction of entire systems to understanding and addressing strategic issues. It has particular expertise in:

- Management information systems
- Enterprise resource planning (ERP)
- Supply chain integration
- Track-and-trace technology
- e-Marketplaces
- e-Government.

Applications

The University applies its expertise to the conceptualisation, development and testing of novel e-Business applications. It does this in collaboration with business and has collaborated with multinational companies (eg. the Ford Motor Company, BAE Systems, Lear, Cargill and Unilever) and SMEs alike.

Sample applications include:

• Managing offset work packages

Offset work packages can be difficult to manage if the supplier has different working methods and systems, making it difficult to spot problems at an early stage, let alone assess knock-on effects. When Airbus UK offset work packages from its A340 and A320 programmes to Korean Aerospace Industries, it invited the University to analyse the business processes underpinning its collaboration with KAI. This revealed a number of 'mismatches' and inefficient processes.

The University re-engineered these processes and developed shared electronic applications to support them, including a top-level project planning system, a spreadsheet-based production scheduling system, a memo system for registering engineering enquiries and a reporting system to record what was achieved the previous week, any ongoing issues, actions planned for the following week and decisions which Airbus UK needed to make. To access these shared applications, Airbus UK and KAI logged into a secure, Internet-based extranet.

• e-QMS System

The University developed an e-QMS system for Alphasonics Ltd, a company which designs and manufactures cleaning equipment for the printing industry.

Facilities

- Interactive computer labs with SAP, witness simulation/modelling and other advanced software development tools
- Extensive server facilities.



Digital Technologies

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those which exploit and/or contribute to the development of Digital Technologies include:

- **Centre for Cell Imaging**
- **Centre for Intelligent Monitoring Systems**
- **Centre for Mathematical Imaging Techniques**
- **Liverpool Computer Science MacLab**
- **Liverpool Verification Laboratory**
- **Liverpool NMR Centre for Structural Biology**
- **Magnetic Resonance and Image Analysis Research Centre**
- **National Instruments e-Automation Laboratory**
- **Semantic Web Technologies Laboratory**
- **SuperSTEM Laboratory**

For more information or questions, contact:

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www.liv.ac.uk/businessgateway



Case Studies

Liverpool Software Verification Laboratory

Individual satellites have been deployed in space for more than 50 years. However, single large satellites are impractical and inefficient as they are heavy and prone to failure. An alternative approach is to deploy several much smaller satellites in formation, which work together to carry out data collection/transmission tasks.

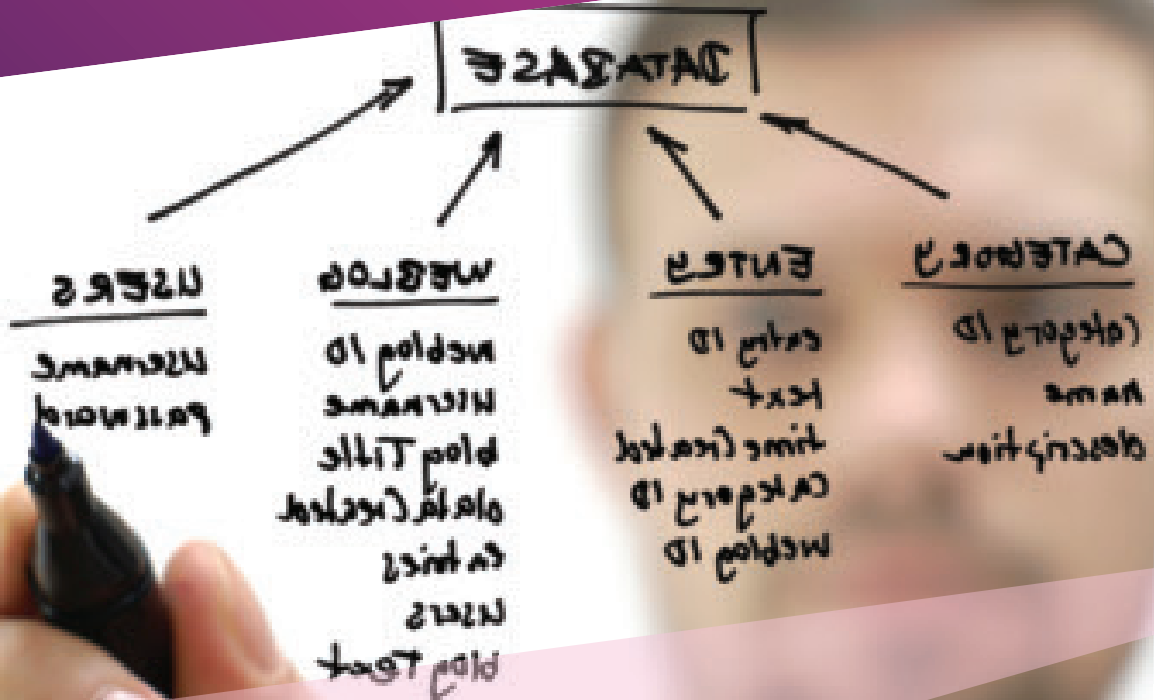
As these satellites cannot easily be controlled directly from Earth, they are essentially autonomous – so how can we ensure that they will work together, as required? And if a satellite should fail, can we rely on the others to self-organise to cope with this?

Computer scientists at the University of Liverpool are developing new programming languages for controlling such formation-flying satellites in collaboration with aerospace engineers at the University of Southampton. These languages mix high-level agent decision-making with traditional control systems used by aerospace engineers. This approach gives the system more transparent and flexible mechanisms for selecting autonomous behaviour and supporting co-operation.

These languages have a strong logical/mathematical basis, and are being developed within the University's flexible software verification framework. This means there is potential to carry out deep formal analysis of the programmed behaviours in order to ensure that the required behaviour is exhibited in all appropriate scenarios.



Management & Enterprise



Overview

Breadth of Expertise

- Supporting entrepreneurship
- Growing enterprises
- Supply chain management
- Logistics
- Fostering innovation
- Strengthening leadership
- Facilitating strategic change
- Making organisations resilient
- Quality

Focus of Expertise

- Private sector
- Public sector
- Communities
- Regions
- Emerging markets
- Service industries
- Social challenges
- e-Business

Services

- Action research
- Market research
- Historical research
- Consultancy
- Mentoring
- Master classes
- Continuous professional development
- Masters programmes

Application Areas

- Manufacturing sector
- Retail
- Tourism
- Financial services
- Distribution
- Non-departmental public bodies
- Government/local government
- Utilities

Key Capabilities

1.0 Entrepreneurship and Business Start-up

2.0 Gaining and maintaining a competitive edge

- 2.1 Innovation
- 2.2 Operations Management and e-Business
- 2.3 Accounting and finance
- 2.4 Business continuity and crisis management
- 2.5 Knowledge, learning and strategic change

3.0 Public Sector Management

4.0 Managing and Marketing Services

5.0 International Business History

The University of Liverpool has in-depth knowledge of many world regions – most notably the Balkans, Latin America, West and South Africa, South Asia and China. It has expertise in economic development, modes of entry and the effective transfer of competitive advantage to countries with different business, legal and socio-cultural environments. Achieving the latter, in particular, has become one of the trickiest aspects of international business strategy, leading to the development of a range of models that can be applied in practice to overcome this range of challenges.

Reflecting the increasing importance of emerging markets as a focus for growth and investment in the global economy, the University is able to offer a range of expertise on business, government, law and cultures in emerging markets.

Much of its expertise resides in its full-spectrum management school, whose primary research focuses on growing enterprises, growing innovation and growing communities and regions. These are mutually reinforcing and of great importance to the business world. Central to this focus is the desire to prepare leaders for tomorrow's challenges.

A real strength of the University is its ability to take ideas developed in one sector, such as manufacturing, and creatively apply these in very different sectors – for example, applying a lean and agile philosophy and toolkit developed for the manufacturing sector to social care and health management.

The University of Liverpool Management School (ULMS) provides a wide range of services, drawing from its extensive expertise, and is always willing to discuss how these may be applied to the opportunities and problems faced by organisations. It has extensive experience of working with organisations in sensitive areas – be they concerned with crisis, counter intelligence or boards of directors – and helping to improve their effectiveness.

1.0 Entrepreneurship and Business Start-up

Keywords: Consultancy; mentoring; master classes; student projects; networks; regional engagement

Overview

It is 30 years since the publication of a seminal report showing that a large proportion of jobs created in the US had been generated not by Fortune 500 or even Fortune 1,500 companies – but by small businesses and firms. This was an unexpected discovery which had an enduring impact on economists and policy-makers around the world. The Bolton Report, commissioned by the Labour Government in the 1970s, came to very similar conclusions about the importance of small firms to the UK economy.

The author, David Birch, subsequently distinguished two types of business: 'income substitution' businesses, set up as an alternative means of generating an income, and 'entrepreneurial' businesses, founded with a view to growing a substantial enterprise – and possibly selling it on and starting all over again.

Since entrepreneurial businesses make a crucial contribution to the development of a dynamic economy, there is much to be gained from learning as much as possible about 'entrepreneurship'.

In its purest form, 'entrepreneurship' refers to individuals who found and grow new businesses. By extension, it also refers to individuals in small or large firms who are concerned with identifying new business opportunities – often by creating new products or processes through innovation.

The University of Liverpool promotes the importance of entrepreneurship and business start-up to its own students and the wider community. It provides learning opportunities for would-be and actual entrepreneurs at both an individual and an organisational level. It engages with small and medium-sized businesses (SMEs) in the region and it helps business intermediaries to engage more effectively.

Expertise

The University has a range of capabilities associated with fostering entrepreneurship and facilitating business start-up and subsequent business growth.

Services

The University:

- Runs workshops on entrepreneurial leadership and business growth
- Offers bespoke consultancy
- Helps small, entrepreneurial firms to address issues by means of projects undertaken by Masters students.

Applications

Strengthening high-tech SMEs

The University is a member of the 'IDEAS at Daresbury' partnership, whose mission is to promote effective knowledge exchange at the interface between SMEs, large companies, universities and the public sector science base. 'IDEAS' stands for innovation, design, entrepreneurship and science.

Daresbury Science and Innovation Campus (DSIC) was set up to minimise business failure and accelerate business growth in high-tech SMEs through open innovation. The IDEAS programme fosters interaction between high-tech businesses, the public sector science base of the region's universities and Daresbury Laboratory, and organisations providing business support, such as Business Link, the NorthWest Regional Development Agency (NWDA) and UK Trade & Investment (UKTI).

IDEAS helps to evaluate and enhance the performance of start-up businesses based at DSIC and high-tech SMEs in the wider North West. It runs workshops on three critical issues: customer-focused innovation, internal resources and competencies, and networks and collaborations. Participants are then given bespoke support in the form of two or three days' academic consultancy and mentoring, intensive master classes and two to eight week projects undertaken on their behalf by Masters students.

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2.0 Gaining and Maintaining a Competitive Edge

2.1 Innovation management

Keywords: *Technology foresight; technology forecasting; creativity; invention; new product development; strategy; business model; leadership*

Overview

Research shows that successful organisations continually step outside their comfort zone, embrace creative disorder and regularly break accepted norms. In other words, they innovate.

Despite this, many organisations are reluctant to embrace innovation. It is a challenging concept: it seems to stand in direct opposition to concepts like order, stability and conformance. And it is difficult to know where to start. Companies may feel they lack the ability to identify or stimulate their creative potential, let alone act on it. Moreover, innovation is challenging to implement. It requires bold leadership – particularly if it questions conventional management wisdom or threatens established practices.

The University of Liverpool helps businesses to address three key considerations: How do you identify innovation potential? How do you initiate innovation? And how do you sustain it?

Expertise

The University's **Innovation Academy** specialises in a range of business-contingent issues relating to technological, product, service, and business model innovation. For instance:

- Where to look for sources of innovation
- When to adopt an emerging technology
- How to refresh an existing product or service range
- How to evolve from one business model to another
- What changes are required to make an organisation responsive to innovation.

Research shows that successful organisations continually step outside their comfort zone, embrace creative disorder and regularly break accepted norms. In other words, they innovate.

Services

Interactive workshops

These workshops help businesses and other organisations to overcome specific innovation challenges they may be facing and deliver long-term, transformational value. These challenges range from issues relating to innovation culture and strategy to issues arising from the proposed introduction of specific processes, products or services.

The workshops are tailored to the needs of the specific organisation. They develop a clear understanding of the organisation's business objectives. If necessary, they transform the way the organisation perceives itself and responds to competitive opportunities and threats. They generate a series of customised processes to address the issues identified, providing outputs that are relevant and immediately applicable.

Executive education

The University's executive education forums help senior managers to understand and acquire competencies required to stimulate and embed innovation within their own organisations. These one-day sessions foster fresh thinking about innovation, as well as covering proven approaches to implementation of innovation. Peer-to-peer interaction is an important feature and participants are encouraged to share their experiences of innovation management and learn from each other.

Research

Innovation Academy researchers often study business-related issues by immersing themselves in businesses confronting particular issues. The Academy also draws on a wide range of research conducted by the University itself and by third parties, addressing a broad spectrum of challenges faced by businesses. By capturing and distilling leading-edge approaches and concepts, it ensures that its clients benefit from the most up-to-date thought leadership and support.



2.2 Operations management and e-Business

Keywords: *Operations management; supply chain management; logistics; management information systems; agility*

Overview

Operations management is concerned with the processes by which inputs, in the form of materials, labour and energy, are converted into outputs, in the form of goods and services. It aims to ensure that operations are efficient – using as little resource as necessary, and effective – in that they meet customers' requirements.

The University of Liverpool's research in this area aims to help improve the operations of individual organisations and whole supply chains. The University works in close partnership with business – in particular with the manufacturing, logistics and service sectors, and with public sector organisations. Its management expertise is enhanced by the involvement of chartered engineers, enabling it to span the gap between management and technology with ease.

The University has amassed considerable expertise in improving business competitiveness through lean enterprise, agility, enhanced logistics and more effective supply chain management. It was one of the first in the UK to extend this into e-business and has a track record of devising and applying novel applications of e-Business and Internet technologies.

✚ *For further information on e-Business see section 4.0 of Digital Technologies, page 101.*

Its the **Agility and Supply Chain Management Centre** specialises in lean and agile manufacturing, bringing together experts in operations management and marketing.

✚ *For further information on agility see section 1.5 of Advanced Manufacturing, page 56*

Operations management is concerned with the processes by which inputs, in the form of materials, labour and energy, are converted into outputs, in the form of goods and services. It aims to ensure that operations are efficient – using as little resource as necessary, and effective – in that they meet customers' requirements.

Expertise

- Supply chain management, including:
 - Mass customisation and build-to-order concepts and their implications for supply chain management
 - Customer-driven supply network design
 - Lean and responsive approaches to operations and supply chain design
 - Supply network strategy development and performance measurement
 - Operations strategy development
 - Technological innovation in supply chains
 - Collaborative planning.
- Logistics, including:
 - Outsourcing/purchasing/commissioning strategies
 - Physical distribution and logistics, including third party logistics operations
 - Optimisation of schedules and routes (distribution planning) using meta-heuristics, iterative search and artificial intelligence techniques – eg. genetic algorithms and simulated annealing
 - Rail freight and its integration within wider supply chain management
 - Track and trace technologies, such as radio frequency identification (RFID), and emergent business strategies
 - The application of 'lean thinking', including tools such as value stream mapping, 5S, Kaizen.
- The development of agility within businesses and their operations to meet the challenges of turbulent market places
- The optimisation of operations – eg. scheduling, resource allocation, layout, etc
- Simulation, to help in process and supply chain design and optimisation
- Total Quality Management (TQM), continuous improvement, SPC, benchmarking, etc
- e-Business, enterprise resource planning (ERP) and management information systems; expertise spans the fundamental technology, through the construction of entire systems to understanding strategic issues
- Sustainability and resilience to resource depletion – most notably 'peak oil'.

Applications

The University's expertise has been harnessed in numerous applications – for instance:

Intermodal port management

It has devised a dynamic scheduling approach for port booking systems – assessing the priorities of booked deliveries by lorries queuing at Liverpool Container Port. It has created a prototype workflow model for integrated maritime logistics network design, to enable the port to integrate shipping operations and logistics-forwarding services with port operations control and customers' operations.

Design of automatic identification and data collection (AIDC) system for logistics supply chains

The University is developing approaches which will facilitate the optimal design of integrated tracking solutions through logistic supply chains – aligning standard functionality, technical specifications with different business contexts and interests in a logistics chain.

Resilient multi-plant networks

It is currently working on the design and prototyping of a user innovation platform capable of harnessing the collective intelligence of a supply chain network to support mass customisation opportunities.

Facilities and services

Interactive computer labs with server facilities, SAP, simulation/modelling software and other advanced software development tools.



2.3 Accounting and finance

Keywords: *Financial reporting; international accounting standards; corporate governance*

Overview

The University has extensive expertise in the areas of financial reporting, corporate governance and finance.

Expertise

Financial reporting

The University has particular expertise in the application of international financial reporting standards (IFRS) which have been implemented throughout the EU over the past few years. This is founded on research into a number of UK organisations which have adopted IFRS.

Corporate governance

The University's expertise derives from research into a number of different aspects of corporate governance. Current projects relate to companies' ownership structures and their effect on corporate value, the impact of Board characteristics on a company's performance and its risk of default, the effect of ownership structure on the likelihood of filing for bankruptcy and the design and practice of executive incentive and remuneration structures.

Finance

The University's research expertise encompasses liquidity, financial flexibility and asset prices, and mutual fund performance.

2.4 Business continuity and crisis management

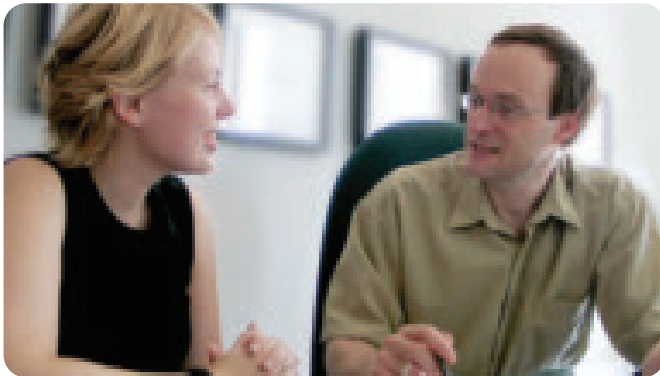
Keywords: *Planning; simulation; learning; knowledge management; resilience; BS25999; counter-terrorism*

Overview

Business continuity requires analysis and planning. It encompasses policies, guidelines, standards, and procedures implemented by an organisation to ensure that it can maintain its proper relationship with suppliers, customers and third parties like banks, regulators and auditors under normal, day-to-day operating conditions. It is the rationale behind operations like project management, system back-up, document management and so on.

Crisis management is concerned with the ways in which organisations respond to unpredictable events which threaten the organisation itself, its stakeholders and/or the public. Examples of such events include natural disasters, technology failures such as power cuts, lawsuits, rumours, strikes, fraud, maverick actions like the tainting of food products, the direct or indirect result of terrorist attacks.

The University of Liverpool has expertise in business continuity and a particularly strong track record of research into organisational preparations for and responses to crisis, and learning from the experience – drawing on disciplines as diverse as psychology, engineering and management.



Expertise

The University can provide comprehensive support to organisations concerned with structural and technical resilience and is currently developing a framework to help organisations exploit social capital more effectively as a key means of building resilience. This will complement its work on materials, building and structural resilience.

Its expertise encompasses:

- Knowledge management
- Mapping strategic strength and vulnerability
- Business continuity
- Resilient materials
- Counter terrorism
- Organisational learning and crisis.

Applications

The University has a track record of harnessing its expertise for the benefit of individual organisations. It has undertaken crisis simulations, business continuity planning and vulnerability analyses, among other projects, for clients as diverse as BP, Ernst and Young, PricewaterhouseCoopers, Emirates, RBS, Merrill Lynch, BNP Paribas, J Sainsbury and the government of Lesotho.

The institution recently completed a three-year, industry-sponsored study of business continuity practice across numerous different sectors. This yielded a rich picture of current management practice in preparing for crisis and valuable insights into what constitutes good practice, as well as a better understanding of the impact of the new business continuity standard, BS25999.

Services

- Preparing for BS25999
- Crisis auditing
- Crisis simulations
- Crisis management training.

2.5 Knowledge, learning and strategic change

Keywords: *Organisational learning practice; strategic change; knowledge management; dynamic capability*

Overview

Maintaining an organisation's competitiveness requires ongoing monitoring of internal and external forces affecting the organisation itself and its operating environment. In order to respond proactively to uncertainties inherent in the ever-changing global market place, strategies and practices must be reviewed and may need to be revised.

Knowledge and learning enable organisations to analyse their current situation and adapt their strategies and practices to help them reach their desired situation. They can also be a source of differentiation from competitors and a foundation for impactful business results.

Mobilising existing knowledge and developing the capacity to learn whilst responding dynamically are critical capabilities exhibited by leaders and organisations that are helping to shape their markets.

Expertise

The University has extensive expertise in reviewing organisational strategies and practices and harnessing knowledge and learning in support of strategic change. This has been garnered through research carried out in organisations from a wide range of sectors – for example, financial services, management consulting, biopharmaceuticals, engineering, aerospace and construction.

This research has enabled the University to acquire theoretical and practical insights which can be applied generically – providing a basis for the design and introduction of pragmatic initiatives. The institution has a track record of designing learning and knowledge management strategies, and instigating successful cultural change programmes.

Much of this work has been undertaken in collaboration with the organisations concerned. GNOSIS is a research initiative which actively engages academics, business practitioners and policy makers in the co-creation of knowledge for action. Its objective is to deliver impact through ideas that make a difference to policy, business practice and scholarship.

Services

- Collaborative research drawing on action learning principles
- Consultancy
- Coaching sessions for senior executives
- Workshops on basic/advanced principles of managing learning, knowledge and change in organisations
- Knowledge/learning/innovation audits
- Executive-in-Residence initiatives enabling senior executives to spend time in GNOSIS actively working on specific research projects and developing critical thinking skills that enhance strategic decision making.

Knowledge and learning enable organisations to analyse their current situation and adapt their strategies and practices to help them reach their desired situation. They can also be a source of differentiation from competitors and a foundation for impactful business results.



3.0 Public Sector Management

Keywords: *National government; devolved government; local government; health services; housing; partnership; innovation; policy-making; governance; accountability; diversity*

Overview

In the present climate, the challenges facing public service managers are becoming more acute. Expectations of quality remain high and there is a demand for new and innovative responses from national, regional and local public agencies alike – yet the resources supporting innovation and the maintenance of quality seem likely to diminish.

Leaders are being asked to work in new ways, with new partners, to achieve a concerted impact which is demonstrable and measurable. This means that building trust, developing shared vision and creating spaces for innovative local responses to the social, environmental and economic challenges of the coming years must lie at the heart of contemporary public sector management. This, in turn, demands a great deal more flexibility in the way we think about services and their delivery, new ways of working, and new skills.

Expertise

The University of Liverpool has a long-standing reputation in the field of public management research, education and training. This derives from the University's conviction that it can help to transform public services by working in partnership with public sector agencies – and from acting upon this conviction.

It has an excellent track record, examples include University experts working as non-executives on parliamentary services boards – with the Wales TUC, with Assembly Government-sponsored bodies in Wales, and with non-departmental public bodies in England.

University staff have also acted as expert advisors to a range of government and parliamentary authorities – advising, for example, on politicians' pay and expenses (expert advisor to the Sir Roger Jones Panel on Assembly Members' Pay and Support, Oct 2008-July 2009); on select and scrutiny committee operation; on accountability lessons between public, private and third sectors; and on coalition and minority government formation and operation.

They have also worked on projects specifically commissioned by political parties. Two such initiatives involved improving diversity profiles in their approved election candidate lists, and projects commissioned by individual politicians at both local and national levels.

The University is currently working with a number of national and local agencies to foster better policy-making, develop middle-managers, and transform services.

Facilities and services

- Short courses for managers on contemporary challenges
- Continuing Professional Development programmes
- Masters programmes aimed at graduate trainees or middle-managers
- Research and consultancy services.

Expectations of quality remain high and there is a demand for new and innovative responses from national, regional and local public agencies alike – yet the resources supporting innovation and the maintenance of quality seem likely to diminish.



4.0 Managing and Marketing Services

Keywords: *Tourism marketing/management; retail marketing/management; place marketing/management; consumer behaviour; customer experience*

Overview

Organisations offering services are found in the private, public and voluntary sectors. They may be microbusinesses or very large organisations – such as the National Health Service. Service-based organisations differ in several key ways from businesses offering products. This has led to the development of different approaches to the management of such businesses and the marketing of their offerings.

Expertise

The University's expertise in service management encompasses areas like service orientation, service innovation, 'servicescape' design, service quality and the service marketing mix. It is currently conducting research into other issues of interest to service organisations – such as the service-dominant logic of marketing and service science.

The University specialises in understanding the customer/consumer experience. It has considerable expertise in research methods ranging from conventional questionnaire surveys, focus groups and in-depth interviews to more innovative methods – including multiple auto-ethnographic accounts and customer-critic approaches, which are more appropriate for researching consumer life-worlds and experiences.

The University's **Centre for Experiential Consumption Studies** takes an interdisciplinary approach to the study of the consumer experience and consumption. Through continued support and development of existing consumer groups it conducts research into a wide range of experiential consumption topics, relevant to consumers and their quality of life, as well as clients in private, public and not-for-profit sectors.

Applications

The University has worked with numerous organisations interested in improving customer experiences. These range from small and medium-sized businesses and larger companies – such as the Mersey Partnership, The Co-operative Travel and Brand Vista – to public sector organisations including the British Library.

5.0 International Business History

Keywords: *Corporate history; longitudinal studies; strategy; structure; competitive positioning; financial composition; corporate identity; stakeholder engagement; strategic decision-making*

Overview

The University of Liverpool has considerable expertise in identifying businesses which have had a significant impact on the economy of Britain and other countries, and researching their histories. Its expertise extends from British to European, North American, Latin American, Far Eastern and African business history.

The resulting histories can have a profound impact on the way firms perceive themselves and engender a stronger sense of corporate identity. They can encourage stakeholders to identify more closely with the firm or organisation. They can explain an organisation's past strategies, structures and competitive positions and inform its understanding of its current position.

This kind of research can also inform current strategic, financial and marketing decision-making, and influence knowledge and technology transfer strategies.

Applications

The University is currently working with the Co-operative Group, whose unique story is particularly resonant in view of the current crisis in modern financial capitalism and the vicissitudes associated with orthodox economic thinking.

University historians are producing a definitive history of this important organisation, and making a range of contributions to its educational activities – including an interactive website and material for schools.

Facilities and services

- Extensive knowledge of available resources
- Archival experience
- Library databases.

Management & Enterprise

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those most relevant to Management & Enterprise include:

- **Agility and Supply Chain Management Centre**
- **Centre for Enterprise and Entrepreneurial Leadership**
- **Centre for Experiential Consumption Studies**
- **Innovation Academy**

For more information or questions, contact:

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Case Studies

Business Continuity

Business continuity is concerned with minimising the risk of crisis and developing the ability to respond to unexpected events in ways that protect customers, communities and other stakeholders by enabling organisations to continue their value-adding activities.

In an effort to protect and enhance the City of London's competitive position internationally, the Financial Services Authority (FSA) organises a regular business continuity benchmarking survey of utilities and large finance sector organisations. Now, following the recent launch of the Business Continuity Standards (BS25999), business continuity practice will diffuse across all business sectors.

Research being undertaken by the University of Liverpool should facilitate evidence-based development of business continuity practice in years to come. It is being sponsored by a consortium of organisations, including the Cabinet Office, the BBC, ICM, BP and the Royal Bank of Scotland.

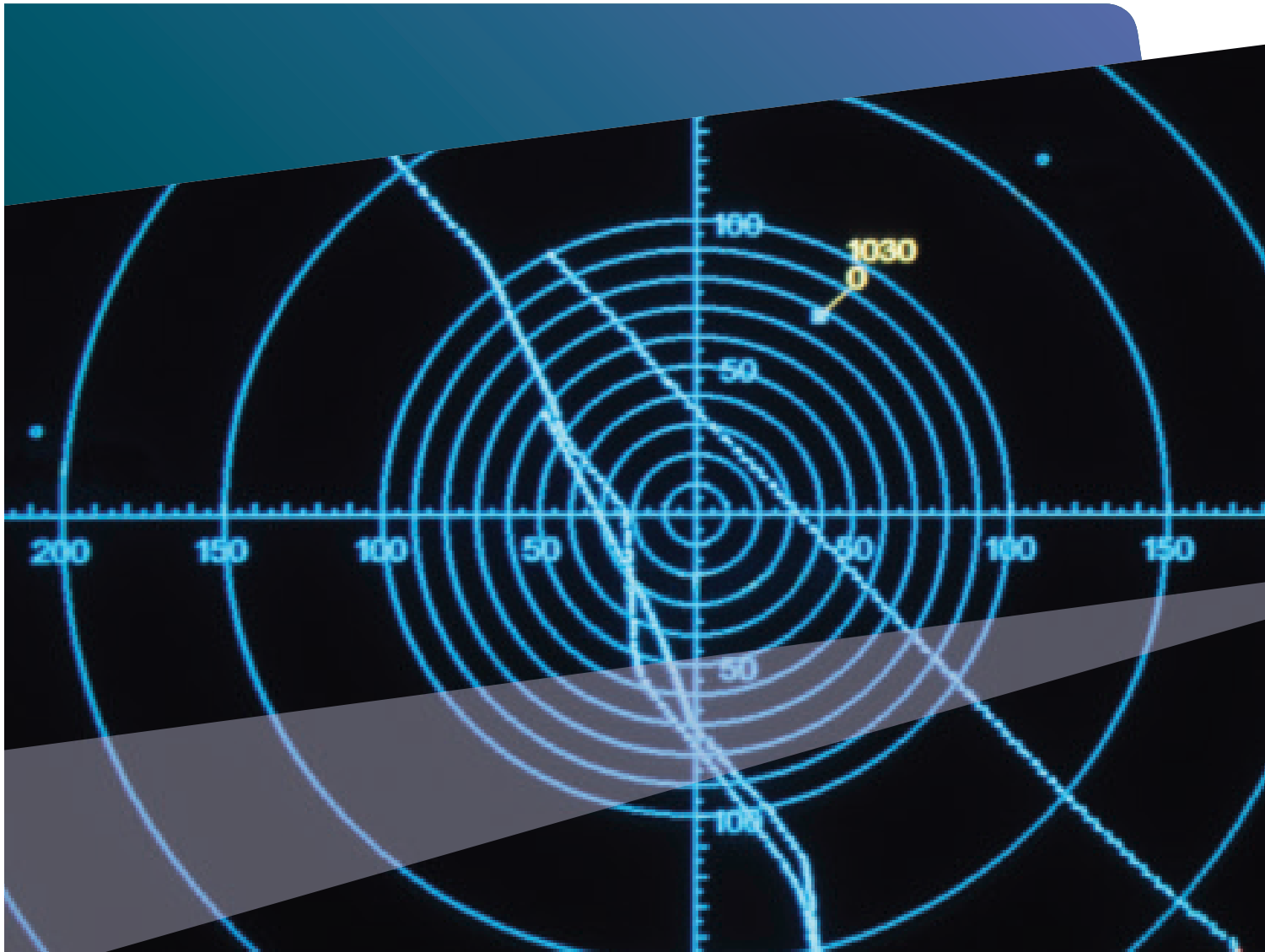
Preliminary findings from this three-year study challenge the FSA's focus on the protection of organisations' facilities and IT systems. They suggest that, as a first step, organisations should identify how they create value, rather than focusing immediately on facilities and IT.

"This project illustrates the real value of research; bringing together University expertise, private and public sector know-how, with Government, working together to develop not only business resilience but challenging in a constructive way, the orthodoxy around how we prepare for and respond to crises."

Professor Dominic Elliott
University of Liverpool Management School



Safety & Security



Overview

Breadth of Expertise

- Measure development/validation
- Assessment/benchmarking
- Prediction
- Improvement
- Debriefing
- Simulation-based training
- Detection
- Sustainability

Focus of Expertise

- Employees
- Organisations
- Crowds/the public
- Systems/processes
- Software
- Food
- Materials
- Pharmaceuticals

Relevant Disciplines

- Psychology/social psychology
- Management
- Mathematics/computing
- Physics
- Climate science
- Crop science
- Physics
- Infectious diseases/pests
- Pharmacogenetics

Application Areas

- Agriculture
- Air travel
- Construction
- Financial services
- Fisheries
- Food
- Football
- Logistics
- National security
- Oil & gas
- Petrochemical
- Pharmaceutical
- Police
- Power generation
- Steel

Key Capabilities

1.0 Organisational Safety and Risk

- 1.1 Industrial safety
- 1.2 Operational risk
- 1.3 Occupational health and safety

2.0 Public Safety

- 2.1 Managing crowds
- 2.2 Managing critical and major incidents

3.0 Security

- 3.1 Homeland security
- 3.2 Food security

Safety is concerned with identifying conditions in public spaces, infrastructure and transport, in workplaces and other institutions, in our properties, possessions and tools, and in our social, medical, consumer and business dealings. If not addressed, it could inadvertently lead to physical, occupational, social, financial, political, emotional, psychological, spiritual or educational harm or damage as a result of poor design, inappropriate strategies, error, accident or failure.

'Security' is concerned with preventing or minimising the risk of deliberate attempts – by terrorists, for example – to threaten people, structures and processes which should otherwise be safe. The University of Liverpool is active in both arenas.

1.0 Organisational Safety and Risk

Traditionally safety and risk culture have been associated with industry and major hazard sites. There is a long history of focusing on accidents and injuries in industry, going back to the industrial revolution. At its most basic level, this relates to direct physical damage to workers from the machinery being operated. As we have become more aware, occupational health has gained attention; this addresses some of the less direct consequences of poor work environments which may lead to stress and, from that, to ill health. It is only recently that concern with such issues has been extended to encompass the implications for more general performance – for the health of the organisation itself.

Central to this is the organisation's operational risk culture. Operational risk is the risk that arises from a variety of activities within an organisation. It is a consequence of its processes, procedures and the way in which these are applied or violated. This is different from, for example, market risk, which is a result of external market forces that are part of everyday business.

Although industrial safety and physical injury may seem far removed from a major financial loss within a bank, evidence suggests that the fundamental processes are the same across the different sectors and outcomes. University of Liverpool research shows that similar cultural and attitudinal factors play a role in both industrial safety and loss in the financial sector.

1.1 Industrial safety

Keywords: *Accident rates; plateau; safety culture; benchmarking; safety attitudes; safety performance; safety improvement; lost time reduction*

Overview

After major disasters, media attention often focuses on the safety of the hardware and the competence of the operators – for instance, the signals, the track and the driver, in the case of a rail crash. However, the root of the problem could lie in the organisation's safety culture.

In the 1970s and early 1980s, there was a strong emphasis on improving industrial safety through changes to hardware and working practices. This led to accident rates falling significantly – but many organisations found that their accident rates reached a plateau, below which they were unable to go. Inquiries often revealed that insufficient attention had been paid to human factors like attitudes to safety, and the climate and culture of the organisation.

The University of Liverpool has long-established expertise in bench-marking individual companies' safety attitudes, developing bespoke programmes of safety improvement initiatives, and re-assessing safety attitudes following their implementation.

Expertise

In the 1990s, University psychologists developed a unique measure of safety attitudes and demonstrated a correlation between safety attitudes and safety performance in a major steel manufacturer. The Health & Safety Executive contracted the University to develop more generic measures and to validate them in a wide range of companies.

This led to the development of a standardised 'safety attitude questionnaire' which can be used throughout industry, and can be adapted to meet idiosyncratic needs of particular industries or companies.

The safety attitude questionnaire has been translated into numerous languages including German, French, Dutch, Spanish, Portuguese, Greek and Chinese. Research in other countries has consistently demonstrated a clear correlation between safety performance and safety attitude, indicating that the measure developed has cross-cultural validity.

Applications

The University originally devised and tested its early measure of safety attitudes in collaboration with British Steel. When the company implemented the safety initiatives recommended by the University, the number of 'lost time' accidents reduced to zero in several hazardous plants. British Steel subsequently embedded these safety initiatives in its total quality performance programme.

Since then the University has worked with well over 100 companies and industrial sites in the UK and mainland Europe – principally in the steel, chemical, oil and power generation industries, and, more recently, the construction industry. Its clients include BP, Calor, Arbed, Nuclear Electric, Scottish Power and Scottish Hydro-Electric.



1.2 Operational risk

Keywords: *Financial services; risk culture; benchmarking; risk attitudes; risk performance; correlation; predictive measures*

Overview

In 2008, Lehman Brothers filed for bankruptcy citing debts of \$613 billion, while RBS, Citigroup and Wells Fargo lost \$59.3 billion, \$53 billion and \$47.8 billion respectively and were saved from bankruptcy by injections of cash from tax payers. Directly or indirectly, these catastrophic losses were a result of sub-prime mortgage lending.

On a less eye-watering scale, several banks have lost more than \$1 billion due to single traders taking advantage of inadequate controls. Many more have sustained relatively trivial losses which, when combined, add up to a non-trivial loss. These sums may not rock a bank to its foundations, but they ramp up its risk profile, particularly if the losses result from operational weaknesses.

Operations involve a complex and interdependent mix of people, systems and processes, and responsibility for minimising operational risk often involves several different departments. This makes operational risk a cultural as well as a managerial issue.

The University of Liverpool was ahead of the banking crisis in profiling operational risk in financial service companies, in the same way that industrial companies are profiled in respect of their safety culture. The measures it developed have demonstrated the relationship between operational risk culture and various areas of finance including product selling, trading and general banking.

Expertise

The University was the first to develop and use a set of empirically-based organisational risk culture measures which it devised, tested and refined with the support of the Financial Services Authority (FSA), the Institute of Internal Auditors (IIA) and six financial services companies. These measures provided clear evidence that certain risk culture factors are capable of predicting a financial organisation's propensity for errors which could lead to significant financial losses.

There were significant differences between the six organisations on almost all the factors measured. There was a clear correlation between the level of losses sustained and the nature of the organisation's risk culture. The less well a company performed against four particular measures, the greater were their losses.

Applications

The banking crisis underlines the need for financial institutions to gain much better insights into their operational risk culture. The University is keen to apply its expertise for the benefit of this sector and the economy as a whole.

1.3 Occupational health and safety

Keywords: *Accidents; behaviour modification; health; risk assessment; stress*

Overview

Occupational health and safety (OHS) is concerned with the management of workplace risk through better understanding and management of employee behaviour. In broad terms, OHS focuses on the cultural and attitudinal factors that lead to risk-taking behaviours (for example, short-cuts) and stress – and from these, ill-health. This focus is based on a body of evidence showing that by addressing human and cultural factors it is possible to reduce accidents and stress-related ill health beyond that achieved by improving hardware and working practices alone.

The University of Liverpool has a track record of research carried out in collaboration with industry and other sectors exposed to some form of risk. These collaborations have informed the development and administration of bespoke applications designed to identify risk and introduce appropriate improvement initiatives.

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Expertise

The University's collaboration with the UK's Health and Safety Executive initiated the development of a proven tool for identifying an organisation's risk of accidents by measuring employees' attitudes towards safety.

The University also has growing expertise in the psychological processes underlying OHS management – derived from work on the importance of trust (carried out in the oil and gas industry) and work on the role of employees' motivation (focusing particularly on the construction industry).

It is currently researching ways to promote active safety engagement among supervisors with support from the Institution of Occupational Safety and Health. This understanding is vital for the promotion of an effective management system that promotes healthier and safer employees.

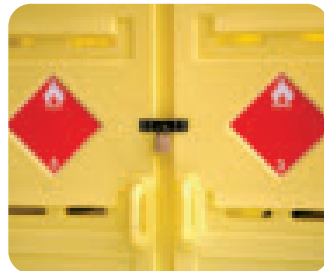
Services

- Company-wide safety climate surveys
- Focus groups on safety/health related issues with the full range of occupational groups
- Safety interventions
- Short-term, solution-driven research.

Applications

The tool developed by the University to measure employees' safety attitudes has been used in a number of UK and European industrial contexts to benchmark safety and to form the basis of strategic interventions. Follow-up surveys and monitoring have shown significant improvements in safety performance.

Interventions have been carried out with major national and international utilities companies, including power generation and distribution; heavy industry in a number of European countries; the petrol-chemical industry industry. The broad but detailed foundation provided by the safety attitude measure has been important in ensuring the success of the University's interventions.



2.0 Public Safety

2.1 Managing crowds

Keywords: *Individuals; crowds; crowd psychology; public order policing; events; violence; escalation; de-escalation; overwhelming force; indiscriminate force; low-profile policing*

Overview

'Crowd' is a neutral term used to describe a lot of individuals going about their business in the same area – commuting perhaps, or shopping – as well as groups of people with a common purpose, like tennis fans watching the big screen outside Wimbledon. However, crowds can effect dramatic social change, by-passing established processes – as in the French Revolution and more recently the 'Orange Revolution' in Ukraine in 2004-05. Crowds forming for peaceful purposes can change character, turning demonstrations into riots – like the poll-tax protests in London in 1990.

Why does the psychology of a crowd sometimes differ from that of the individuals forming the crowd? The most persuasive theorist was Gustave Le Bon, who pathologised crowds, arguing that they drove people to abandon personal responsibility, surrender to contagious emotions and carry out irrational actions. His ideas attracted the interest of Hitler and Mussolini, and influenced policing methods around the world.

Today we know that if police forces adopt high-profile policing methods based on Le Bon's theories, they can inadvertently contribute to the process through which collective violence emerges in crowds.

The University of Liverpool has played a key role in obtaining empirical evidence showing that indiscriminate use of overwhelming force is counter-productive, and that crowds respond most positively to low-profile policing. The institution is now one of the world's leading centres of scientific expertise on crowd psychology and public order policing, and has particular expertise in crowd management approaches in relation to football matches with an international dimension.

Why does the psychology of a crowd sometimes differ from that of the individuals forming the crowd?

Expertise

The University's expertise is derived primarily from gathering data on the development of riots at major football tournaments like the European Championships and the World Cup. This encompasses structured, quantitative data, recorded in real time in the field, and qualitative data gathered from the police and fans.

After observing events at dozens of international matches, researchers found that the risk posed by crowd events is dynamic: it moves along a continuum from low to high – and sometimes back again. This movement is determined by group interaction, and this can be managed more – or less – effectively by different forms of police deployment.

Thanks to the University's research, European police forces now have a solid scientific basis for accepting that the nature of their own interactions with crowds – like groups of football supporters – exerts a strong influence on crowd behaviour and on the outcome of initial disturbances.



Applications

Consultancy

The University was a leading consultant to the Public Security Police in Portugal (PSP) during its preparations for the 2004 European Football Championships.

The University has also worked with a variety of other police, governmental, football and fan organisations, including the Council of the European Union, CEPOL (the European Police College), the UK Home Office, the Associations of Chief Police Officers in England, Wales & Scotland, the United Kingdom Football Policing Unit, Police Academies of the Netherlands, Portugal, Scotland and Sweden, the New South Wales Police in Australia, UEFA, FIFA's Daniel Nivel Foundation, and the Football Supporters Federation.

The University has also provided consultancy to Her Majesty's Inspectorate of the Constabulary in its inquiry of public order policing following the G20 Demonstrations in London in 2009.

Handbooks and training

In 2005, the University's research findings and conclusions were incorporated into the European Union Handbook on International Police Cooperation and Measures to Prevent and Control Violence in the area of football related violence.

The University played a major role in developing a framework for a pan-European training programme for police personnel, funded by the European Commission. This involves a formal partnership between 29 European countries at the level of Interior Ministry or National Police Authority.

Drawing upon its expertise, the University offers a professional development course in major event management that is relevant for those dealing with large scale crowd events.

2.2 Managing critical and major incidents

Keywords: *Natural disasters; accidents; terrorist attacks; criminal behaviour; pandemic; operational practice; retrospective debriefing; prospective assessment; simulation-based-training; fidelity; immersion; resilience*

Overview

Natural disasters on the scale of Hurricane Katrina and the Indian Ocean tsunami are critical incidents with few parallels, but small-scale incidents can also present significant challenges. Even the murder of a single individual, such as the former Russian security agent Alexander Litvinenko, can have significant international repercussions. Decisions made by agencies coordinating the response can have a beneficial impact on the lives of individuals, families and communities involved – or a shattering impact.

Although the quality of military decision-making has benefited from independent analysis for some years, until recently there was little research on police decision-making. This is no longer the case, thanks to the University of Liverpool, which has focused its attention on the management of critical and major incidents.

The University's research in this area is guided by practitioners' needs. Its outputs have both operational and strategic value. Its analyses have helped to shape developments in critical incident management by highlighting best operational practice and advising on methods to enhance decision-making skills and other competencies. It has helped to build future resilience in areas as diverse as counter-terrorism, rape and murder investigations, rescue and recovery following disasters for a wide range of public sector agencies at levels ranging from local (for example, individual police forces) to national (such as the Home Office) and international (including the US Department for Homeland Security).

Natural disasters on the scale of Hurricane Katrina and the Indian Ocean tsunami are critical incidents with few parallels, but small-scale incidents can also present significant challenges.

The University's expertise is derived primarily from the work of its specialist **Centre for Critical and Major Incident Psychology (CAMI)**. This was founded on two key principles: pragmatic research which has real world value, enabling CAMI to provide the scientific evidence required to help governments, the public sector and industry to become more agile and responsive in enhancing public safety, and training, which CAMI provides to professionals from police services and other agencies.

Knowledge exchange is a central tenet of CAMI's work. In the past five years it has contributed to the training of more than 800 professionals from police services and other agencies and gathered (as data) the experiences of over 4,000. Through CAMI, the University has been able to establish the only dedicated postgraduate course within a Russell Group university aimed directly at a student cohort of serving officers, with graduates ranking from Detective Sergeant to Chief Superintendent.

For further information see 'specialist centres, facilities & laboratories' on page 142.

Expertise

Much of the University's expertise has been gained through the exploitation of two particular technologies devised at the behest of Britain's Association of Chief Police Officers – a debriefing e-focus group tool known as '10kV' and a simulation-based training system called 'Hydra'.

10kV

10kV enables people who were involved in coordinating a critical incident to discuss it in-depth, in a structured way – and, above all, anonymously. Its name reflects the fact that co-ordinating a critical incident can feel like being hit by a significant voltage.

Launched in 1999, 10kV has been deployed to capture contemporaneous records of the experiences of professionals involved in the most high profile policing incidents of the last decade – for example, the Soham murders, the explosion at the Buncefield oil depot, the Ipswich prostitute murders, the bombs detonated in London in July 2005, the poisoning of Alexander Litvinenko, hostage negotiations in Iraq, a hijack in Athens and the Indian Ocean tsunami. It has also been used prospectively to assess security preparations for the 2012 Olympics.

Hydra

Early involvement in Hydra has helped to make the University of Liverpool the nonpareil for expertise in simulation based training (SBT). SBT scenarios range from terrorist attack to weather-related incidents, such as climate change floods or a tsunami, and disease pandemics, as well as threats to critical infrastructure such as grid failure. All threaten public safety; all involve high stakes and significant physical, financial and emotional risk. Hydra-based SBT has been delivered to practitioners from a range of agencies in the UK and overseas, including Singapore, US, China, Australia, Canada.

Some incidents happen only once in a career, so SBT is an indispensable means of developing expertise. The University is at the forefront of research contributing to public policy and training in this area. The emerging picture reveals that many agencies still train for emergency preparedness by relying on table-top exercises with inadequate fidelity and little evaluation of their pedagogical value. In light of this, the University is conducting ongoing research into immersion and enhancing psychological fidelity in SBT.

Other applications

In addition to delivering SBT and facilitating debriefs of front-line operations, the University makes significant contributions to public policy. For instance, it acts as an advisor to UK police forces on suspect interviewing, on the use and distribution of controlled drugs, and the development of policy on the policing of illegal drug use, and to the fire service on patterns of offender behaviour in relation to arson.

An ongoing counter-terrorism project is examining the causes of radicalisation among vulnerable groups, for instance young people. This will inform the development of a tool to help practitioners identify signs of vulnerability at the earliest stages and intervention strategies to inhibit further radicalisation.

Facilities

- Hydra suite – the only Hydra simulation training system in the world to be installed in a university
- 10kV debrief suite – only permanent installation in the world
- The Henri Tajfel Social Identity Laboratory – incorporating digital recording and editing suites designed to facilitate the study of small group and inter-group interaction.

Services

- SBT advice and design
- Critical incident training
- Investigative advice and training
- Suspect interviewing advice.



3.0 Security

3.1 Homeland security

Keywords: *Radioactive materials; gamma radiation detection; charge collection in semiconductor devices; pulse shape analysis techniques; explosives; rapid luggage screening; neutron bombardment; elemental composition*

Overview

The destruction of two passenger planes in the 1980s by bombs hidden in hold-luggage introduced the world to a new and deadly terrorist threat. Airport security has tightened considerably, but the authorities lack some of the tools needed to do their work efficiently and effectively – for instance, a commercially viable way of identifying explosives in luggage without the need to investigate by hand.

Nuclear terrorism is another major concern. It is believed that Alexander Litvinenko was poisoned by a radioactive isotope, polonium-210, which was almost certainly smuggled into the UK. Radioactive materials could also wreak havoc on a much larger scale if they were used to make 'dirty bombs'. Their existence alone could instil fear and panic in target populations because of the threat of radiation poisoning. If they were actually deployed, the immediate area would be contaminated for some time, impeding clear-up operations, disrupting households and damaging the economy.

Radioactive materials emit gamma rays, and explosives can be induced to emit gamma rays – so gamma ray detection offers a means of protecting air travellers and communities.

Expertise

The University has particular expertise in the development of the technology needed for gamma ray detection, gained through its nuclear physics research. Its expertise encompasses a wide range of radiation detector technologies, in particular using sensors that have a position-sensitive readout.

It has one of only three laboratories in the world which can characterise position-sensitive semiconductor detectors (including germanium and cadmium zinc telluride) that allow gamma-ray interaction positions to be determined to millimetre accuracy with the aid of pulse shape analysis.

✚ *For further applications of gamma radiation, see section 1.3 of Digital Technologies, page 91.*

Applications

This expertise has already been harnessed in the development of novel devices.

Portable gamma ray spectrometer

Since a number of the isotopes that are of interest in relation to homeland security are gamma ray emitters, they can be identified through the spectroscopic measurement of the gamma rays they discharge. A spectroscopic detector that can also provide an image of the source, indicating its size and distribution, for example, would be invaluable in detecting the illicit movement of radioactive material.

The University has co-developed a portable gamma ray spectrometer with radiation detectors made from cadmium zinc telluride (CZT), which can function at ambient temperatures. CZT's spectral response was enhanced using charge correction algorithms informed by pulse shape analysis techniques developed to track the movement of gamma ray interactions through germanium detectors with millimetre precision. This system will produce spectroscopic images that can both determine the isotopes present and their location. This work is being carried out in collaboration with Centronic, Corus Northern Engineering and John Caunt Scientific Ltd. A demonstrator system is close to completion and will produce spectroscopic images of any gamma ray-emitting isotope. If this proves successful, these companies will consider commercialisation.

The University is also working with BAE Systems on the development of a robust gamma ray spectrometer capable of being deployed in hostile working environments, where additional care needs to be taken in understanding the sensor performance in the particular working environment.

The University has particular expertise in the development of the technology needed for gamma ray detection, gained through its nuclear physics research. Its expertise encompasses a wide range of radiation detector technologies, in particular using sensors that have a position-sensitive readout.

Detecting the 'atomic fingerprint' of explosives

Airports urgently need a commercially viable way of rapidly identifying explosives in luggage, without the need to investigate by hand. The X-ray technology currently used to screen hold luggage is chemically blind; it can identify organic substances but cannot unambiguously discriminate between harmless substances such as cheese and potentially harmful ones, like Semtex.

In principle, technology based on neutron bombardment would overcome this problem by identifying the elemental composition of items packed in hold luggage. These could then be compared to a database of 90,000 chemicals, only two of which have the same composition as explosives.

The basic research required to translate this idea into viable technology was carried out by four universities, led by the University of Liverpool. A prototype is nearing completion and will soon be tested using real explosives. The project was undertaken in collaboration with industry partners like John Caunt Scientific Ltd and BAE Systems, with the Home Office Scientific Development Branch, which advised on security policies, and with Manchester Airport plc, which advised on the airport environment.



3.2 Food security

Keywords: *Population growth; availability; quality; access; climate change; sustainability; engineering; resilience*

Overview

There is growing international recognition that the convergence of several different trends – most notably the world's ever-increasing population, growing shortages of natural resources and climate change – is likely to threaten global food security within a single generation, creating what the Government's Chief Scientist, Professor Sir John Beddington, describes as 'a perfect storm by 2030'.

'Food security' – defined as physical and economic access to food for all people at all times to meet dietary needs and food preferences – encapsulates a wide range of issues and concerns. Supply is one such example, encompassing subsidiary issues like volume, provenance and diversity and resilience in the face of disruptions to the production and processing of raw food materials. Access is another, due to concerns about transport and distribution as well as food safety along the supply chain. Others include affordability and the related issue of poverty, sustainability in food production, including cropping and rearing practices, food quality and nutrition and impacts on health – and the related issue of consumer confidence.

Addressing the future global and national challenges of food security requires skills from many different disciplines and collaborations across disciplinary boundaries. The University of Liverpool has relevant expertise in many relevant disciplines, ranging right across the institution from the health and life sciences to science and engineering and the social sciences.

Expertise

The University's expertise encompasses:

- Crop science and plant biotechnology
- Nutrient cycling
- Insect pest management and infectious diseases
- Marine and fisheries resources and management
- Restoring degraded environments
- The impact of climate change on health, water resources and food production
- Food-borne diseases
- Food security and livestock
- Carbon footprinting and farming sustainability
- Strategic supply chain management.

Safety & Security

To identify and capitalise on synergistic and complementary capabilities within the institution, the University has recently established a 'virtual' food security forum. This is fostering joined-up thinking and an integrated approach to tackling the challenges posed by threats to food security, taking account of priorities set by governments and their agencies, NGOs, international agencies – and by business.

Network

The forum runs a network to provide a means of exchanging knowledge and ideas amongst organisations – exploring the potential for innovative collaborations and helping to shape and gain support for new initiatives. E-resources will be available via a dedicated website. Membership of this network is open to all individuals and organisations from the public, voluntary and private sectors

The network will offer:

- A series of bimonthly seminars, presented by experts from the University and the wider world
- Think-tank sessions to anticipate and shape the future direction of research
- A channel for public engagement in food security policy, science and technology.

The seminars will be organised around interdisciplinary themes relating to food security – for instance, genomic initiatives in crop science; livestock health; globalisation of food supply; the impacts of climate change on marine and terrestrial food production; natural resource management, carbon footprint, food and health; and poverty alleviation.

Summaries of 'think-tank' discussions will be circulated to network members, while seminars will be video-recorded and published on the website.

In the immediate future, the network is focusing on:

- The future and impact of biofuels
- Food safety and animal zoonoses
- Genome sequencing and allele mining for new crop cultivars and functional foods
- Assessing ecosystem services, and their role in food production and poverty alleviation
- Using down-scaled global climate model outputs to regional scenarios in support of climate change adaptation for food security
- Managing food supply chains in a changing globalised world.

Specialist Centres, Facilities and Laboratories

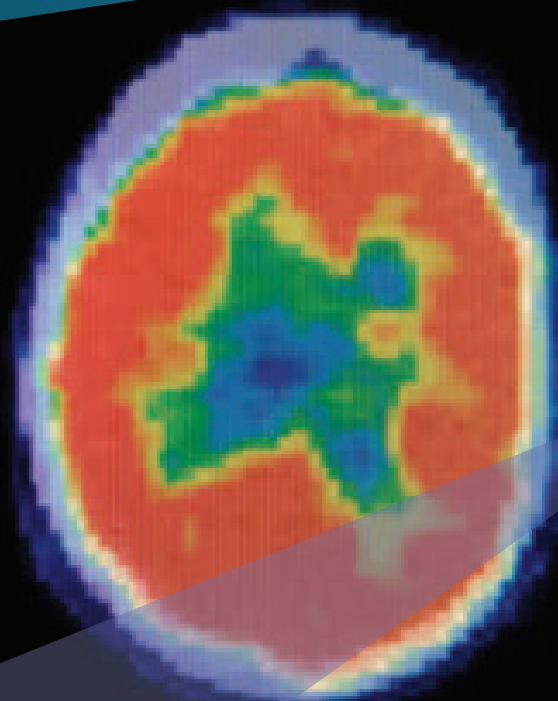
Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those which exploit and/or contribute to the development of safety & security include:

- **Centre for Critical & Major Incident Psychology (CAMI)**
- **Centre for Drug Safety Science**

For more information or questions, contact:

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Case Studies

Managing Crowds

Gangs of marauding football hooligans battling with riot police might seem like an inevitable feature of major international football competitions, but that's a misconception. By treating football violence as a crowd management problem, social psychologists from the University of Liverpool have helped to identify and develop policing techniques which can minimise the impact of hooligans on large 'tribal' crowds.

These techniques were put to the test at the 2004 European Championships. Two years earlier, the host nation's Public Security Police (PSP) had invited Liverpool researchers and their Dutch collaborators to observe policing in Oporto and advise how it might be improved. The researchers presented their findings and recommendations to all of Portugal's police commanders in 2003.

At the start of 2004, the PSP developed its policing strategy for Euro2004 – opting for low-profile policing whilst maintaining a capacity for rapid intervention, but calling on this only when an increase in risk warranted it. This strategy was tested at three potentially high-risk pre-Euro 2004 matches, where it was possible to compare the impact of the national republic guard's traditional high-profile policing methods with the PSP's new low-profile approach. The fans' behaviour vindicated the PSP's low-profile approach and reinforced earlier findings concerning the negative impact of routinely employing traditional high-profile policing irrespective of risk levels.

As a result of this research, European police forces have a solid scientific basis for accepting that the nature of their own interactions with groups of football supporters exerts a strong influence on crowd behaviour and on the outcome of initial disturbances. In 2005, these scientific findings were encapsulated in addendums to the European Union Handbook on International Police Cooperation and Measures to Prevent & Control Violence & Disturbances in Connection with Football Matches with an International Dimension.



Cities, Culture & Regeneration



Overview

Breadth of Expertise

- Theory
- Evidence base
- Evaluation/impact assessment
- Strategic/geodemographic analysis
- Profiling
- Design & modelling
- Exhibitions/curation
- Conservation
- Translation & cultural awareness
- Partnership

Focus of Expertise

- Urban space/landscapes
- Urban renewal
- Cultural policy
- Creativity
- Communities
- Inclusion/exclusion
- Cultural industries
- European Capital of Culture
- Literacy/reading
- Sports

Disciplines

- Economics
- Human
- Geography
- Planning
- Sociology & social policy
- History
- Architecture
- Film studies
- Music
- Archive studies
- Modern languages

Application Areas

- Architecture
- Businesses
- Cultural practitioners
- Economic development
- Heritage
- NHS Trusts/hospitals
- Libraries
- Museums & galleries
- Policy-makers
- Sports bodies
- Trade union & members
- Visual arts

Key Capabilities

1.0 Research

- 1.1 Regeneration potential of cultural and creative industries
- 1.2 Social cohesion
- 1.3 Culture research
- 1.4 Architecture and the visual arts
- 1.5 History & heritage management
- 1.6 Film and media
- 1.7 Music

2.0 Initiatives

- 2.1 Community and workplace engagement
- 2.2 Active engagement in culture

3.0 Consultancy and Outreach

- 3.1 Sports
- 3.2 Languages and culture

Many major cities are seeking to reinvent themselves in the face of profound social, technological and economic change. Cultural provision, in particular, has come to play an increasingly important role in underpinning urban regeneration.

The University is a key player in researching the relationships between cultural policy, urban renewal, regeneration, inclusion and exclusion, as well as the governance of urban space, urban communities, order and disorder. Much of this work has had a particular, though not exclusive, focus on Liverpool and its region, while emerging research has a broader focus on European cultural policy interventions.

Following the success of Liverpool's year as European Capital of Culture in 2008, the University has built up further knowledge and expertise in relation to the arts and culture, and has been commissioned to assess the wider legacy of the lead-up to 2008 and the year itself.

The University is actively engaged in the cultural life and wellbeing of the city, and has pioneered a number of innovative initiatives, some of which are described in this section.

Its well-established relationships with the city's many quality cultural institutions help to ensure that the cultural landscape in Liverpool is interconnected, enabling the city to build upon its unique concentration of cultural assets as it assumes a leading role in shaping the future award of British Capital of Culture.

1.0 Research

1.1 Regeneration potential of cultural and creative industries

Keywords: *Evidence base; interdisciplinary research; conceptual rigour; empirical studies; policy-makers; communities; creativity*

As part of the broader 'knowledge economy', cultural and creative industries such as media, advertising, architecture, art, music, and software production are increasingly presented as a coherent growth sector in urban economies. Their activities have become a central plank of the place-marketing strategies that those governing urban regeneration use to attract tourists and other inward investment.

However, despite the frequency with which politically and economically-motivated claims are made for the centrality of such cultural production to urban regeneration in the UK, the evidence base supporting them is uneven at best. Similarly, the rapid changes associated with urban regeneration – specifically the expansion of residential and retail space – can disrupt the very environs that give rise to the creativity crucial to the cultural industries.

The University of Liverpool studies the challenges and opportunities that regeneration presents for urban policy-makers, for those who are active in cultural industries, and for communities affected by the rapid changes which can accompany urban regeneration. Its research is interdisciplinary and conceptually rigorous – informed by a range of theories relating to fundamental shifts in urban cultural governance and the urban economy. It seeks to assess the social, economic and political relationships associated with urban regeneration, and crucially, it includes critical scrutiny of the role of community participation in the process.

The results of this research enable the University to contribute in an informed way to debates about the nature of urban regeneration and local economic change. It engages with policy-makers, community activists and academic researchers in relation to cultural policy in the city, particularly in the context of Liverpool, European Capital of Culture 2008 and its legacy.

As part of the broader 'knowledge economy', cultural and creative industries such as media, advertising, architecture, art, music, and software production are increasingly presented as a coherent growth sector in urban economies.

Expertise

- Interdisciplinary expertise in the study of the contemporary city, drawing on insights from sociology, human geography, planning, political science, and economics
- Conceptually-grounded empirical enquiry embedded in current academic research debates, which connects with concerns of policy-makers
- Postgraduate taught programmes grounded in social research methodologies that equip students with the capacity to assess claims made for regeneration relative to existing evidence.



1.2 Social cohesion

Keywords: *Social policy; sociology; political science; social exclusion; social inclusion*

Social cohesion is a term used in social policy, sociology and political science to describe the 'glue' that brings people together in society, covering many different kinds of social phenomena. It has become an important theme in British social policy, in which the University of Liverpool plays an eminent role through its **Merseyside Social Inclusion Observatory (MSIO)**.

The Observatory brings together a unique partnership of organisations from the public, private, voluntary and community sectors to identify what leads to social exclusion and effective routes out of it. It is the only centre of its type in the UK as it has an explicit focus on social inclusion and broader economic issues, as well as primarily engaging in both qualitative and quantitative research.

Merseyside Social Inclusion Observatory focuses on policy-relevant research, effective community engagement and best practice, particularly through the development of linkages with regeneration-focused policies, programmes and activities.

It works closely with the Government Office for the North West (GONW), the Northwest Regional Development Agency (NWDA), the Learning and Skills Council, local authorities and other voluntary and community sector bodies.



Activities

Key activities at a pan-Merseyside level include:

- **Geodemographic analysis:** the use of small area data to construct national classifications of neighbourhoods based on their social, economic and demographic characteristics and their application within urban policy (in terms of the 'efficiency' and 'completeness' of targeted policies)
- **Breaking the intergenerational cycle:** an examination of intergenerational poverty and disadvantage with a particular focus on factors which provide early signals of future disadvantage, especially amongst young NEETs (those Not in Employment, Education or Training)
- **The role of community planning** in responding to issues of social exclusion and implications for national and international approaches to the governance of local neighbourhoods
- **City regionalism, urban regeneration and social inclusion:** a focus on developing appropriate governance and delivery frameworks conducive to improving the economic and social conditions of the population across Greater Merseyside and beyond
- **Social exclusion and local government reorganisation:** analysis of the impacts of local government reorganisation in the UK, and implications for the delivery of regeneration policies and programmes
- **Black and minority ethnic (BME) communities:** using detailed data to produce a profile of the BME population, including housing, labour market, education, crime, health and travel to work and learning patterns, as well as the effectiveness of new governance mechanisms, such as Local Area Agreements (LAAs) in responding to BME needs
- **Consideration of the impact of economic migrant workers,** including their relative contribution to the local, regional and national economy, their impact within particular neighbourhoods and their contribution and demands upon particular service areas such as housing, education, and health
- **Strategic analysis or assessment of the impact of specific policy initiatives and programmes** such as the Housing Market Renewal Initiative (HMRI)
- **Entrepreneurship, deprivation and worklessness:** an examination of causal linkages and the effectiveness of policy responses
- **Neighbourhood profiling:** identifying a prevention strategy for social exclusion and deprivation, by analysing the root causes of deprivation, and identifying actions needed and resources available to organisations across Greater Merseyside.

Cities, Culture & Regeneration

1.3 Culture research

Keywords: *Impact assessment; culture-led regeneration; cultural policy; major event; media representation of city/urban environments; local identity; sense of place*

The arts, culture and creative practice could be viewed as 'soft' options – add-on luxuries which have little relevance to society; their value could be determined solely in terms of crude economic measurements such as employment and tourism. Equally, they could be valued in terms of their contribution to quality of life and national health, and their enhancement of a modern creative education.

In an increasingly tough economic environment, evaluating arts, culture and creative practice requires a robust methodology. The development and deployment of suitable methodologies is one of the University of Liverpool's strengths. It is one strand of its broad-ranging expertise – gained through a long history of interdisciplinary research and successful collaborative relationships with practitioners, policy-makers and professional institutes.

Expertise

The University's expertise encompasses:

- Investigating the role of arts, culture and creative practice in the contemporary world from a range of critical perspectives across disciplines
- Leading the development of a national evidence base for culture
- Assessing the impact of cultural policy interventions on economic growth
- Measuring the vibrancy and sustainability of the city's cultural system
- Understanding cultural engagement, access and participation
- Creating new tools for assessing the impact of cultural activity on quality of life
- Assessing the impact of large scale events on city image and self-perception
- Assessing the impact of culture-led regeneration across economic, social, physical and cultural dimensions
- Strategic thinking and partnership development in culture-led regeneration: the philosophy and management process.

Applications

Impacts 08

Impacts 08 is a longitudinal research programme set up to evaluate the economic, social and cultural impact of the European Capital of Culture (ECOC). Team members draw on academic research strengths but pride themselves on generating data and reflections of direct use in policy development, implementation and review.

The research programme offers an innovative, holistic approach to measuring the impacts of culture-led regeneration. It goes beyond the usual quantitative indicators - taking into account the lived experiences of the people of Liverpool, instead of focusing exclusively on job creation and tourism growth. Economic outputs are made more meaningful by situating them within a wide variety of other outputs, outcomes and qualitative data.

Impacts 08 has constructed an evaluation framework and grown the evidence base for the impact of culture upon regeneration and city renaissance to inform national debate, influence funding decisions and assist regional cultural planning. It has also helped individual organisations to consider how they operate and how they can assess and articulate their value by fostering the development of monitoring and evaluation capacity within the cultural sector. It has achieved this partly through providing an evidence base to inform the Arts Council England-funded Thrive! programme in the city-region and supplying regular updates to the Liverpool City Council, Liverpool Culture Company and the Northwest Regional Development Agency (NWDA).

The research programme offers an innovative, holistic approach to measuring the impacts of culture-led regeneration.

Impacts 08 has constructed its evaluation framework in such a way that it can be applied to other settings – creating an exportable model that will add to the reputation of the city as a leader on Cultural policy, for example, informing future European Capitals of Culture and the London 2012 Olympic Games. It has generated increasing interest from practitioners and policy-makers elsewhere in the North West of England, in the wider UK and the European Union.

The University recently won a significant European Commission contract to establish an international cultural policy research exchange network in conjunction with Marseilles, Turku and Stavanger – to share best practice with future Capitals of Culture.

Northwest Culture Observatory

The work of Impacts 08 is complemented by that of the **Northwest Culture Observatory**, which is led by the University and run in collaboration with Liverpool John Moores University and Liverpool Hope University.

The Observatory functions as the region's strategic culture research intelligence network. It makes sense of the needs of different groups in policy communities; interprets and conveys such needs to the academic community; champions evidence-based research; and builds intellectual capacity.

In 2010 the University and its partners will be working to bring together the Observatory's role with that of Impacts 08 as part of what may become a broader **Liverpool Institute for Culture Research**. Harnessing the expertise of Impacts 08 and the Observatory's networks, the Institute would aim to foster cutting-edge research on arts and culture, and translate and disseminate its findings to policy communities and practitioners in an accessible manner.



1.4 Architecture and the visual arts

Keywords: *Architecture; visual arts; museums; galleries; media organisations*

The University of Liverpool has a long and distinguished record of research in the field of architecture, with present strengths in:

- New architectural types such as portable, temporary and flexible buildings and structures
- Computer-mediated design methods
- Emerging modelling technologies
- Prediction and simulation of the visual and acoustic aspects of our built environment
- Advanced methods of monitoring and predicting building life cycles
- The inter-relationship between architecture and the visual arts
- Historic and developing architecture, particularly in relation to cities and urban situations.

Acoustics and lighting engineering design

Research into building acoustics and lighting engineering design is one of the University's key strengths. This includes research on low-frequency sound transmission in buildings, which has resulted in the development of methods to predict the extent to which properties are likely to be affected by noise from mechanical services, road traffic and domestic entertainment systems.

Researchers are currently investigating the acoustic properties of biomass materials and the design and testing of new materials for highway noise barriers.

Emerging modelling technologies

The University also focuses on the development and application of emerging modelling technologies to improve decision-making processes in the life cycle of building assets. The research, undertaken in collaboration with the NHS, is providing innovative methods of estimating and benchmarking facilities-management costs in acute-care hospitals. This has attracted interest in policy circles in the EU and the International Organisation for Standardisation (ISO), among others.

Work on risk in relation to design, scheduling and cash flow, utilises innovative complexity and stochastic techniques to develop decision support systems.

Cities, Culture & Regeneration

Facilities

The University has major specialised facilities, including:

- Controlled environment rooms
- Noise transmission suites
- An anechoic chamber
- A lighting laboratory with an artificial sky.

The University is also the home of CAVA, the **Centre for Architecture and the Visual Arts**, a research agency and key forum for debate in the University and the wider world. The Centre has a track record of successful collaborations with visual arts organisations in the organisation of seminars, conferences, publications and exhibitions.

1.5 History and heritage management

Keywords: *Archival/library resources; print; media; music; slavery; merchant houses; Museum of Liverpool; Victoria Gallery & Museum*

The University of Liverpool brings interdisciplinary strength to the study of the city's past, especially in fields such as the historic built environment, the histories of print, media and music, and the conservation and promotion of archival and library resources.

Its **Centre for Archive Studies** has an international reputation for research into the theory and historical development of archival practice. It also provides continuing professional development and postgraduate courses in archive and records management.

The University has built close working relationships with history and heritage organisations in Liverpool and further afield. It is a member of the World Heritage Site Steering Group and is an active advocate of the policy of regeneration through conservation. It has contributed to exhibitions and collections, and played prominent roles in a series of major history and heritage events.

Museums, collections and exhibitions

University researchers have played an important role in many of the city's recent museum developments, feeding original research directly into wider public dissemination. Knowledge exchange between the University and National Museums Liverpool has helped create exhibitions and develop collections in Egyptology, popular and classical music, architecture and public space, slavery studies, and Liverpool history. Researchers have also contributed to the prestigious new Museum of Liverpool.

Recent projects illustrating the range of expertise available include:

- **Victoria Gallery & Museum:** a prestigious architectural conservation project that created a new museum for the University and the city, with an extensive outreach and educational mission
- **Liverpool in Print,** in collaboration with Liverpool Record Office: computerising the fragile and unique resources of Liverpool Central Library's Local Studies Catalogue, while adding finding guides and reading lists to open up the collection to scholars and interested readers at all levels.
- **Leverhulme Mercantile Liverpool,** in collaboration with Merseyside Maritime Museum – a project co-funded by the Arts & Humanities Research Council and English Heritage which researched Liverpool's Victorian business elite. Its outputs included an exhibition at National Museums Liverpool venues of early photographs of the interiors of merchant houses in Liverpool.

Events

The University has played a prominent role in a series of major history and heritage events in recent years. It was a key partner in the Big History Show (2007), which attracted 6,000 people to St George's Hall, and co-sponsored Liverpool 800 (2006), the city's best-selling anniversary history book, which is being adopted as a model by other cities.



1.6 Film and media

Keywords: *Film footage of Liverpool; amateur & professional; documentaries; features; TV films; catalogue; oral histories; GIS; digital map*

Today, Liverpool is reputed to be the second-most filmed city in the UK. It has 'doubled' for London, Paris, New York, Moscow, Dublin, Venice and Berlin – and is also a setting for numerous films in its own right. This is not a new phenomenon: the city has been documented and represented in film for more than a century, but much of the material was fragmented, dispersed and in private collections.

Working in close collaboration with private individuals and collectors and local, regional and national organisations such as National Museums Liverpool, North West Film Archive, Northwest Vision and Media and the British Film Institute, the University of Liverpool recently brought together and documented around 1,700 films made in or about the city between 1897 and 1984. The 'City in Film' project was funded by the Arts & Humanities Research Council (AHRC).



Outputs City in Film

The University has set up an online searchable catalogue. This provides a firm foundation for studying the many and various ways in which moving image materials, including early actualities, amateur footage, independent productions, television documentaries and feature films, depict the city's architecture and urban landscapes.

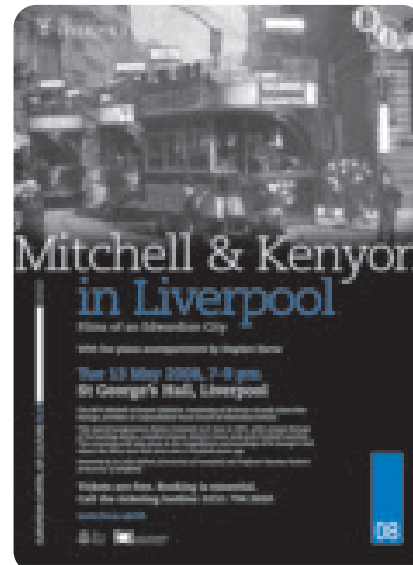
This resource facilitates new understanding of the ways in which we experience and remember place, and the role of moving images in shaping the design of the contemporary urban environment.

www.liv.ac.uk/lsa/cityinfilm/catalogue

Mapping the City in Film

In this follow-on project the University is exploring the relationship between film, memory and the urban landscape. Amateur and independent filmmakers on Merseyside have documented and visually mapped Liverpool's urban landscapes since the 1920s. The project is collecting oral histories of these organisations.

Using geo-spatial geographical information systems (GIS) software, it is studying the relationship between mapping and moving images practices. Working in partnership with the new Museum of Liverpool, it is creating a digital map of the city's history. Together with stories from filmmakers about how and why the films were made, this will become part of a permanent exhibition in the History Detectives gallery, scheduled for opening in 2010/11.



1.7 Music

Keywords: *Popular music scholarship & research; training; conferences & symposia; popular music sound recordings & artifacts*

The University established its **Institute of Popular Music** (IPM) in 1988 as the first academic centre in the UK created specifically for the study of popular music. The main focus of the IPM is research – often undertaken in collaboration with local and national organisations. One such project involves disseminating some of the IPM's expertise on Liverpool's popular music history via an online resource.

The **Institute of Popular Music** also promotes research through events, conferences and symposia, and publications of international standing. It also supports a number of postgraduate research students working within the University on popular music projects, and provides subject-specific research training to postgraduates both within and from outside the University in conjunction with the Institute of Musical Research, London.

The **Institute of Popular Music** research and teaching are supported by a wide range of resources, including an extensive collection of popular music sound recordings and artifacts.

This has allowed the **Institute of Popular Music** and its academic staff to engage directly with local and regional cultural organisations in the development and delivery of large public events like **The Beat Goes On** exhibition in partnership with National Museums Liverpool.

This exhibition highlighted the remarkable achievements of Merseyside artists over the years – people who have influenced generations of musicians. Visitors were able to learn about and hear examples of the different cultural and musical traditions within the region and its vibrant music and club scenes.

2.0 Initiatives

2.1 Community and workplace engagement

Keywords: *Trade unions; community & workplace engagement; lifelong learning; work-based learning*

The University of Liverpool's expertise in this area encompasses:

- Understanding the role of work-based lifelong learning and the role of stakeholders
- Developing understanding of the role of education in the work-place
- Promoting trade union members' (and the wider society's) access to education
- Promoting cultural engagement and community cohesion through learning.

Over the years, the University and the North West's largest public sector union, UNISON, have developed a multifaceted relationship which has fostered a series of initiatives that build on this expertise.

Trade Union and University Lifelong Learning Partnership

Trade unions and universities like Liverpool share the recognition that social promotion and mobility can be directly enhanced through participation in work-based lifelong learning. To innovate and strengthen the collaborations between the institutions, TULIP - Trade Union and University Lifelong Learning in Partnership - was launched, supported by EU Leonardo funding. This network of 14 partners from nine countries, represents trade unions, universities and a university lifelong learning network, and aims to improve the quality and delivery of work-based lifelong learning to trade union members and employees.

TULIP presents models which describe ways in which the two sectors can work together to open the doors to learning for trade union members. It also offers resources which can support the development of cooperation and the opportunity to link with experienced colleagues.

The University has a clear commitment to equity and diversity and a long tradition of work with adult learners and offers innovative, more flexible courses of study relevant to working lives. The trade union sector is a natural partner in pursuit of the University's lifelong learning activities.

Lifelong learning, reading and work

In order to open up lifelong learning activities to UNISON's target audience – mainly low-paid women, many of whom have few formal qualifications – the University's **Centre for Lifelong Learning** and UNISON formed a number of reading groups.

Shared reading activities stimulate critical thinking, analytical skills, the construction of argument and the precise articulation of concepts, emotions and ideas – all essential to fulfilling and effective workplace performance. In addition, reading remains not only an essential skill for anyone involved at any level of educational activity, but is also a gateway to all areas of higher education.

In another initiative the University invites UNISON members with an interest in the arts to participate in group activities that raise awareness of the place of art in society. The University and the union share the same rationale: bring together individuals from very different backgrounds and circumstances to introduce them to the idea that they may be able to pursue their interests through participating in University lifelong learning activities. Simply put, to show participants how education can be accessible and relevant to their daily lives; foster understanding that learning can be lifelong; and show that it does not depend on traditional structures of education.

Working with voluntary sector organisations

To strengthen collaborations between universities and voluntary sector organisations, the University is participating in 'VALUE' – Volunteering & Lifelong Learning in Universities in Europe. This is a network of 20 partners from 13 countries, represents individual organisations and European networks in both sectors.

VALUE aims to bring the two sectors together to share ideas and models and to explore the potential for developing new university lifelong learning opportunities for both volunteers and staff in volunteering organisations. At the centre of the network's investigations are volunteers and the sophisticated learning – both formal and informal – that they experience in their volunteering work.

VALUE is also developing a freely accessible resource base including reports, case studies and bibliographic references which is available on the network website, www.valuenetwork.org.uk.

ESRC Collaborative Studentship

In this initiative, a PhD student has been given access to UNISON members; to the union's records on international development and financial assistance; and to international events.

The research carried out by the student has provided UNISON with insights into its members' perspectives on current international policies, and to integral research on the changing nature of the sector and what this means for their members.

To strengthen collaborations between universities and voluntary sector organisations, the University is participating in 'VALUE' – Volunteering & Lifelong Learning in Universities in Europe.



Cities, Culture & Regeneration

2.2 Active engagement in culture

Keywords: *Students; graduates; creative economy; social out-reach; literacy; reading*

The University of Liverpool itself – through its staff, its graduates and its students – actively contributes to the cultural life and wellbeing of the city. It is also engaged in initiatives designed to encourage its graduates to contribute to the city's creative economy.

The Reader Organisation

The University is a sponsor of **The Reader Organisation** (TRO) – its first arts spin-out organisation. Founded as *The Reader* magazine in 1997, **The Reader Organisation** is now helping to bring about a reading revolution, addressing the sad fact that nearly a quarter of the adult population has difficulties with reading. 'Literacy' is not just the ability to read, but the state of being a reader. **The Reader Organisation** fosters this by adopting a radical approach which is firmly centred on making the serious pleasure of reading available, in many different ways, to as many people as possible.

Its innovative social outreach project – 'Get Into Reading' – is a unique shared reading programme in which more than 120 groups across Merseyside meet weekly to enjoy books and poems together, guided by trained facilitators. By making the content of great books available to all through a culture of shared reading, TRO also helps group members to value books as a source of shared meanings.

The Reader Organisation works in partnership with organisations like Liverpool Primary Care Trust, Mersey Care NHS Trust, Bibby Line Group, Merseyside Fire and Rescue Service and Wirral Metropolitan Borough Council. It operates in care homes, libraries, hostels for the homeless, drug rehabilitation centres, schools, prisons, community centres and hospitals. Reading group members include looked-after children, company employees, people with learning disabilities, dementia, brain injury and other neurological conditions, carers, excluded youngsters and ordinary people doing their best to live their lives in deprived communities.

The Reader Organisation also delivers the annual Penny Readings, Liverpool Reads (a big book give-away) and Community Shakespeare, all of which aim to positively engage local communities with reading and with each other.

The Reader Organisation is still supported by the University of Liverpool, has its base on campus, and relies on staff and student involvement to continue its valuable work. It is currently collaborating with University of Liverpool researchers on several projects related to the emerging discipline of reading and health. Funded by the NHS, the Department of Health, the Ministry of Justice and the Arts & Humanities Research Council (AHRC), these cutting edge projects have the potential to influence public policy and service commissioning.

Culture Campus

The University is a key shareholder in **Culture Campus**, an international centre for learning, research, advocacy, development, participation and expression in contemporary visual, media and popular culture.

This brings together the University of Liverpool, Liverpool John Moores University, Liverpool Hope University, the Foundation for Art & Creative Technology (FACT), Tate Liverpool, Liverpool Biennial of Contemporary Art and the other members of the Liverpool Arts and Regeneration Consortium (LARC).

Its mission is to inspire the best quality graduates to contribute to the cultural sector and the wider creative economy in Liverpool. It lobbies and guides Liverpool's major educational institutions on what the creative sector is looking for from its new recruits, establishes and nurtures collaborations.

Its innovative social outreach project – 'Get Into Reading' – is a unique shared reading programme in which more than 120 groups across Merseyside meet weekly to enjoy books and poems together, guided by trained facilitators.



3.0 Consultancy and Outreach

3.1 Sports

Keywords: Football; business; finance; law; media; marketing; international relations

The University conducts research into sports – particularly football, and has considerable expertise in researching the economic and social impact of professional sports. Other investigations have focused on the policing of football fans; football and gender; corporate social responsibility; international relations; and the media in Europe.

It exploits the insights it gains in the form of executive short courses for the industry and consultancy for organisations like Liverpool FC and Everton FC, Liverpool City Council, FIFA, the All Party Parliamentary Football Group and the European Commission. It recently completed a review of mini football in Wales, for instance, which has stimulated far reaching changes in the format, size and approach to the junior game there.

The University also has experience of:

- Work around sports governing bodies and issues of effective Board leadership
- Accountability in relation to sport
- Advancing equality in and through sport
- Advocacy and development through junior sports programmes
- Advisory work – for example, via the UEFA football development exchange study programme and with Kurdistan's Ministry of Sport
- Appointment to public sports bodies – including UK Sport, the Sports Council for Wales and the Welsh Football Trust.

The University is frequently invited to provide an expert opinion to national and international media.

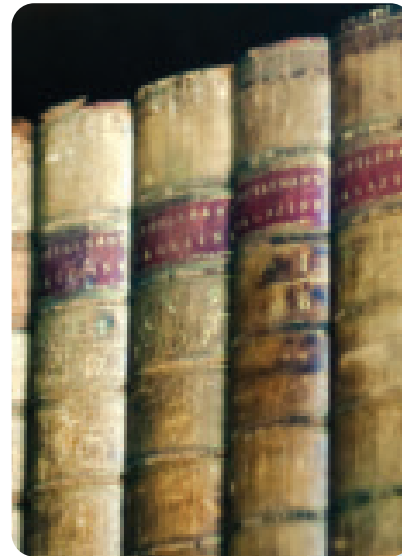
The University conducts research into sports – particularly football, and has considerable expertise in researching the economic and social impact of professional sports.

3.2 Languages and culture

Keywords: Languages; cultures; translation; cross-cultural knowledge

The University has extensive expertise in a range of languages and cultures – both European and non-European. It has a track record of advising external organisations and individuals in need of country or region-specific guidance. Its specialists are often invited to provide an expert opinion; in this capacity it has advised the national and international media, the Foreign & Commonwealth Office, and, recently, Scotland's Parliament, which sought guidance on issues relating to the linguistic landscape and language use in Scotland.

The University also has expertise in cross-cultural translation – encompassing, for a range of languages and cultures, semiotics, semantics and sociolinguistics; translation (in the widest understanding of the field); intercultural awareness; and cross-cultural analysis.



Cities, Culture & Regeneration

Specialist Centres, Facilities and Laboratories

Further information on specialist centres, facilities and laboratories can be found in a dedicated section (see page 142). Those most relevant to Cities, Culture and Regeneration include:

- Centre for Architecture and Visual Arts
- Centre for the Study of International Slavery
- Eighteen-Century Worlds Research Centre
- Culture Campus Liverpool
- Impacts 08
- Institute for Popular Music
- Merseyside Social Inclusion Observatory
- Northwest Culture Observatory
- The Reader Organisation

For more information or questions, contact:

University of Liverpool
Business Gateway
0845 0700 064
business@liv.ac.uk

www.liv.ac.uk/businessgateway

Case Studies

Impacts 08

Thirty years ago the arts were seen as spiritually rewarding for creative individuals and people capable of appreciating their output. Today, they are expected to contribute to economic and social regeneration, too – but what do they actually achieve?

Members of Impacts 08 team experts in assessing this. Pioneering methodologies developed to assess the long-term impacts of the European City of Culture on Glasgow are now being refined, extended and applied to Liverpool. A six-year project commissioned by Liverpool City Council is evaluating the long-term economic, social, cultural and environmental impacts of Liverpool's year as European Capital of Culture – from the pre-bid phase to 2010 and beyond.

"I would recommend working with the University to other organisations. There are people in the University from top to bottom who are dedicated to ensuring that they look out to the world and that make sure that this city and its residents are going to benefit from it."

John Kelly
Executive Director of Regeneration, Liverpool City Council



Its my Park

A University historian initiated a project which set out to address some of the wider issues affecting children and young people. The project fostered a better understanding of the historical importance of their local park and created opportunities for the development of educational and social skills. It has had a visible impact on the local community, particularly on children at primary level.

It was supported by a grant in excess of £450,000 from the Heritage Lottery Fund and is a good illustration of the way in which University research can be used to improve peoples' lives through civic engagement.

Arena Housing

In an innovative Knowledge Transfer Partnership (KTP), the University of Liverpool and Arena Housing Association worked together on a housing-led regeneration project in Liverpool.

The Liverpool areas of Anfield and Breckfield are the site of the country's largest regeneration project. More than 1,800 homes are to be demolished, with approximately 1,000 homes being built in their place. Over £45million was spent on the scheme during 2006-08 alone.

The KTP project set out to secure the sustainability and stability of the area and look for ways to stimulate new enterprises, improve health and security, and open up new opportunities for training and employment.

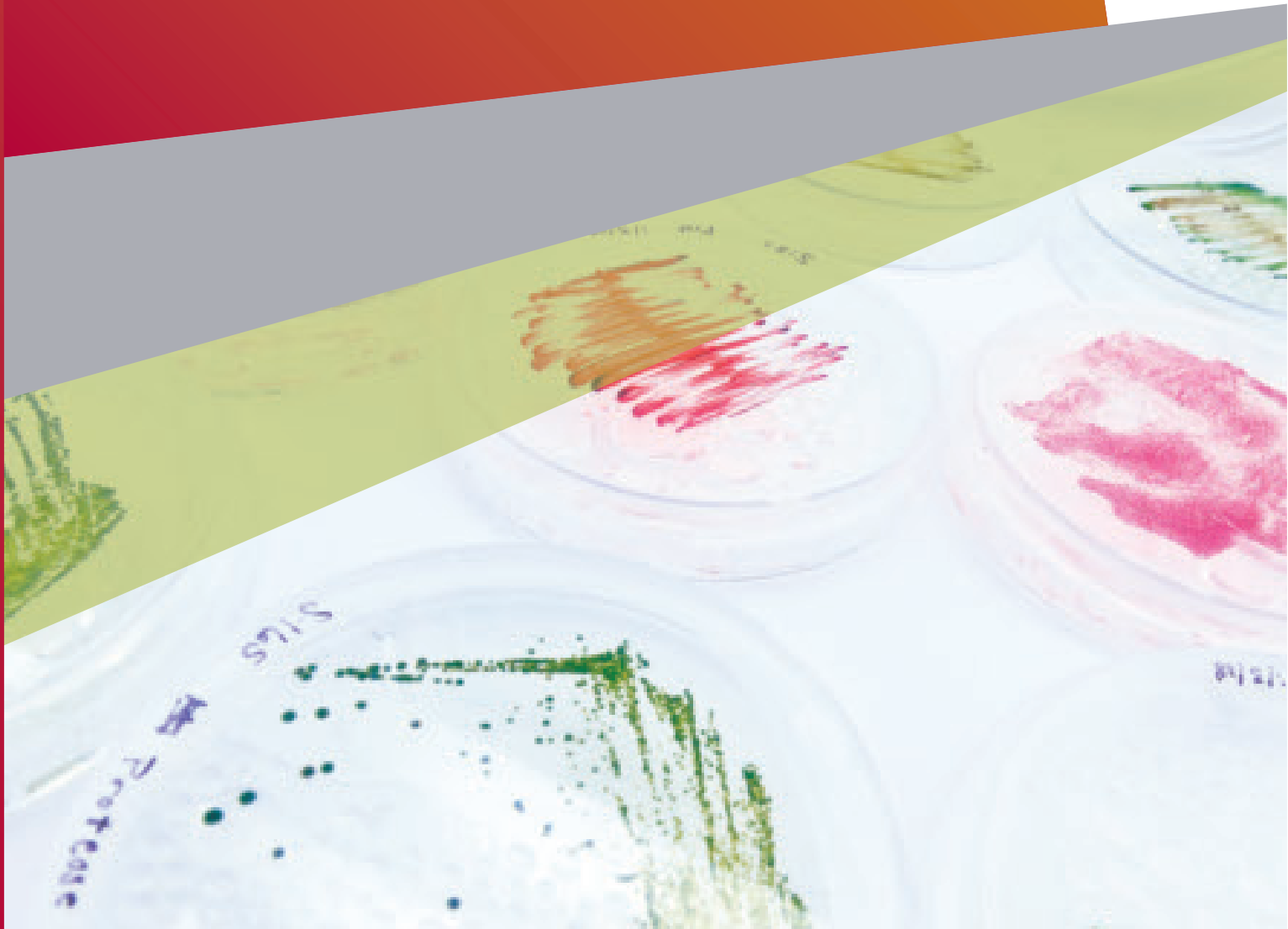
In the long-term, the project plans to set up a community-led organisation that will have the resources to develop the area physically, economically and socially without being dependent on government grants.

Arena Housing has benefited from the project in a number of ways. The KTP kickstarted a major shift in the thought process within the organisation, which realised that its own assets are an income generating base that could form the core of sustainable regeneration. The proposed solution was an asset-owning community-led vehicle which can maintain its own housing stock, empower the local community and help regenerate the area.

"The project has enhanced our reputation as an innovative and forward thinking organisation and given Arena good publicity."

Brian Cronin
Chief Executive, The Arena Group

Specialist Centres, **Facilities & Laboratories**



The University of Liverpool has established a number of centres of specialist expertise geared to working with external organisations. Dedicated staff within these centres are focused on meeting the requirements of business, industry and public sector organisations

The University also has a range of facilities and laboratories which match its expertise in science and engineering, health and life sciences, and humanities and social sciences. We provide access for organisations to utilise our facilities on a one-off or regular basis.

Below is a list of expertise that provides links and access to the University's specialist centres, facilities and laboratories. If you can't find what you're looking for or need further assistance please contact the **Business Gateway**.

Specialist Centres

Management & Enterprise Advanced Manufacturing

The **Agility and Supply Chain Management Centre** assists local companies in the manufacturing sector to grow by using the tools and techniques associated with best practices. The Centre has developed an implementation framework which comprises a set of auditing and planning tools to guide companies through the agility adoption stages. It offers a number of services ranging from awareness seminars and general and bespoke workshops, to detailed projects to improve internal company processes and establish a better understanding of growth opportunities. The latter includes assisting companies to develop new business processes, new products and target new markets. The model used by the Centre capitalises on the availability of additional resources such as PhD and MSc graduate projects that can be tailored to the needs of companies.

www.agilitycentre.com

Health & Wellbeing

Biomedical Research Centre in Microbial Diseases is a pioneering centre set up by the Royal Liverpool and Broadgreen University Hospitals NHS Trust; the University of Liverpool and Liverpool School of Tropical Medicine to carry out translational research into the diagnosis and treatment of some of the world's most serious infections. The Centre focuses on four areas of research which recognise existing strengths in Liverpool, both in research and clinical excellence.

www.rlbuht.nhs.uk/NIHR_BRC/Introduction.asp

Cities, Culture & Regeneration

The **Centre for Architecture and Visual Arts** (CAVA) has been established to dynamise high-level research into architecture and the visual arts in the University, the city, and the world beyond. As well as collaborating with institutions such as Tate Liverpool, National Museums Liverpool and the Foundation for Art and Creative Technology (FACT), CAVA has an international focus on high-quality debate regarding the history, contemporary status and future of architecture in relation to the visual arts. The Centre specialises in 20th century and contemporary visual arts history, theory, practice and policy studies. It provides research expertise to professional organisations involved in the areas of visual arts collection, curation, exhibition, public education and dissemination. It also offers specialist historical, social and cultural perspectives for organisations seeking to review and develop their visual arts provision in these fields of professional practice.

www.liv.ac.uk/lisa/cava

Health & Wellbeing *Digital Technologies*

The **Centre for Cell Imaging** (CCI) is a world-class resource thanks to generous grant aid and innovations achieved through collaborations with Zeiss, Hamamatsu, AstraZeneca and Kinetic Imaging (now Andor). Its equipment includes unique combinations of hardware and software to support long-term, time-lapse, multi-parameter fluorescent and luminescent imaging. A range of confocal microscopes, which are able to take a series of sections in depth, allows 3D images of cells to be created.

Tools are available for multiphoton excitation of fluorescent probes that allows imaging deep into tissue.

Alongside nine microscopes, the **Centre for Cell Imaging** has a fast fluorescence/ luminescence/ absorption automated plate reader and a flow cytometer and sorter – all installed in a state-of-the-art, custom-built suite of laboratories. The flexibility of the equipment and array of biological tools available has allowed research into pituitary disorders, developmental disorders, blindness, diabetes, obesity, cancer, malaria, inflammation, asthma, and arthritis to be carried out within the Centre.

www.liv.ac.uk/bio/research/groups/cci

Safety & Security

The **Centre for Critical & Major Incident Psychology** (CAMI) is devoted to providing internationally recognised studies of psychological processes associated with managing critical and major incidents. These include, but are not restricted to, decision-making, leadership, stress and emotion. The aim of CAMI is to support the development of high quality research, education and training through the publication of studies and by extending and strengthening links between academics and practitioners.

www.liv.ac.uk/psychology/ccir

Health & Wellbeing *Safety & Security*

Centre for Drug Safety Science, funded by the Medical Research Council, is a joint venture between the Universities of Liverpool and Manchester to bring together a critical mass of knowledge and technologies in order to advance our understanding of adverse drug reactions. Through collaboration between researchers, industry and regulatory authorities, the Centre's mission is to create a world-leading centre for the investigation of fundamental mechanisms of clinically important adverse drug reactions with the overall aim of preventing such reactions by improved drug selection, drug design and more informed patient selection.

www.liv.ac.uk/drug-safety

Management & Enterprise

The **Centre for Enterprise and Entrepreneurial Leadership** (CEEL) combines active engagement with entrepreneurs and small firms with high-quality academic research. It aims to develop insights which are of real value to policy-makers and practitioners as well as the broader academic community.

www.liv.ac.uk/managementschool/business/ceel

Management & Enterprise

The **Centre for Experiential Consumption Studies** takes an interdisciplinary approach to the study of the consumer experience and consumption. Through continued support and development of existing consumer groups it conducts research into a wide range of experiential consumption topics, relevant to consumers and their quality of life, as well as clients in private, public and not-for-profit sectors.

Health & Wellbeing

The **Centre for Genomic Research** is one of the most advanced laboratories of its kind in the UK. It possesses a range of next generation DNA sequencing technology, including one of the first Roche/454 GS-FLX sequencers in the UK, which is available for the scientific user community. The Centre is also well equipped with state-of-the-art microarraying technology and supporting instrumentation providing standard and bespoke array fabrication. The Centre has the latest computational tools and trained staff to deliver bioinformatic services for data handling and analysis.

www.liv.ac.uk/cgr

Health & Wellbeing

The **Centre for Integrative Mammalian Biology**, established between the universities of Liverpool and Manchester, focuses on the study of how genes influence body function and is central to development of new therapeutic approaches to human and animal diseases. The academic consortium provides long term infrastructure support through education and training in integrative mammalian biology. In addition, the Centre has a concerted business development effort aimed at increasing industrial interactions with companies in the North West region and beyond.

www.cimb.ls.manchester.ac.uk

Digital Technologies

The **Centre for Intelligent Monitoring Systems (CIMS)** is one of the University's applied R&D centres. It designs intelligent systems that extract and monitor information, and automate corrective procedures, building on combined strengths of sensor technology, software development, telemetry and system integration, together with a unique patented approach. It concentrates not just on new technology, but also on how existing technologies can be applied in innovative ways that benefit industry, the community and the environment. CIMS has comprehensive facilities which can be used to develop concepts through to commercially exploitable prototypes.

www.cims.org.uk

Cities, Culture & Regeneration

The **Centre for Lifelong Learning** encourages, promotes and supports lifelong learning opportunities for a wide variety of clients. It works with young people, adult learners, community groups, staff and students in the University of Liverpool, and local, regional and global businesses.

www.liv.ac.uk/cil/

Environment & Climate Change

The University's **Centre for Marine Sciences and Climate Change** provides a research forum to understand marine sciences and how climate change operates, as well as considering the broader impacts on society, wellbeing and health. It also develops strategic research initiatives which complement the research strengths at the Proudman Oceanographic Laboratory (POL) and contributes to the national strategy being developed by research councils, particularly the Natural Environment Research Council (NERC).

www.liv.ac.uk/climate

Materials *Health & Wellbeing*

The **Centre for Materials Discovery** (CMD) champions the use of high throughput (HT) technologies across multiple industrial sectors. It offers a range of services designed to enable businesses to enhance existing in-house R&D programmes by optimising existing products and/or fabricating new materials with desirable characteristics. Industrial clients may commission contract research, engage in collaborative research or gain direct access to CMD's facilities following bespoke training. Their staff may also co-locate with the Centre's own researchers for extended periods.

www.materialsdiscovery.com

Digital Technologies

The **Centre for Mathematical Imaging Techniques** (CMIT) enables scientists, medics and engineers in the University – and businesses outside the University – to benefit from state-of-the-art mathematical techniques whilst giving applied mathematicians opportunities to tackle cutting-edge 'real world' problems.

www.liv.ac.uk/~cmchenke/cmit

Health & Wellbeing

The **Centre for Medical Statistics and Health Evaluation** (CMSHE) provides innovative statistical analysis support and advice to clinical researchers, and delivers a number of CME-accredited courses that are designed to provide healthcare professionals with research skills. Areas of expertise include survival analysis, meta-analysis, joint modelling of longitudinal and survival data, pharmacogenetics and stereology.

www.liv.ac.uk/medstats

Cities, Culture & Regeneration

The **Centre for the Study of International Slavery** (CSIS) aims to contribute to the understanding of slavery and its legacies and to foster research and debate in this field. Founded as a partnership between the University of Liverpool and National Museums Liverpool, the Centre works together with other universities and organisations to develop scholarly and public activities related to slavery in its historical and contemporary manifestations.

www.liv.ac.uk/cs/is/

Health & Wellbeing

The **Clinical Trial Research Centre** (CTRC) is a centre of excellence in clinical trial design, management and analysis, accessed by both the public and private sectors, and one of only a small number of units in the UK awarded Full Clinical Research Collaboration registration status. The CTRC incorporates the Medicines for Children Research Network Clinical Trials Unit, the Liverpool Cancer Trials Unit, the Epilepsy Trials Unit and other groups in infection, oral health, obstetrics and gynaecology. CTRC offers a full range of clinical trial services, including feasibility assessments, trial costing, coordination with trial sites and relevant clinical research networks, managing relevant approvals procedures and trial monitoring.

www.ctrc.org.uk/

Health & Wellbeing

The **CR-UK Liverpool Cancer Trials Unit** (LCTU) is a Cancer Research UK-funded centre, which, through its advisory board, has extensive NHS representation from all research active clinicians in the general, acute and specialist NHS trusts in the region. There are currently seven clinical trials open, including trials relating to pancreatic cancer (ESPAC-4, Telovac, ESPAC-T plus, EUROPAC-2), Uveal melanoma (ITEM), head and neck cancer (HOPON), and follicular lymphoma (PACIFICO).

www.lctu.org.uk

Environment & Climate Change

The University's **Environmental Radioactivity Research Centre** (ERRC) is concerned with a wide range of problems in environmental radioactivity. The laboratory specialises in the use of low-background hyper-pure germanium gamma spectrometers, for measuring low level environmental radioactivity. Collaborating with universities and international environmental research centres, the ERRC has made a significant contribution to our understanding and management of environmental change.

www.liv.ac.uk/info/research/env_modelling

Cities, Culture & Regeneration

Culture Campus Liverpool is an international centre for learning, research, advocacy, development, participation and expression in contemporary visual, media and popular culture. It brings together the University of Liverpool, Liverpool John Moores University, Liverpool Hope University, the Foundation for Art & Creative Technology (FACT), Tate Liverpool, Liverpool Biennial of Contemporary Art and the other members of the Liverpool Arts & Regeneration Consortium (LARC). At the heart of its mission lies the job of aspiring, supporting and enabling the best quality graduates to be attracted, stay, work and contribute to the cultural sector and the wider creative economy in Liverpool.

www.culturecampus.co.uk

Cities, Culture & Regeneration

Impacts 08, The Liverpool Model is a joint research initiative between the University of Liverpool and Liverpool John Moores University which evaluates the social, cultural, economic and environmental effects of Liverpool hosting year as the European Capital of Culture in 2008. Commissioned by Liverpool City Council, it examines the progress and impact of this experience on the city and its people. Its aim is to develop a research model for evaluating the multiple impacts of culture-led regeneration programmes that can be applied to events across the UK and beyond, including future European Capitals of Culture and the Cultural Olympiad for London and the UK in the lead up to the 2012 Olympics.

www.impacts08.ne

Cities, Culture & Regeneration

The **Eighteenth-Century Worlds Research Centre** is an interdisciplinary initiative involving some three dozen scholars and curators at the University of Liverpool and National Museums Liverpool. It promotes study and research in the political, social, economic, intellectual, and cultural life of the global 18th century across disciplines and departments at the University of Liverpool.

www.liv.ac.uk/18cworlds

Materials Advanced Manufacturing

The **Impact Research Centre** enables the University to address problems involving the large dynamic loading response and failure of materials and structures that occur throughout the field of engineering. Its facilities include; gas gun; powder guns; drop hammers; hyperbaric chamber; catapults; Hopkinsons bars; high rate servohydraulic test machines; and a high energy test cell equipped with for example a pulse pressure loading rig (PPLR).

Management & Enterprise

The University's pioneering **Innovation Academy** has developed its own open approach for managers who wish to develop better practice in innovation. It has drawn organisations from many sectors, private and public, small and large. Its approach to open innovation is based upon extreme benchmarking and exploiting the benefits of cross fertilisation. Current partners include a range of high growth firms, as well as health sector partners.

www.liv.ac.uk/managementschool/innovationacademy

Cities, Culture & Regeneration

The **Institute for Popular Music** plays an important part in popular music scholarship internationally, attracting students and visiting scholars from around the world, and contributing at international levels to the body of popular music scholarship. It also collaborates with many organisations and organises and hosts national and international conferences and symposia.

www.liv.ac.uk/music/ipm/

Environment & Climate Change

The **Institute for Sustainable Water, Integrated Management and Ecosystem Research** (SWIMMER) works with industry, governments, regulators and non-governmental organisations to create innovative strategies for water and environment management.

www.liv.ac.uk/swimmer

Materials

The **Knowledge Centre for Materials Chemistry** is a virtual centre of expertise providing multidisciplinary research and innovative knowledge based on world-class capabilities in applied materials chemistry. The Centre acts as a single point of contact for companies of all sizes to access a substantial range of facilities and expertise in applied materials chemistry at four leading academic institutions at the Universities of Bolton, Liverpool and Manchester and the Science and Technology Facilities Council at Daresbury. It offers proactive help in the formulation and delivery of collaborative R&D projects, fast track project initiation with dedicated project scientists in our partner institutions, excellent project management and knowledge transfer expertise.

www.materialschemistry.org

Advanced Manufacturing

The **Lairdside Laser Engineering Centre** bridges the gap between research concept and shop-floor production, allowing UK businesses unrivalled access to expertise, equipment and training in the field of laser material processing. The Centre's ability to transfer processes from laboratory experiment to robust industrial method is a valuable new resource for manufacturing industry. The Centre also incorporates the North West Laser Engineering Centre.

www.lasers.org.uk/llec/index.htm

Health & Wellbeing

The **Liverpool Cancer Research Centre** brings together NHS cancer services and University of Liverpool cancer researchers with the aim of developing a world-class Liverpool Cancer Centre that will work towards achieving each of the 10 strategic goals of CRUK in Liverpool, Knowsley and St Helens, and the Mersey Region as a whole. A particular focus of the Centre is to improve understanding of how cancer starts and progresses, and the development of better treatments with fewer side effects, especially tackling cancer in low income communities.

http://science.cancerresearchuk.org/research/centres/liverpool_cancer_centre/

Digital Technologies

The **Liverpool Computer Science Maclab** supports research into mobile computing and widens access to more diverse and cutting-edge computing facilities. It provides a creative and supportive space whereby students and researchers alike can explore new techniques using mobile computing platforms such as the iPhone and iPod Touch, to support research into open multi-agent systems research and mobile e-finance.

www.csc.liv.ac.uk/department/maclab

Health & Wellbeing

The **Liverpool Experimental Cancer Medicine Centre** (LECMC) is a joint initiative by Cancer Research UK and the National Institute for Health Research (NIHR), co-partnered with the two leading NHS Trusts of Clatterbridge Centre for Oncology NHS Foundation Trust and the Royal Liverpool University Hospital (RLUH). The Centre provides infra-structure support for staff and running costs to under-pin early phase (I/II) trials and translational research.

www.lctu.org.uk

Health & Wellbeing

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www.lctu.org.uk

Environment & Climate Change

The **Liverpool Institute for Biological Complexity** is positioned within a wide scientific context to bridge disciplinary and institutional barriers, to facilitate research interactions and to foster the development of necessary infrastructure.

www.liv.ac.uk/biocomplexity

Management & Enterprise

The **Liverpool Law Clinic** is a pro bono legal advice centre established under the framework set out by the national pro bono charity Law Works. It provides legal advice by second and final year Law School students under the supervision of a qualified solicitor and under the overall supervision of the Manager of the Clinic, an academic member of the Law School staff. To ensure it delivers a service of the highest quality, the Clinic only provides advice on matters falling within the expertise and competence of its advisors. Advice covers a range of issues, including landlord and tenants' rights, personal injury, employment, consumer rights.

www.liv.ac.uk/law/clinic

 *Health & Wellbeing*  *Digital Technologies*

Nuclear Magnetic Resonance spectroscopy lies at the heart of the **Liverpool NMR Centre for Structural Biology**, which helps scientists to determine the 3D structures of proteins. The Centre can run experiments on materials in solution or in solid state. Its spectrometers have magnets with field strengths at 9.4Tesla (400MHz), 14.09T (600MHz) and 18.8T (800MHz) – supporting investigations into a wide range of molecules and biological and chemical systems.

In addition to NMR, the Centre has expertise in other biophysical techniques such as isothermal titration calorimetry and fluorescence spectrophotometry, with data from both methods complementing NMR experiments.

www.liv.ac.uk/bio/research/nmr/

 *Cities, Culture & Regeneration*

The **Liverpool University Centre for Poetry and Science** focuses on active exchanges between poets and scientists, drawing on the city's established strengths as a location where both poetry and science flourish. The Centre is externally funded by the Calouste Gulbenkian foundation.

www.poetryandscience.co.uk


 *Digital Technologies*

The **Magnetic Resonance and Image Analysis Research Centre** (MARIARC) is equipped to carry out:

- 3 Tesla MRI and 1.5 Tesla MRI
- Magnetoencephalography (MEG)
- Electroencephalography (EEG)
- Functional transcranial Doppler scanning (fTCD).


Its facilities are used for a variety of research purposes. It has particular expertise in functional MRI (fMRI), diffusion tensor imaging (DTI), perfusion imaging, arterial spin labelling (ASL) and magnetic resonance spectroscopy (MRS).

www.liv.ac.uk/mariarc

 *Cities, Culture & Regeneration*

The **Merseyside Social Inclusion Observatory** [MSIO] brings together a unique partnership of organisations from the public, private, voluntary and community sectors to identify what leads to social exclusion and effective routes out of it. It is the only centre of its type in the UK as it has an explicit focus on social inclusion and broader economic issues, as well as primarily engaging in both qualitative and quantitative research. It focuses on policy-relevant research, effective community engagement and best practice, particularly through the development of linkages with regeneration-focused policies, programmes and activities.

www.liv.ac.uk/civdes/msio

 *Health & Wellbeing*

The **National Centre for Zoonosis Research** (NCZR) is a combined venture of the universities of Liverpool and Lancaster, the Health Protection Agency and the Veterinary Laboratories Agency. It is the hub for collaborative research across the UK and further afield. The Centre undertakes research into zoonotic infections, and is a catalyst for national and international collaborations, taking multidisciplinary and multi-institutional approaches to zoonosis research.

www.zoonosis.ac.uk

Health & Wellbeing

The **North West Hub for Trials Methodology Research** (NWHOTMR) is a collaboration with Lancaster and Bangor Universities, funded by the Medical Research Centre. The Liverpool-based Hub provides a focus for research in the NW region around trials methodology, developing a world-class centre where methodological issues facing the clinical trials community can be investigated, and improving patient care by improving the validity and relevance of the healthcare evidence base. The Hub will provide expertise in areas such as drug safety, medicines for children, epilepsy and cancer. This will include research into the design and analysis of both early and late phase trials, including innovative adaptive design and pharmacokinetic studies, and issues related to the patient perspective, including methods to improve recruitment and retention.

www.liv.ac.uk/nwhotmr

Advanced Manufacturing

The **North West Laser Engineering Consortium** (NWLEC) is a strategic alliance between the Universities of Liverpool and Manchester. At the forefront of laser applications in micro- and nanotechnology, it draws on expertise from both universities to research and develop laser capabilities for the benefit of industry in the North West.

www.nwlec.org.uk

Health & Wellbeing

The **NIHR Biomedical Research Unit Pancreatic Diseases**, awarded to the Royal Liverpool University Hospital and the University of Liverpool, is undertaking translational research into pancreatitis and pancreatic cancer. Through pioneering new drugs and interventions, as well as new diagnostic techniques and preventive strategies, the Unit translates research discoveries into better outcomes for patients, enabling patients to benefit more quickly from scientific breakthroughs in these disease areas.

www.liv.ac.uk/research/environment/Pancreatic_Biomedical_Centre

Health & Wellbeing

The **NIHR Medicines for Children Research Network** improves the co-ordination, speed and quality of randomised controlled trials and other well designed studies of medicines for children and adolescents, including those for prevention, diagnosis and treatment. The MCRN Coordinating Centre is led by a consortium comprising the University of Liverpool, Royal Liverpool Children's Hospital, Imperial College London, National Perinatal Epidemiology Unit (NPEU; University of Oxford), Liverpool Women's Hospital and the National Children's Bureau.

www.mcrn.org.uk

Cities, Culture & Regeneration

The **Northwest Culture Observatory** is the region's strategic culture research and intelligence network. Its core partners are the University of Liverpool, Liverpool Hope University, Liverpool John Moores University, Arts Council England and English Heritage. The Observatory works across the breadth of cultural domains, including sports, the arts, heritage, tourism, museums, libraries and archives and creative industries. It also collaborates closely with the partnerships emerging out of the Impacts 08 work.

Health & Wellbeing

The **Ophthalmology Research Unit** (ORU) combines the University's ophthalmology research division and the clinical St Paul's Eye Unit in the Royal Liverpool University Hospital. It performs basic science and clinical research into the control of eye disease and ocular tissue repair and regeneration. It is a centre of excellence for the teaching and training in the control and treatment of eye disorders, and is at the forefront of development of novel techniques to improve the understanding and treatment of ocular disease. The expertise and resources within the Unit and the applied nature of its activities have resulted in numerous collaborations with industry in technology and product development.

www.liv.ac.uk/ophthalmology

Materials

The **Surface Science Research Centre** is a key facility which enjoys international acclaim. Current research themes cut across the disciplines of chemistry, physics, biology and materials science, and combine the efforts of both experimentalists and theoreticians. The overarching ambition of this work is to achieve nanoscale control, design and assembly of function.

www.liv.ac.uk/ssci

Health & Wellbeing

The **Tesco Dairy Centre**, in partnership with the University's Faculty of Veterinary Science, is a national resource centre for farmers and part of the Tesco Sustainable Dairy Group, offering expertise in cattle lameness, fertility and calf health. The Centre aims to help farmers in enhancing the commercial benefits of their work, as well as offering advice on animal health and welfare.

Cities, Culture & Regeneration

The Reader Organisation (TRO) is the University of Liverpool's first arts spin-out organisation and exists to bring about a 'reading revolution'. Its work encourages people of all ages and backgrounds to become readers, or to extend their reading habits, and aims to improve wellbeing and build community through shared reading. Get Into Reading, TRO's innovative social outreach project, has more than 120 reading groups across Merseyside. Get Into Reading has been singled-out by the Government as an example of best practice in helping improve public mental health and wellbeing in the 'New Horizons' strategy by the Department of Health.

www.thereader.org.uk

Advanced Manufacturing

The **Virtual Engineering Centre** (VEC) catalyses virtual engineering activities and joint research programmes across the sector and between industry and academia. Virtual Engineering (VE) involves integrated product/process modelling and the creation of virtual prototypes. Major aerospace companies are committed to VE because it provides a cost effective method of presenting future options to the customer and capturing their requirements. However, integrated VE tools and techniques have not been successfully implemented across the whole lifecycle and throughout the supply chain, presenting a major barrier to organisations adopting the technology. The Virtual Engineering Centre aims to address this and will explore solutions to many important engineering issues.

The Centre will act as:

- A **physical virtual engineering centre** which will contain 'best practice' facilities that display integrated, interactive simulation and modelling software across the full range of virtual capabilities
- A **research partnership** that will add value to existing research activities within the region by providing a commercially relevant focus
- A **knowledge exchange** centre to increase awareness and give potential users an opportunity to 'try before they buy' so that they can become more confident of the business advantages that can accrue from using VE tool
- An **educational centre** to help meet the current skills shortages in VE in the UK.

The Centre is funded by the Northwest European Regional Development Fund (ERDF), the Northwest Regional Development Agency (NWDA) and the University of Liverpool. Other collaborators are the Science and Technology Facilities Council at Daresbury, the Northwest Aerospace Alliance, Airbus, Morsons and BAE Systems.

🌿 Health & Wellbeing

The **Wellcome Trust Centre for Research in Clinical Tropical Medicine** is one of four centres throughout the UK established in 1995 to focus support for the Trust's Public Health and Tropical Medicine fellowship schemes, which facilitate the recruitment and training of outstanding clinicians, in order to maintain the UK's strength in clinical tropical medicine. The Centres can provide a UK base to support researchers engaged in projects outside the UK.

🌿 Health & Wellbeing

The **Wolfson Centre for Personalised Medicine** has a multidisciplinary team which collaborates with researchers locally, regionally, nationally and internationally to identify genetic predisposing factors for drug responses associated with a number of disease areas. It focuses on areas which are important from a public health perspective – including anticonvulsant therapy in epilepsy; inhaled steroids in children with asthma; acute coronary syndrome and variability in response to treatments; non steroidal anti-inflammatory drug (NSAID)-induced peptic ulceration; and the toxicity and efficacy of drugs used to treat infections such as HIV.
www.liv.ac.uk/pharmacogenetics/centre_for_personalised_medicine



Facilities

Health & Wellbeing

With its **Advanced Genomics Facility**, Liverpool has invested in next generation genome sequencing instruments, including one of the first Roche/454 GS-FLX sequencers in the UK, which are available for the scientific user community. The facility also has the latest computational tools and trained staff to deliver bioinformatic services for data handling and analysis.

www.liv.ac.uk/agf

Health & Wellbeing

The **Biomedical Electron Microscopy Unit** provides state-of-the-art EM and prepv facilities for applications ranging from basic high resolution imaging of immuno-labelled samples through to frozen hydrated cryo-EM and 3D tomography.

www.liv.ac.uk/emunit/

Health & Wellbeing

The **Functional Proteomics Facility** comprises a comprehensive range of instrumentation and facilities across campus for proteomics, protein chemistry, protein expression and biophysical analysis.

www.liv.ac.uk/bio/research/core_facilities/proteomics

Health & Wellbeing

The **Liverpool Microarray Facility** unit is well equipped with the latest high-tech arraying technology and supporting instrumentation providing standard and bespoke array fabrication. The facility also provides training and education services, and collaborates on technology development.

www.liv.ac.uk/lmf

Materials Health & Wellbeing Advanced Manufacturing

The University's unique **Ultra Mixing and Processing Facility** supports the development of nanomaterials for a broad range of applications – for example, medical, personal care, food, paints, detergents and lubricants. It can deliver emulsions at a volume sufficient for most application testing and can also facilitate enhanced particulate dispersion.

Health & Wellbeing

Liverpool Tissue Bank possesses tissue samples collected from patients banked together with associated clinical data to provide a valuable resource for research groups investigating the mechanisms of disease. University biobanking complies with the requirements of the Medicines and Healthcare products Regulatory Agency (MHRA) and the Human Tissue Act (England and Wales, 2006). Subject to ethical approval samples are made available to external groups.

www.liv.ac.uk/ctbrc/

Laboratories

✚ *Materials* ✚ *Advanced Manufacturing*

The **Knowledge Exploitation Laboratory** brings academic and industrial partners together, accelerating the transfer of research into industry in the fields of molecular engineering, advanced manufacturing, and sensors and monitoring. Its main purpose is to engage end users and technology suppliers in increasing the technology readiness level (TRL) of research to facilitate its exploitation. Industry can acquire knowledge through a range of mechanisms, for example, recruiting researchers or placing personnel in the University with direct access to scientists and University facilities.

✚ *Digital Technologies*

The **Liverpool Verification Laboratory** specialises in the formal analysis and automated verification of autonomous systems. It has developed world-leading agent verification tools and devised a route for the bespoke development of new agent languages which are both sophisticated and verifiable. The aim of formal verification is to analyse systems in order to ascertain whether users can be sure that such systems will behave in line with high-level, logically defined requirements. The Verification Laboratory is actively engaging with companies such as Motorola and Marconi, and organisations such as NASA, to develop practical verification tools.

✚ *Digital Technologies* ✚ *Energy & Sustainability*

The **National Instruments e-Automation Laboratory** is established in a partnership between National Instruments and The University of Liverpool, supported by National Grid Company plc. It is equipped with:

- A real-time simulator
- A range of hardware, microprocessors, embedded systems and data acquisition devices
- Real-time automation platforms
- Comprehensive software development systems
- Three IP networks, including a wireless local area network which is used for work on network-based industrial automation.

The Laboratory develops and integrates key internet and computer technologies with innovative management practices.

www.liv.ac.uk/e-automation

✚ *Digital Technologies*

The **Semantic Web Technologies Laboratory** carries out research designed to support the development of the Semantic Web and the application of Semantic Web technologies.

www.csc.liv.ac.uk/semanticweb

✚ *Digital Technologies*

The **Superstem Laboratory**, based at Daresbury Laboratory, is equipped with two SuperSTEM microscopes, both of which minimise spherical aberration. The Laboratory has undertaken studies for national research centres and companies as diverse as Qinetiq, Pilkington, Johnson Matthey and the Diamond Trading Company. Sample projects undertaken in collaboration with business include helping to resolve issues posed by the conversion of gases to liquid hydrocarbons, and ascertaining the source of colour in diamonds to inform the development of new methods of identifying their signature characteristics.

Associated institutions

The University of Liverpool benefits from very close working links with the following important institutions adjacent to the University campus:

 *Health & Wellbeing*  *Environment & Climate Change*

The **Liverpool School of Tropical Medicine** (LSTM) is an international centre of excellence, devoted to research, education and training, and consultancy. It was founded in 1898, becoming the world's first institution devoted primarily to tropical health. It has extensive links with UN organizations, health ministries, universities, non-governmental organizations and research institutions worldwide, working in partnership to control diseases of poverty and to develop more effective systems for health care.

www.lstmliverpool.ac.uk

 *Environment & Climate Change*  *Energy & Sustainability*

Proudman Oceanographic Laboratory (POL), a part of the Natural Environment Research Council, conducts world-class research in; estuary, coastal and shelf sea circulation, ecosystem dynamics; wind-wave dynamics and sediment transport; global sea level and geodetic oceanography; and marine technology and operational oceanography. The Laboratory hosts a range of national and international services for the benefit of the wider community.

www.pol.ac.uk

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- Virtual Engineering Centre
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This publication highlights areas of the University's knowledge and expertise which have demonstrable or potential value to organisations in the private, public and third sectors, and details the services we currently have on offer. It covers a wide range of disciplines, but should not be seen as a comprehensive review of the University's research activities. To be fit for purpose, it is necessarily selective.

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Professor Jon Saunders
Deputy Vice-Chancellor

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