Department for Business, Innovation & Skills

University Enterprise Zones Pilot

Application Form

January 2014

[redacted]

Director Sensor City

17th November 2017

[redacted]

Director, Sensor City

17-11-2017

CONTENTS

1. SUMMARY INFORMATION

Applicants should refer to the Guidance for Bidders before completing this form. It provides details of the criteria which will be used to assess the bids, and details which you are required to provide as part of the application.

This form is designed to allow you to expand text boxes as required, so there is no word limit per question. However, applications should not exceed 11 pages, including the cover page. Annexes are permitted, though they should only contain relevant additional supporting documents, and any key pieces of evidence should be summarised clearly.

The document must be in Arial Size 12 Font.

1.1 Applicant Details

University name	University of Liverpool
Address	Foundation Building, 765 Brownlow Hill, Liverpool, L69 7ZX
Lead contact name	[redacted]
Direct telephone number	[redacted]
E-mail	[redacted]

1.2 Brief Project Summary

Brief description of project	To establish a unique sensor-systems business incubator focused on creating, nurturing and establishing commercially-viable, hi-tech companies; and, over a 10-year period, drive growth both locally and beyond, creating a cluster of over 300 new businesses and over 1000 jobs in emerging technologies.
Total project cost	[redacted]
Amount of funding applied for	[redacted]
Amount of additional co-investment	[redacted]

2. PROJECT PROPOSAL

Provide an outline proposal for a pilot University Enterprise Zone. This should describe where the zone will be located, strategic context for its development, the concept for the zone (e.g. sector or technology specialism), the existing infrastructure and the partnership involved in developing it. It should describe any proposal to build incubator and grow on space as part of the University Enterprise Zone pilot and details of the offer to businesses. It should also set out arrangements to meet operating costs.

The **vision** builds upon existing excellence and established close working ties in a partnership between the University of Liverpool (UoL), Liverpool John Moores University (LJMU), the Liverpool City Region (LCR) LEP and Liverpool City Council (LCC) to create a world-leading University Enterprise Zone (UEZ) in sensor technologies. This new business accelerator and incubator will drive economic growth through open innovation and knowledge transfer, simultaneously enhancing the Third Mission[1] of the universities.

Sensor City UEZ has a clear technology focus to develop and implement novel sensor systems that integrate sensors, firmware programming and advanced algorithms. Sensor systems and measurement technologies are integral to the science-based economy; they underpin innovation across sectors ranging from manufacturing to healthcare and capitalise on the comparative economic advantage of the LCR.

We append letters[2] from a wide range of businesses that demonstrate both the demand for a sensor system centre and the current lack of capacity in this important growing area. In response, our proposal incorporates key features to kick-start and support new high-tech businesses via provision of specialist facilities, academic expertise, bespoke coaching, business mentoring, access to industry and a network of funders. As a result we will create, attract and support new high-tech SMEs and provide larger multinationals with a creative centre for sensor research, development and commercialisation.

Location wider Partnership

Sensor City UEZ will allow academics, private sector partners and investors to combine forces and so provide the critical mass needed to establish a knowledge hub for sensor-related technology that will be both nationally and internationally leading. The UEZ will comprise a bespoke 2500m^2 new building located in the Copperas Hill redevelopment zone, at the heart of the Liverpool Knowledge Quarter (KQ) - a designated Mayoral Development Zone[3] that is a prime location for business incubation adjacent to the universities, the business district and transport links (see plan[4]). Both universities play an active role on the KQ Board and this area has been identified within the KQ Strategic Investment Framework[5] as one of the principal sites for economic redevelopment.

Building on Existing Excellence, Infrastructure and Partnerships

The partners have a strong track record of driving local economic growth

[redacted]

both physical and human, which are each essential for a successful Enterprise Zone[6].

Physical Assets: Facilities of the University Partners and Grow-on Space

Developing hi-tech businesses will draw upon specialist facilities housed within the universities and our strong existing network of Knowledge Exchange Centres[7]. They will also benefit from easy access to Liverpool Science Park (LSP, a joint not-for-profit venture between UoL, LJMU and LCC) and Sci-Tech Daresbury infrastructure, which both provide neighbouring grow-on space while maintaining strong university links.

Human Assets: Leading Academic Expertise

This UEZ will, for the first time, bring together our assets in the field of sensors

Exemplar Sensor Activities (see Annex for expanded information[9])
Sensor City will expand our enterprise activities in sensor systems, two of which are illustrated to show our capabilities and highlight the scale and breadth of opportunity.

Wearable Sensors: A major recent breakthrough (2013) in wearable sensor technology can be woven into any garment to allow monitoring of a patient's vital signs such as heart rate, blood oxygen levels and temperature. This non-invasive, wireless and batteryless landmark achievement was chosen to be the 2,500,000th UK patent in recognition of the importance of its potential impact[10]. The Minister for Intellectual Property, Lord Younger said: "*This new technology demonstrates the importance of collaboration, and the wealth of knowledge transfer taking place, between our world class Universities and UK companies.*" The application of wearable sensors is set to revolutionise healthcare, reducing costs as well as improving the quality of life[11].

Mini Mass Spectrometer: Our scientists have the first patent on a miniature quadrupole mass spectrometer (QMS), leading to the creation of SME spin out Q Technologies[12]. This original technology used gold coated optical fibre on a silicon substrate to achieve the world's smallest ever QMS and the first to be microengineered in silicon. The market for portable MS is multi-£bn with applications in security and forensics, process monitoring, environmental and biomedical sensing.

Offer to Businesses: Targeting Innovative and High Growth SMEs
Our UEZ, incorporating incubation best practice[13], will develop customised packages of business and technical support to address market failures and take ideas from concept through to realisation.

Co-Working space: Sensor City will be configurable for a variety of small business ventures. The space will encourage interactions, with shared meeting rooms, break out areas and refreshment facilities. It will foster creativity and present an attractive and enticing environment for budding entrepreneurs and businesses to work together.

A Technology Development Zone: All businesses, particularly micro SMEs, face barriers in accessing necessary high-cost specialist equipment along with associated expertise. Sensor City will remove this barrier, providing integrated underpinning open laboratory services that will include software development, an electronics lab, equipment for system integration testing and validation, desktop manufacture etc. Close location to the universities will facilitate knowledge exchange and access to further facilities. This will reduce costs, accelerate the time to market and help overcome 'The Valley of Death' that stems from lack of investment at intermediate technology readiness levels (TRLs)[14].

Entrepreneurship Coaching and Business Mentoring: Flourishing technology businesses require both technical and business skills. We will foster both and accelerate technology enterprise development through bespoke coaching and company mentoring from academics, entrepreneurs and businesses. We will also encourage industry-partnered student internships.

Business Schools have a very important role to play in sharing skills and expertise between SMEs and universities[18]. We will integrate provision from the LJMU Centre for Entrepreneurship, the Liverpool Business School and the UoL Management School to provide the skills training that is needed for next-generation CEOs and managers.

Access to Funding: We will support entrepreneurs in the UEZ by creating a series of funds to support pre-seed opportunities, proof of concept studies We will develop an active investor network of Business Angles and Venture Funds[19] and our expertise in attracting European support will facilitate bids such as Horizon 2020.

Arrangements to Meet Operating Costs

The operational budget comprises three key components, a) salaries of the core team, coaches, mentors etc. b) infrastructure and equipment , c) marketing, communication and events . We will minimise the operational budget by levering no-cost contributions from the universities, including academic mentors and the student project resources. Operational costs will be covered through private sector sponsorship and the provision of commercial services rental from the start-ups will cover basic servicing costs.

Wider Benefits

Economic Benefits: It is predicted that the investment in the development and operation of UEZ over the next five years will translate into economic benefit[21], the majority of which will be within the LCR.

Social Benefits: Health and Wellbeing is a key theme of Sensor City with a focus on supporting social health care[22]. Sensors also play vital roles in security applications.

3. PROJECT OBJECTIVES AND DEMAND FOR SERVICES

3.1 Project Objectives

What are the objectives for the project and how do they fit will with wider Government objectives?

The objectives for Sensor City are to:

- Foster urban regeneration through business start-ups and growth. Over a 10-year period this will create over 300 new businesses and result in over 1000 new jobs.
- Establish and sustain a unique best practice hi-tech sensor business incubator
- Assist graduate entrepreneurs in forming hi-tech businesses, using coaching, mentoring and networks to sustain them and facilitate access to investment
- Increase SME innovation through exploitation of state of the art facilities and academic expertise within the Universities
- Integrate an established academic base, existing businesses and new partners to take the sensor sector to critical mass and scale

Sensors are an enabling technology impacting sectors across the wider economy[23], featuring within the 8 great technologies[24] core to Government's industrial strategy[25] and cutting across 3 of the strategic themes of high value manufacturing[26]. Sensors involve emerging technologies with the potential to support sustained economic growth[27] and are inherent to a number of key future characteristics of manufacturing[28]. They are vital to improvements in the healthcare, energy, aerospace, defence and transport sectors.

Engagement of the Universities' business schools in skills provision mirrors the Government objective of incentivising wider University-led business support for innovative SMEs locally via the "Third Mission"[1] and is consistent with a Government desire for Universities to deliver economic growth in partnership in local areas[29].

3.2 Demand for services

What demand is there for the services being proposed and what evidence is there that there is a market failure that needs to be addressed?

3.2.1 Demand

Global & National: The importance of the sensor market to the UK economy is hard to overstate. Sensors are underpinning technologies, with a sizeable market in their own right plus an enormous multiplier effect in markets they enable. Growth in the sensors market was around 9% per year between 2008 and 2010, rising to 10.6% in 2013. For sensor systems the market is currently $490bn globally[30] and in the last decade 1 in 3 global patents were sensor related[31]. The wider electronics systems market is growing rapidly and is estimated to contribute 7.1% to UK GDP by 2020. No single country will have a global monopoly though "nodes of leading capability" will emerge[32]. The ambition is for Sensor City to become a key UK node of sensor capability.

Analysis by the Electronic, Sensors and Photonics KTN[31] shows that the UK sensor industry contributes £13bn and 73,000 jobs to the economy, generating £6bn of exports. Nearly 900 UK companies list sensors as their principal activity; 84% of these are SMEs.

The "Internet of Things" is a huge growth opportunity for sensor systems and technologies. Ericsson predicts that there will be 50 billion connected devices globally by 2020 bringing direct global revenues of between $948 billion and $2.5 trillion by 2020[32]. Sensor City will ensure the UK is well positioned to develop this opportunity.

Local Demand[33]: There are *ca.* 1.4 million people employed in professions directly aligned with the UK sensor market of which 159,000 are in the North West and 27,000 in the LCR. Between 2009 and 2012 the number of sensor-related jobs in the NW grew by 11.7% while those in the LCR grew by 15.6% compared to a 0.4% drop nationally. This impressive local growth is testament to the demand for sensor-related skills.

The appetite and enthusiasm for Sensor City can be seen These derive from an extensive consultation exercise with the private sector from which this proposal arose. During this exercise several micro SMEs indicated a strong desire to locate to Sensor City demonstrating an early pipeline.

3.2.2 Market Failure

The ESCO A Blueprint For UK Economic Growth 2013 report into electronic systems states that "*investment in R&D ... is thinly spread and there is scope for improved alignment and connectivity between industry, academia and funding bodies*". Sensor City will strengthen these connections by providing a nationally recognised focus.

The UK's position in Electronics Systems (including sensors) is under threat from global locations where the strategic partnership between industry, academia and government is stronger[31] and the UK must ensure that the right innovation environment is in place[32]. In addition, there are a number of clearly identified further reasons for market failures[34].

- A disconnect exists between industry (especially SMEs), academic research into sensors and access to facilities for research and development
- It is difficult to bridge the sensor innovation gap / "valley of death"
- There are skill shortages in the sensor market
- High cost of prototyping and custom development acts as barrier to growth for SMEs

The impact of these market failures at a local economy level and the need for government intervention are clearly evidenced

4. FINANCIAL INFORMATION

4.1 Co-investment

What is the indicative amount, nature and source of co-investment (this should be at least twice the amount of funding applied for)? You will be required to provide proof of the co-investment details.

LJMU and UoL, who are equal partners in this venture, propose to build and operate an incubator [redacted]

The remaining co-investment will be made up of a mixed model from University private income, industry partners and venture funds.

4.2 State Aid Compliance

Does your proposed investment comply with State Aid rules?

Sensor City complies with State Aid rules:

Aid at the level of the "Grant" Recipient - the University: Compliant on the basis the recipient is a 'research organisation' within the meaning of Article 2.2 of the Community Framework for State Aid for Research and Development and Innovation OJC 323, 30.12.2006 (the "Framework"). The Project covers non-economic activity falling within Article 3.1.1 of the Framework and economic activities within Article 3.1.2 of the Framework. Where the project delivers economic activities the entirety of the aid attributable to delivery of this activity will be ring-fenced and passed down, ie "flow through", to the end users in a State Aid compliant manner. eg German Incubators precedent (2005/782/EC notified as C(1315)2005 fin *Germany: Construction of municipal infrastructure and managed workspace.)* and the end users will take these benefits within the framework of the allowable block exemptions.

Aid at the level of the 'End beneficiaries' – the users (SMEs, research collaborators, users of the research infrastructure): Aid to the end user will be determined on a per individual user basis; within the Framework of the *de minimis* block exemption (i.e. under EUR 200,000 over any three year period) Commission Regulation 1407/2013 OJ

L 351/1 of 18.12.2013, or the General Block Exemption Regulation ("GBER" Commission Regulation 800/2008 OJ L 214 of 09.08.2008) or its replacement[37].

5. STRATEGIC PARTNERSHIPS AND OBJECTIVES

5.1 Local Enterprise Partnership

Demonstrate how this proposal contributes to the Strategic Economic Plan being developed by the relevant LEP.

In March 2012 the LCR LEP was formed and is the most private sector orientated LEP in England (450 private sector members as well as the six local authorities).

The Liverpool City Region Growth & Strategic Economic Plan states a key ambition is to build on our strengths as a national hub for innovation, science and creativity. Section 7.3.2 of the plan states the LEP is committed to "*developing further science, technology and R&D collaboration facilities in the Liverpool KQ and developing new models of R&D collaboration with business* Section 7.3.4 of the Plan makes reference to the **LCR Innovation Plan**, which has been developed in conjunction with 50 different organisations, 100 individual participants and over 60 firms.

The Innovation Plan was informed via a mapping exercise of LCR assets by the University of Cambridge Institute for Manufacturing. This included input from BIS, TSB, EEF, SEMTA, MAS, The Manufacturing Institute, STFC, UoL, LJMU and over 50 local manufacturers. Their report "**Making It – Advanced Manufacturing In Liverpool City Region to 2020**" was launched by the Secretary of State, Vince Cable in October 2013. It identified six short term opportunities that align with national strategic requirements[38]. Sensor City is the realisation of one of these LEP strategic priorities.

It should be noted that our plans incorporate growth with adjacent building space earmarked for a future second phase of development to give corporates the opportunity to co-locate.

The clear objectives and growth targets set out in section 3.1 are directly aligned to the LEP strategy to bridge a deficit in jobs, businesses, household income and GVA gap. The close alignment with the LEP Innovation Plan and our strong network of partners will ensure sustainability.

5.2 Wider strategic plans

Demonstrate how this proposal fits with the wider strategic plans of the relevant university or universities.

The two partner universities have a strong track record of enabling economic growth in the region (section 2). Working together with the LCC we created the Liverpool Science Park (LSP) as a 3-way joint venture in 2006. Both universities maintain a strong, strategic connection through Board membership of the LCR LEP and the KQ. They each have extensive activities in enterprise and innovation, which have roots both within the student body and the Management (UoL) and Business (LJMU) Schools. Both Schools will play an important part in the development of activities within the UEZ, providing essential coaching and mentoring. [redacted]. The inner city location of the UEZ will facilitate even stronger links between academics and entrepreneurship developments

within the City.

6. INDICATIVE PLAN AND MILESTONES

6.1 Provide an indicative plan that shows the timetable for the establishment of the zone and the delivery of the facilities.

The project involves establishment and delivery of the building and initiation of entrepreneurship, coaching and mentoring. The start date is July 2014.

Building: Months 1-7, Preparation and concept designs; 8-15, contract tender; 16-32 final design and construction; 33-34 install equipment and hand-over.

Entrepreneurship Coaching: Jul 2014-Sep 2015, devise, validate coaching based on existing frameworks/bespoke modules, engage mentors;

6.2 Predicted spend profile

Outline the predicted spend profile during development, demonstrating that the award will be spend across the three year period

This is mapped to the building timeline above. In summary the spend will be: [redacted]

[redacted] will be spent on capital Revenue expenditure over the first three years will total [redacted]

7. RISKS AND CONTINGENCIES

Outline the risks (management, financial, commercial), strategies for their mitigation, and contingency planning. Please add additional lines to the table as required.

No.	Risk	Mitigation
1	Failure to obtain planning	Early consultation with local planning authority[39]
2	Cost over-run/scope creep	Regular review of the budget and brief
3		
4	Lack of utilisation of UEZ by business/entrepreneurs	The proposal builds on a strong graduate pipeline a robust UEZ marketing strategy
5	Unable to recruit staff	Focus on technologies with good job prospects, high profile advertising and company engagement.

8. DATA PROTECTION ACT

BIS is subject to the Freedom of Information Act 2000, which gives a public right of access to information held by a public authority, which may result information arising from this work, or the outputs from the work undertaken being subject to disclosure if a valid request is made. We will comply with such requests in accordance with the legislation and our own policies.

Institutions can if they wish provide potentially sensitive information (such as information relating to commercial interests) in a separate annex attached to the application form. This will highlight to us that there are concerns about disclosure.

Where we consider it to be appropriate and practicable we will seek views of applicants before disclosing this information in response to a Freedom of Information request. The applicant acknowledges that the information provided in the annex is of indicative value only, and that BIS may nevertheless be obliged to disclose this information. Our assumption will be that all information in the main application documents can be disclosed on request.

9. DECLARATION

I declare that the information in the application form and accompanying [redacted] the best of my knowledge and belief

Signed..... [redacted] .....

Name..... [redacted]

Position.....Provost, University of Liverpool.....

Date.....31.3.14.....

Now email this application to uez@bis.gsi.gov.uk. The deadline for this application to be received by BIS is 5pm on 31 March 2014.

This publication available from www.gov.uk/bis

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Department for Business, Innovation and Skills
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000

If you require this publication in an alternative format, email enquiries@bis.gsi.gov.uk, or call 020 7215 5000.

BIS/14/570

University Enterprise Zones Pilot

Annex

Annex Contents

Annex 1: References and Notes

[1] Encouraging a British Invention Revolution: Sir Andrew Witty's Review of Universities and Growth – October 2013 (BIS/13/1241)
[2]

[3] The Liverpool Knowledge Quarter is one of 5 Mayoral Development Zones http://liverpool.gov.uk/mayor/how-the-mayors-office-works/mayoral-development-corporation/
[4] See Annex 2 for a map and outline plan of the proposed Sensor City UEZ
[5] The KQ Strategic Investment Framework: http://www.liverpoolvision.co.uk/wp-content/uploads/2014/01/Knowledge-Quarter-2011.pdf
[6] Dhruv Bhatli (2014) Best Practices at Top University Business Incubators (UBI Index)
[7] See Annex 3 for a list of Knowledge Exchange Centres that will participate in the UEZ
[8] A

[9] More details and further exemplar activities that demonstrate capability can be found in Annex 5
[10] BIS press release (16 Sep 2013) https://www.gov.uk/government/news/revolutionary-smart-sensor-technology-is-latest-patent-milestone
[11]

[12] www.q-technologies.co.uk
[13] Top University Business Incubators – Global Benchmark, UBI Index, 2013; Best Practices at Top University Business Incubators: Cases and Insights, UBI Index, 2014
[14] "Bridging the Valley" (2012) Science and Technology Select Committee http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/writev/valley/valley85.htm
[15] According to investors, the route to market for high-tech businesses is a major barrier to growth,

[17] www.engineeringyes.org
[18] Report by Lord Young, "Growing Your Business", in May 2013 (BIS/13/729)
[19]

[21] Based on the multiplier from BIS which reports that every £1 of HEIF funding generates £6.30 within the UK economy[29].
[22] . The outputs will result in improved social care, monitoring in the home and assisted living technologies.

[23] 'Concept to Commercialisation'- A strategy for business innovation, 2011-2015 (TSB); Enabling technologies – Strategy 2012-2015 (TSB)
[24] Eight Great Technologies – 2013 (Policy Exchange)
[25] Government approach to industrial strategy – Sept 2012 (Vince Cable, speech); Analysis of industry sectors - Sept 2012 (BIS) - economics paper No.18; Industrial strategy explained – Sept 2013 (BIS/12/1140) – booklet

[26] A landscape for the future of high value manufacturing in the UK – Feb 2012 (Study conducted for TSB)
[27] Technology & Innovation Futures: UK Growth Opportunities for the 2020s – 2012 Refresh -2012 (Gov Office for Science); Emerging technologies and industries: strategy 2010-2013 -2010 (TSB)
[28] The future of manufacturing: a new era of opportunity and challenge for the UK – 2013 (Gov Office for Science)
[29] British Invention: global impact – The Government's response to Sir Andrew Witty's review of Universities and Growth – March 2014 (BIS/14/540); Business-university collaboration: the Wilson review – Feb 2012 (BIS/12/610)
[30] "ESP KTN Making Sense of Sensors" 2011
[31] "A Patent Landscape Analysis of Sensor Systems" ESP-KTN; "Cohort analysis of the UK sensor industry" ESP-KTN.
[32] The ESCO Report: A Blueprint For UK Economic Growth 2013
[33] Data derived from Office for National Statistics, Business and Employment Register 2013 by LCR LEP.
[34] SQW Consulting "The Modern Manufacturing Strategy and Action Plan for the Northwest" Evidence Base of Market Failure Considerations (2008)
[35]

[37] We note GBER is currently due to expire on 30-6-14 and will be replaced by an updated instrument for several years thereafter. Legal advice to-date confirms this this is unlikely to differ in any material respect to the above however we will take further advice as the new regulation is adopted.
[38] Technology Strategy Board (TSB) 2012 report "A Landscape For The Future Of High Value Manufacturing In The UK".
[39]

Annex 2: Map and Outline Plan of Proposed Sensor City UEZ

The Sensor City UEZ will comprise a bespoke 2500m^2 new building located in the Copperas Hill redevelopment zone, at the heart of the Liverpool Knowledge Quarter - a designated Mayoral Development Zone that is a prime location for business incubation adjacent to the universities, the business district and transport links (Figure A2.1). The build will be on a brownfield site adjacent to Copperas Hill on land that is owned by LJMU and will be provided as part of the bid.

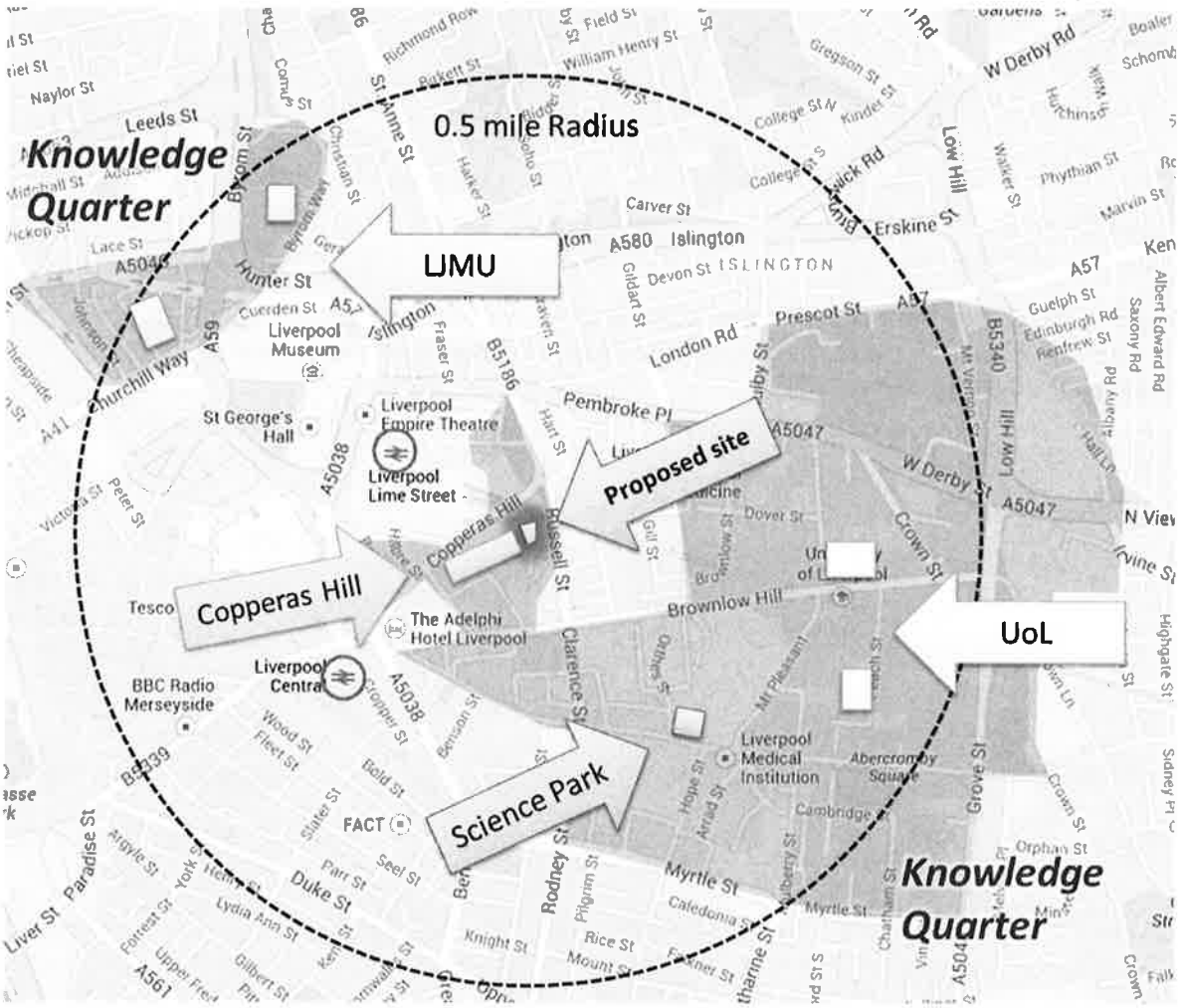


Figure A2.1. Map of the proposed location of the Sensor City building within the Knowledge Quarter (blue shading) and relative to the two universities (key participating departments are highlighted) and the Liverpool Science Park.

Our proposal is designed so that the Sensor City building (magenta, "Phase 1") is positioned with sufficient space to allow for future growth in a separate development (orange, "Phase 2") (Figures A2.2, A2.3).

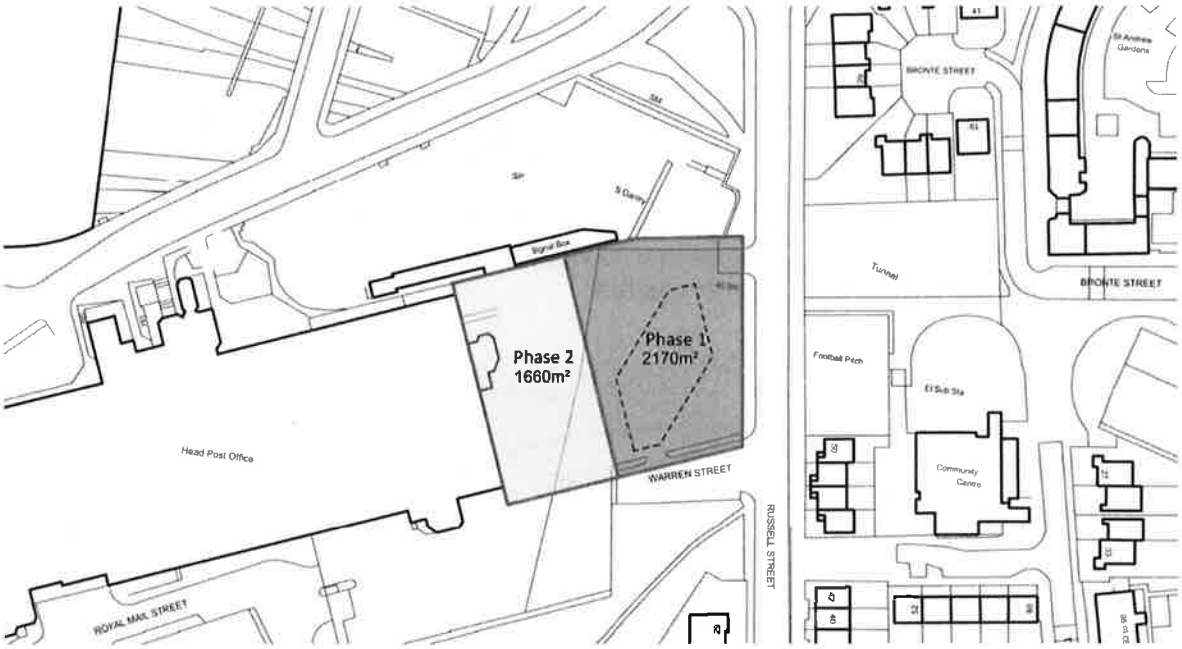


Figure A2.2. Site plan showing the location of the proposed Sensor City building (magenta, "Phase 1") with road access to Russell Street and the provision for future expansion (orange, "Phase 2").

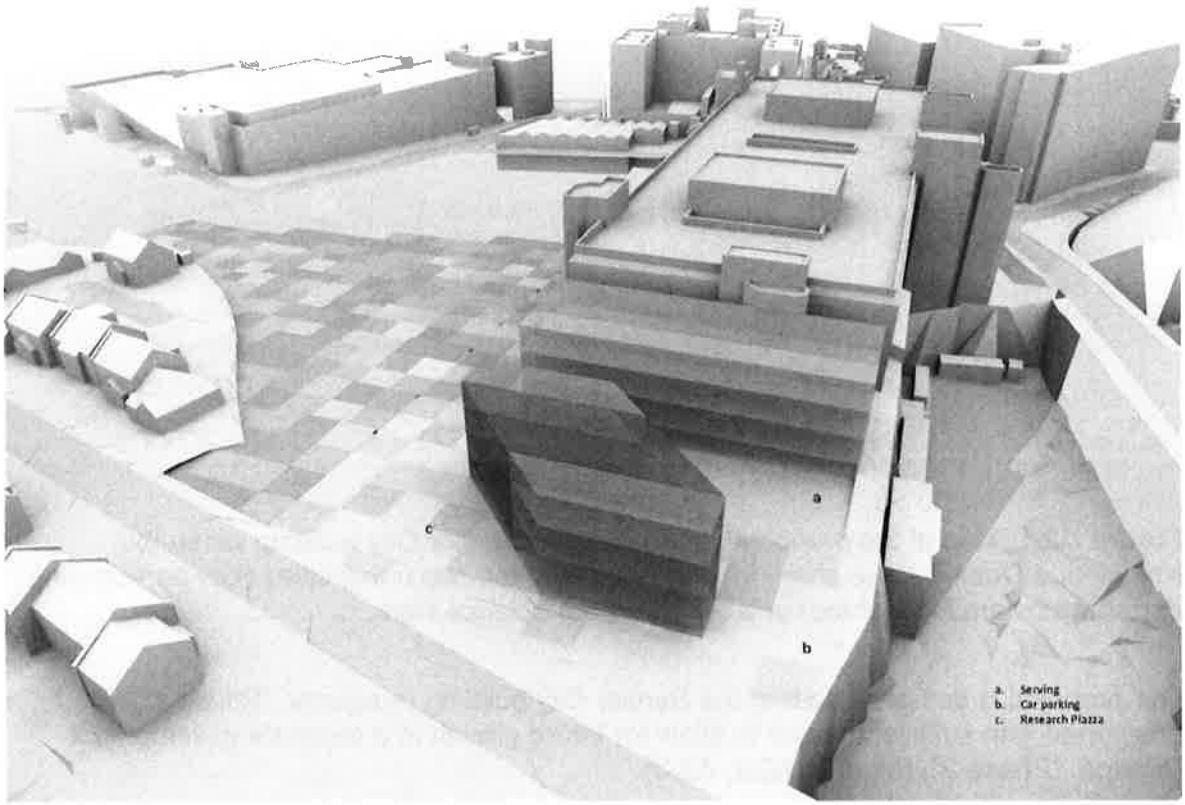


Figure A2.3. Indicative 3D plan of the Sensor City building (magenta, "Phase 1") together with provision for possible future expansion (orange, "Phase 2").

Annex 3: Knowledge Exchange Centres with Academic Involvement

The universities have a strong track record of company engagement in areas that relate to sensor technology development. Academics from the following centres will be amongst those who provide the expertise that UEZ will draw on.

The **General Engineering Research Institute (GERI),** based within LJMU is active in a variety of fields ranging from optical metrology, advanced manufacturing technology, radio-frequency & microwave research to electronics, image processing and mechanical engineering.

Centre for Intelligent Monitoring Systems (CIMS), of UoL provides small companies with unrivalled expertise in sensor technology, software development, telemetry, system integration together with a unique approach to sensor systems and has a worldwide reputation in sensing and monitoring systems.

The **Virtual Engineering Centre (VEC),** a UoL advanced virtual science & technology centre for development of virtual-based applications through an integrated university-industry partnership model currently serving over a dozen sectors. The VEC is digitally connected to other institutes and industry partners and will be interconnected and integrated into the Sensor City facility.

The **Nanoinvestigation Centre at Liverpool (NiCaL)**, supported by the European Regional Development Fund (ERDF), provides regional SMEs with access to UoL's most advanced and powerful electron microscopy facilities. To date NiCaL has assisted 45 small businesses based in the Northwest.

Built Environment and Sustainable Technologies (BEST) Research Institute at LJMU has expertise in areas that include virtual design and architecture, wastewater treatment, non-invasive and wireless sensors, energy systems, green design and sustainable building.

The **Centre for Material Discovery (CMD)** is a UoL advanced high-throughput chemistry laboratory that provides factory automation in new compound discovery and development for a wide range of industries that will also incorporate sensor materials and designs. The CMD was created through a combination of RDF, ERDF, UoL & Unilever funding and has enjoyed an 8 year successful range of partnerships with industry SMEs and large companies, including Unilever.

Annex 4: Areas of Expertise in Sensor Technologies and our Academic Expertise

Areas of Expertise

Sensor Technologies	Types

Sensor Technologies	Types

Academics engaged in sensor and sensor system research

Department / Centre / Institute	Academic

Department / Centre / Institute	Academic

Annex 5: Recent Sensor Technology Developments by our Academics

The following Case Studies are provided to highlight our capabilities:

1. Detectors for high energy physics, nuclear structure and healthcare applications
2. Centre for Intelligent Monitoring Systems
3. Smart product improvement
4. Mini Mass Spectrometer
5. Patient Positioning
6. Wearable Sensors

Case Study 1

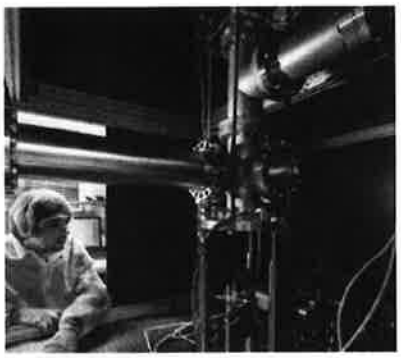
Detectors for high energy physics, nuclear structure and healthcare applications

Physicists based in Liverpool design and build world-class particle detector systems incorporated at the heart of the Large Hadron Collider (LHC), CERN.

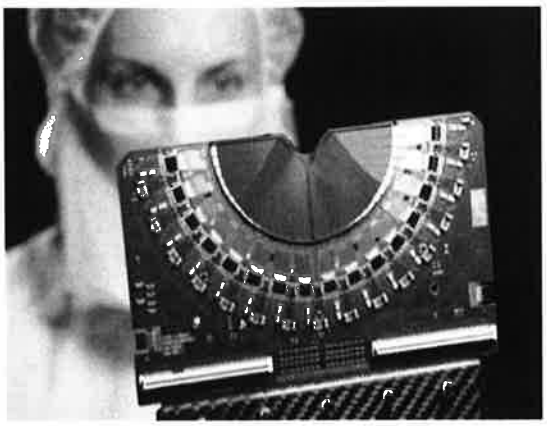
These detectors were used in the ATLAS experiment responsible for the discovery of the Higgs boson, as well as in LHCb experiments understanding matter/anti-matter asymmetry in the universe and ALPHA studying anti-Hydrogen for the first time.

Each project has pushed technological advancement in radiation and particles detectors to new and more ambitious limits, with spin-off benefits now appearing in other applications. These include:

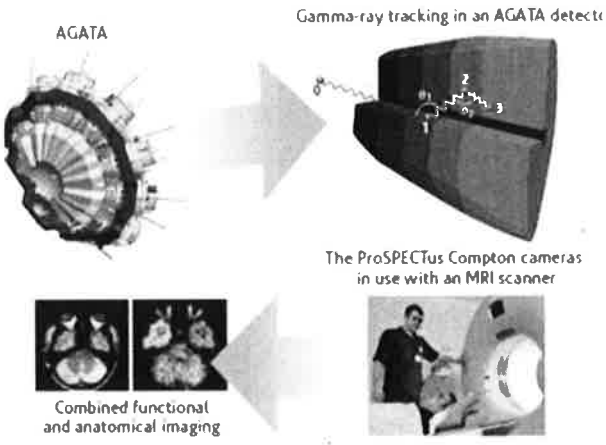
- **Healthcare** – where more sensitive, higher spatial resolution detectors are bringing direct advantages to clinicians and patients
- **Security** – thanks to novel scanning techniques and portable radiation imaging systems
- **Energy** – for both operations and decontamination processes on civil nuclear sites and increasingly of interest in oil and gas exploration.



Cold-atoms interferometry represents the new frontier (1) for the detection of radioactive materials by sensing their gravity fields and (2) for inertial navigation systems alternative to current GPS technology. We collaborate with Nobel Prize winner Martin Perl on this exciting field.



The LHCb VErtex Locator (VELO); the most up-to-date, state-of-the-art particle detector ever built.



Next generation single photon emission computed tomography (ProSPECTus) will reduce the time needed to detect brain tumours. We are helping to improve both the diagnosis and treatment of cancer

Case Study 2

Centre for Intelligent Monitoring Systems

The Centre for Intelligent Monitoring Systems (CIMS) is an internationally renowned applied research and development centre, based in the University of Liverpool. It builds on combined strengths of sensor technology, software development, telemetry, system integration together with a unique approach to sensor systems.

CIMS translates research into working, pre-commercial prototype sensor systems to develop and improve a wide range of applications which have been identified by our industrial partners. These applications are in industrial processing, healthcare, environment and energy sectors.

The purpose of these sensor systems is multi-fold, covering for example quality assurance, assistive living, particulate detection and condition monitoring.
Funding for the research and development has been received from Japan, China, USA, Europe and the UK.
The research and development capability of CIMS and the sensor systems are constantly being extended through the development of point-of-care diagnostic systems with MAST (a manufacturer of diagnostic products); the detection of jaundice in India with a mobile phone device; and domiciliary healthcare products, which won an e-innovation award from the Deputy Prime Minister's Office.

Condition monitoring of a transformer

Monitoring Neonates for bilirubin

Fuel sensor system

Case Study 3

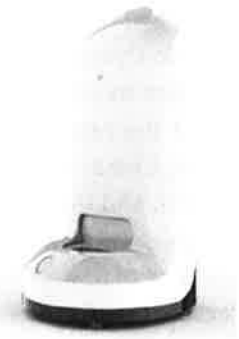
Smart product improvement

The hard- and software components of an existing machine belonging to clinical microbiology specialist firm Mast Group were becoming obsolete. Then they asked Liverpool to help incorporate the latest technologies into its new product to enhance performance and to address new markets.

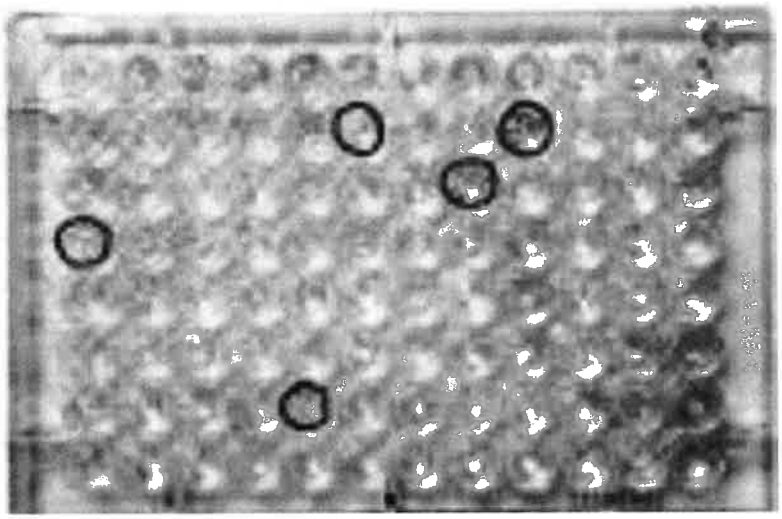
The redesign incorporated technology developed by researchers from the Centre for Intelligent Monitoring Systems (CIMS). This technology was embedded into both the sensor hardware and software of the machines. By incorporating cutting edge sensor systems, Mast Group were successful in producing a machine with greater performance and capabilities than their predecessor product.

Outcomes

- New superior machine is now commercially available
- Knowledge has been transferred to the company and additional products have also been updated
- Mast's new high performance machine has a competitive edge over competitor products
- Mast Group subsequently applied for and was awarded further TSB funding for a separate project, and are working with Professor Spencer to create more new products.



A URI plus system developed from the Knowledge Transfer Partnership



Microtiter plate used in the uri plus

Case Study 4

Mini Mass Spectrometer

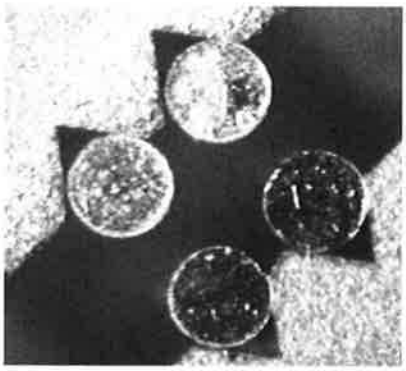
Liverpool has the 1st patent on a miniature quadrupole mass spectrometer (QMS) which led to the creation of a new spin-out company: Q-Technologies.

Original technology used gold coated optical fibre on a silicon substrate to achieve the world's smallest ever QMS and the first to be micro-engineered in silicon.

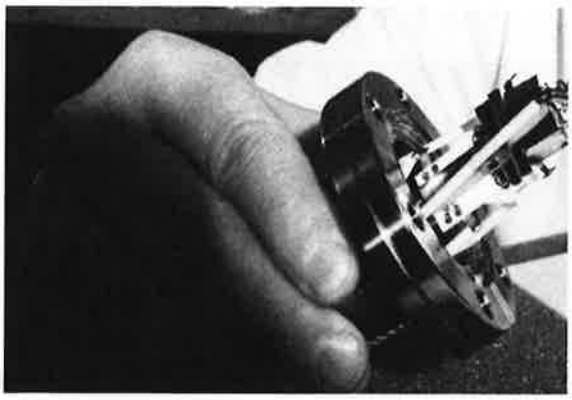
The market for portable MS is huge (multi-billion pound) with applications in security and forensics, process monitoring, environmental and biomedical sensing.

A recent €3.2 million Framework 7 collaboration between eight European partners demonstrated a new, low-cost MS using novel additive manufacturing techniques. The patents are held by Q-Technologies, a high-tech SME.

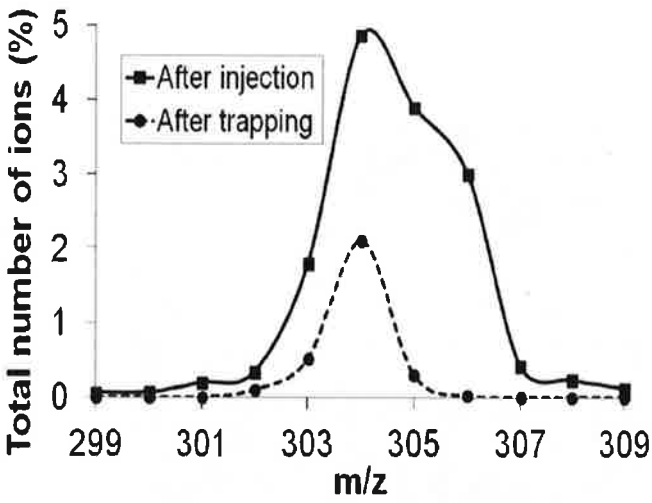
This new approach will allow a greater mass range in a smaller footprint than hitherto, allowing greater scale of impact than was previously possible. The new technology will also drive further business growth and performance at Q-Technologies.



Micro-machined quadrupole mass filter showing gold coated optical fibres in silicon wafer holder developed at the University of Liverpool. Patents held by Q-Technologies



Micro-engineered QMS including source and detector on a vacuum flange.



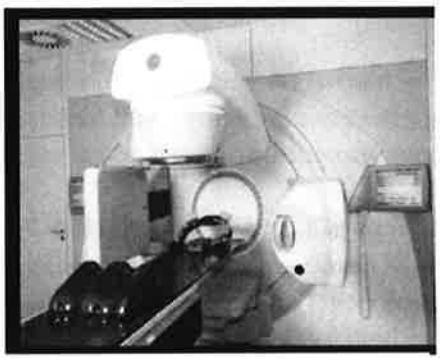
Mass window isolation of cocaine fragment m/z 304 Spectra obtained using handheld artificial sniffer MS developed under SNIFFLES (www.sniffles.eu)

Case Study 5

Patient Positioning

Radiotherapy is a highly successful treatment for cancer. Recent progress in medical imaging and developments in the understanding of radiation biology are pushing it to new limits. Clinicians need methods to precisely measure 3-D patient position during treatment. A new sensor system from LJMU delivers this capability.

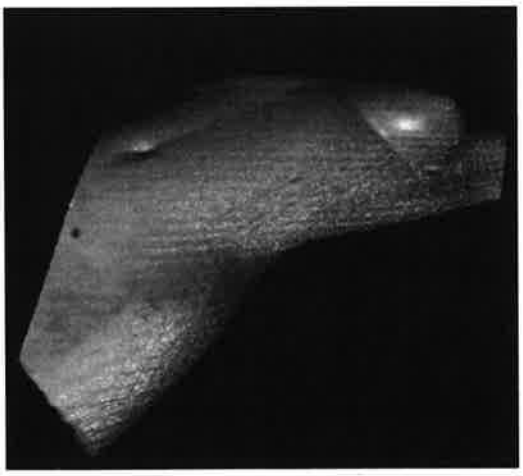
Radiotherapy is becoming increasing targeted. This delivers both better treatment and also spares healthy tissue from unnecessary radiation dosage. If targeting can be improved, then treatment can become more radical and aggressive, leading to improvements in cure-rates and the ability to safely treat tumours close to critical organs.



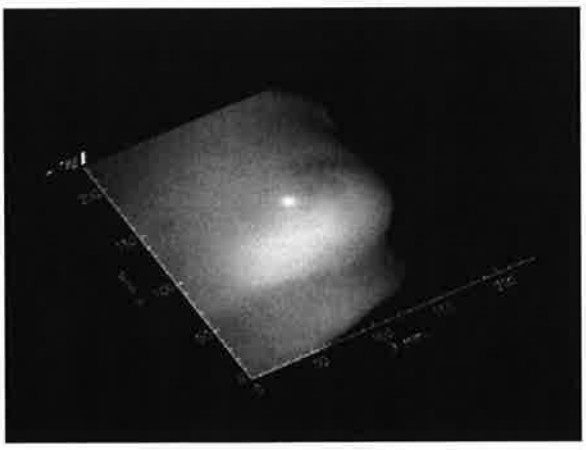
A typical radiation therapy treatment machine in a hospital.

During two European Framework programmes, and a major EPSRC grant, the team at LJMU have developed the world's fastest 3-D body scanner. Based on optical structured light techniques, the three view sensor achieves a measurement rate of over 12million (x,y,z) 3-D data points per second to sub 0.5mm accuracy.

Initially developed in the laboratory, the system has been installed in the treatment rooms of one of the UK's leading centres for cancer treatment, where it has already delivered exciting new results in two clinical trials.



Torso measurement for precise patient location during treatment.



Still image of a 3D reconstruction of a patient breast under treatment. The system can produce over 30 such images per second.

Case Study 6

Wearable Sensors

A major recent breakthrough (2013) in wearable sensor technology has been developed that can be woven into any garment. It allows monitoring of a patient's vital signs, such as heart rate, blood oxygen levels and temperature, in a way that is non-invasive, wireless and battery-less.

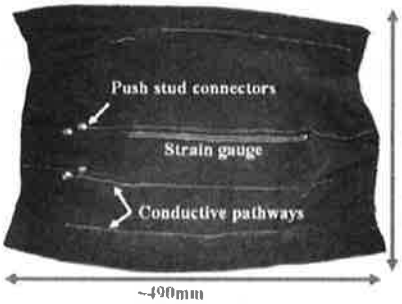
Invisible, and undetectable to the wearer, these non-invasive sensors are sensitive enough to pick up a wide range of vital signs and can transmit these readings in real time to devices located many metres away.

This landmark achievement was chosen to be the 2,500,000th UK patent in recognition of the importance of its potential impact.

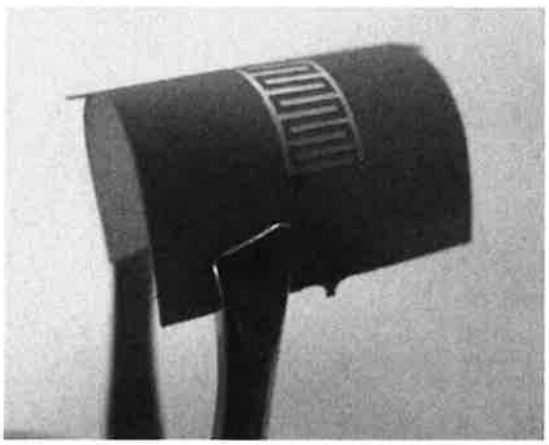
The range of potential applications for this wearable sensor technology is immense, not just in the healthcare sector but also in sporting and military applications.

The traditional hospital identity bracelet, for example, could eventually be adapted to include this sensor technology. Garments could also be developed for people with dementia living in the community, giving care workers a non-invasive way of monitoring their health and wellbeing.

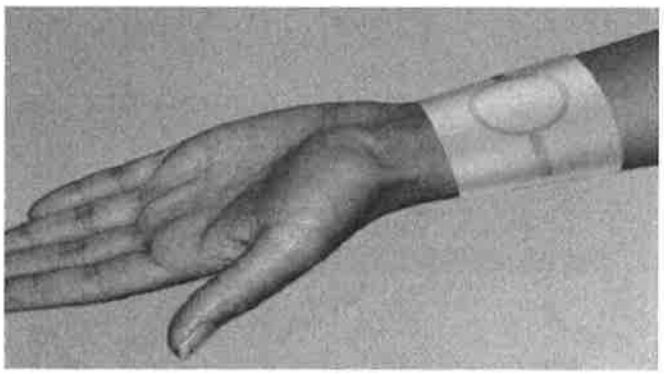
Ultimately, whether worn in the hospital or at home, this technology could represent significant potential cost-saving advantages for the NHS and could also improve patient care.



Flexible sensors woven inside cloth



Flexible sensor



Flexible sensor can be embedded in plastic or bracelet for non-invasively measurements of diabetes

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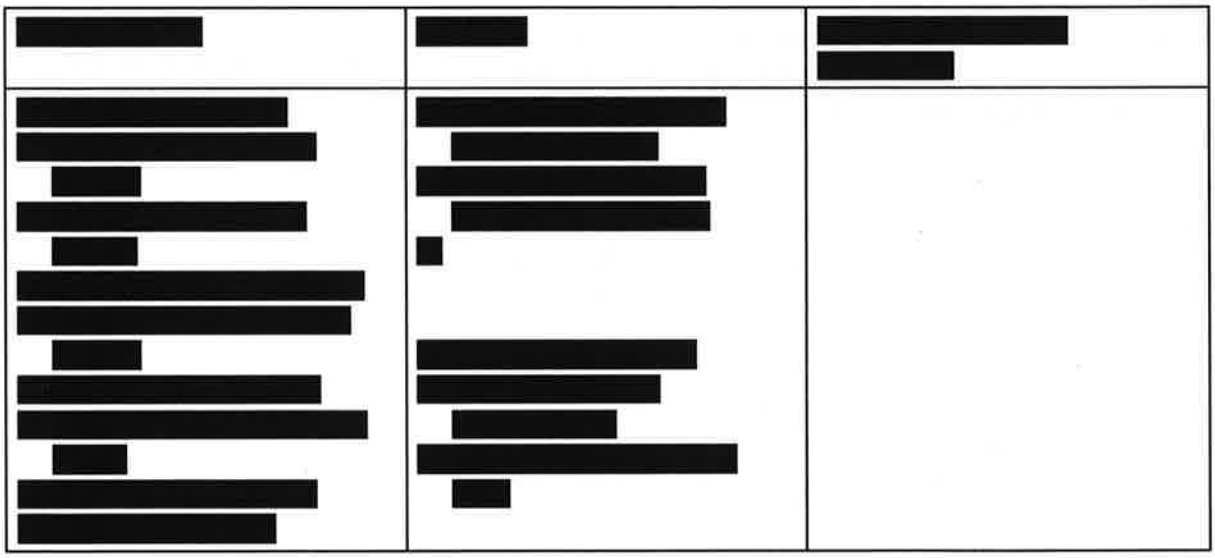

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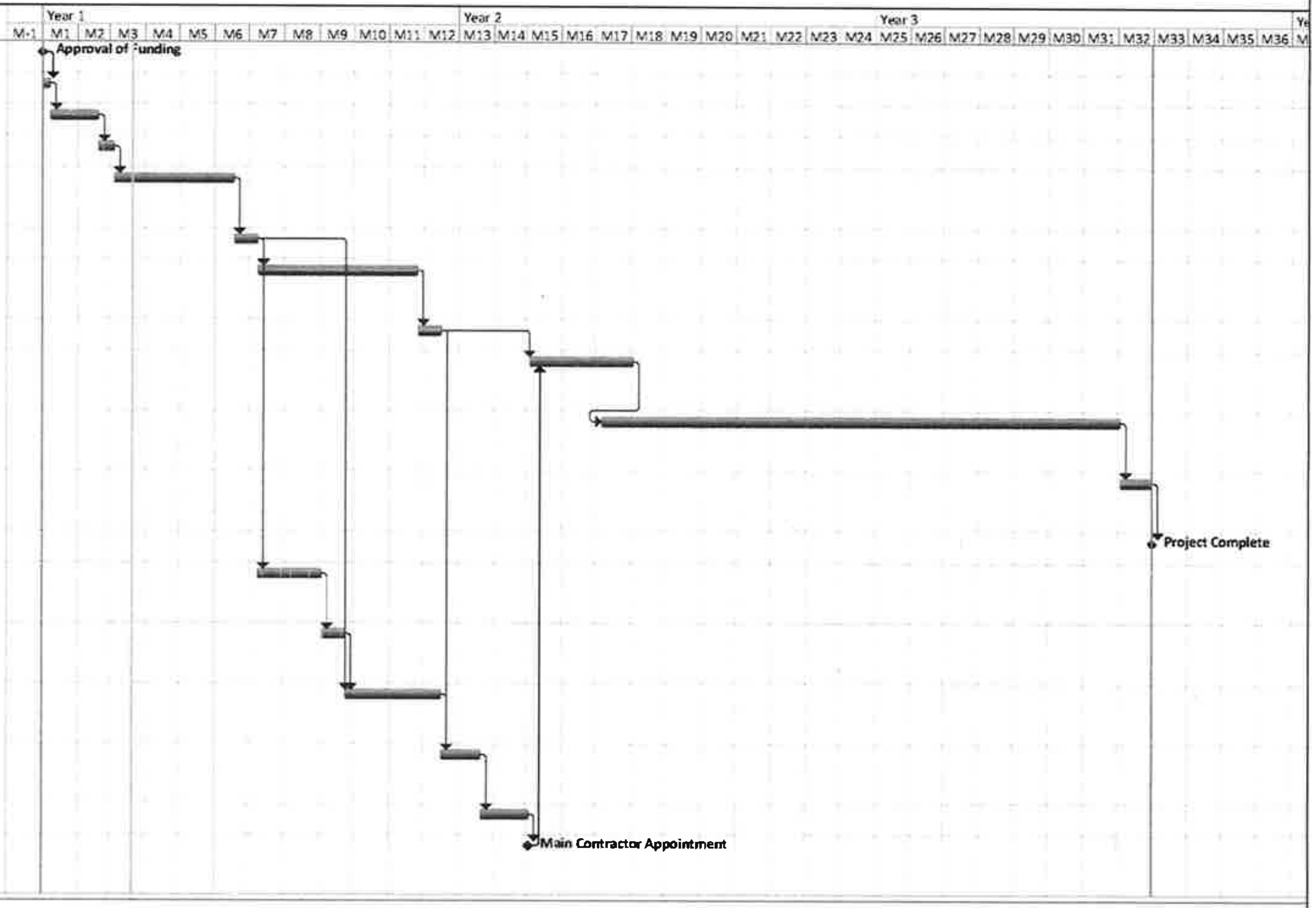
SENSOR CITY MASTER PROGRAMME

ID	Task Name	Duration
1	Approval of Funding	0 days
2	Instruct design team	5 days
3	RIBA Stage 1 Preparation	6 wks
4	Stage Approval	2 wks
5	RIBA Stage 2 Concept Design	15 wks
6	Stage Approval	3 wks
7	RIBA Stage 3 Developed Design	20 wks
8	Stage Approval	3 wks
9	RIBA Stage 4 Technical Design	13 wks
10	RIBA Stage 5 Construction	65 wks
11	RIBA Stage 6 Handover and Close Out	4 wks
12	Project Complete	0 days
13	1st Stage Contractor Tender	8 wks
14	1st Stage Contractor Appointment	3 wks
15	Contractor works with Design team under PCSA	12 wks
16	Contractor prepares fixed price tender sum	5 wks
17	Tender Analysis	6 wks
18	Main Contractor Appointment	0 days



Project: Sensor City
Date: Fri 21/03/14

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Deadline · Progress

Page 1

Figure A9.2 Indicative timeline and milestones for the construction phase