Institution: The University of Leeds (UoL)

Unit of Assessment: UoA 9 School of Physics and Astronomy (PHAS)

a. Context

As detailed in REF5, this UoA comprises five major research groups: Astrophysics (AP), Condensed Matter (CM), Molecular and Nanoscale Physics (MNP), Quantum Information (QI) and Soft Matter Physics (SMP). Our research leads predominantly to technological and economic impact, realised through a range of companies, from start-ups based on specific research applications through to established companies licensing IP/technology or partnering with our academics to develop impact. The end-user sectors in which we generate impact are **(1) Healthcare; (2) High value chemicals and manufacturing; (3) Digital technology and communications; (4) Instruments and sensing; (5) Energy**. Our three Impact Case Studies selected for this REF come from sectors **(1)** and **(2)**.

b. Approach to impact

BREADTH: The School and UoL actively encourage the commercialisation and generation of impact from research outputs. We increasingly embed partnership-working with potential stakeholders as early as possible in the specification of 'challenge-led' research programmes to maximise potential impact. Over many years we have applied our research and established strong collaborative and impact links into a wide spectrum of technology sectors:

(1) Healthcare (labels (a)-(e) for later reference)
(a) *Drug design and characterisation* (MNP microfluidics and spectroscopy/imaging research)
(b) *Drug delivery* (MNP microfluidics; SMP biomolecular simulation of protein and nucleic acid dynamics and interactions)
(c) *Cosmetics and Personal Care* (SMP and MNP membrane and lipid bilayer research)
(d) *Magneto-Cardiogram Technology* (QI magnetic imaging and sensing research)
(e) *Medical Diagnostics* (SMP NMR science and technology)
(2) High value chemicals and manufacturing (labels (f)-(h) for later reference)
(f) *High Impact Materials* (for body armour, luggage, sports equipment, loudspeakers) (SMP materials and processing research)
(g) *Designer Plastics and Polymers* (SMP research on the dynamics of entangled polymers)
(h) *Cellulose Processing Technology* (SMP materials processing and NMR research)
(3) Digital technology and communications (labels (i), (j) for later reference)
(i) *Spintronic Devices* (CM spintronics research)
(j) *Communications Technologies* (AP radio data communication system research and QI quantum cryptography research)
(4) Instruments and sensing (labels (k), (l) for later reference)
(k) *Pipeline Imaging Technology* (QI magnetic imaging and sensing research)
(l) *RAMAN Microscope Technology* (MNP Raman spectroscopy research)
(5) Energy (label (m) for later reference)
(m) *Battery Technology* (underpinned by SMP research on polymer gels)

APPROACH: The School follows a **two-stage** approach to impact. **Stage D: technology and application DEVELOPMENT** and **Stage T: technology and application TRANSFER**. We select on a case-by-case basis from the numerous support mechanisms available through the UoL central Research Innovation Service office (RIS) and their Commercialisation Services (CS) team to support individual developments.

- **DEVELOPMENT:** This stage is underpinned by parallel and complementary support mechanisms, which we utilise specific to each impact case:

D(i) *Sector Hub Funding*: Higher Education Innovation Funding (HEIF) and other developmental funding at Leeds is exploited through a Sector Hub Model, to develop impact and innovation pathways, and to build partnerships and knowledge exchange. The Hubs enable focused and strategic links to industry sectors and partners. For each impact direction, we engage the relevant Sector Hub (e.g. Digital Technologies, High Value Chemicals and those in the Healthcare cluster).
D(ii) *IP Protection and Management*: We engage the UoL RIS CS team for advice, support and

budget for IP protection strategies and their implementation with UK and International IP filing.
D(iii) *Opportunity Development*: We engage the RIS CS team for support in exploitation of IP through market scoping and validation, business model design and access to Proof of Concept funding, including a dedicated University Enterprise Fund (based on previous equity realisation and licence income) and regional and national support schemes for innovation.
D(iv) *Collaboration*: UoL has a strong track record of impact generation through the approach of cross-School or cross-Faculty collaboration. We also engage in direct collaboration with external and industrial partners *early,* i.e. prior to transfer (stage ***T***). E.g. SMP work with Unilever, through the Sector Hubs in ***D(i)***, or focused arrangements with specific companies. We utilise the RIS CS team for support with establishment of contracts and agreements to facilitate our collaborations.

- **TRANSFER** to initiate Commercialisation and Impact: We engage the RIS CS team evaluating and adopting routes to commercialisation of our most promising opportunities through a stage-gate decision-making process:

T(i) *Licensing and partnership with existing companies*: The approach provides support in commercial partner search, either through the open innovation portal Leeds Innovation Network, or through building on Sector Hub strategic links (see ***D(i)***), and support in licensing term negotiations and legal agreements.
T(ii) *Company creation and Spin-out*: We utilise the RIS in-house expertise and support for preparation of business plans, fund raising, company creation and the building of company management teams. Spin-out can be done in partnership with the UoL strategic commercial partner IP Group PLC, or directly (with appropriate external Venture Capital or equivalent support). IP Group PLC has a Leeds campus office and provides further developmental funding, followed by expanding, staged investment through all regimes of new company growth.

Another very important impact factor for this spin-out route to commercialisation is the transfer of staff (academic and/or PDRAs/students), which provides both knowledge and expertise transfer.

EVIDENCE for completed and highly successful use of the two-stage approach to impact is clear in our selected case studies (see section **d.**). The Renishaw Raman Microscope came through paths ***D(ii)(iv)***, followed by ***T(i)***. The formation of Avacta was via paths ***D(ii)(iv)***, followed by ***T(ii)***. Commercial high-impact polymer composites are founded on path ***D(ii)***, followed by both ***T(ii)*** (creation of Vantage Polymers), then ***T(i)*** (transfer to BP Amoco, now Propex Fabrics).

Further evidence of the two-stage approach across all user sectors **(1)-(5)**, is as follows:

Stage ***D(i)***: Examples include cosmetics applications with Unilever (c), spintronics research with Hitachi (i) and quantum communications research (j), with the latter now also moving to *stage* ***T(ii)*** through the formation of a new spin-out company CryptographiQ.

Stage ***D(ii)***: Across all technology sectors, the UoA research applications listed (a)-(m) utilise the IP Protection and Management support provided by the UoL RIS CS team. A significant and still-growing portfolio of IP exists across this spectrum, established over many years. Recent additions to this portfolio have been made under the application areas (b), (d), (j) and (k).

Stage ***D(iii)***: Applications of our quantum communications research (j) are supported through the University Enterprise Fund, to progress to a full technology demonstrator.

Stage ***D(iv)***: *Academic and commercial collaboration examples*:

- Novel cellulose processing (h) involves collaboration with Innovia Films: Ries has a Royal Society Industrial Fellowship supporting 50% of his time to develop this and this project is supported by a CASE studentship award.
- Cosmetics and personal care (c) with a lipid skin mimic system has received support from Yorkshire Forward. The strategic collaboration between the UoA SMP group and Unilever provides scientific underpinnings for the well known Dove brand of cosmetic products.
- Our application of magnetic imaging techniques to detailed magneto-cardiography (d) received initial faculty HEIF funding then progressed to University-level IP support. This has now progressed to patient trials, involving collaboration between the UoA QI group and staff in the UoL Faculty of Medicine and Health.
- Our application of magnetic imaging techniques to pipeline defect imaging (k) has now progressed from stage ***D(iv)*** to field trials. This development is in collaboration with

Electronic & Electrical Engineering and Speir Hunter Ltd., the latter funding a studentship.

*Stage **D(iv)** through to stage **T(ii)***: Another major highlight of our impact, evidencing complete progress through our impact approach, is the formation and successful spin-out of a UoL company (Comms Design Ltd, http://www.commsdesign.ltd.uk), also involving academic staff transfer. This began with research collaborations between our AP group and staff in Electronic & Electrical Engineering to solve the problem of radio frequency communication, data collection and error correction between ~1600 detectors in the distributed Pierre Auger Observatory. The technology was more effective and cheaper than any commercially available solution (j), so progressed from stage ***D(iv)*** through stage ***T(ii)***. Comms Design Ltd. is generating significant impact (2008 on), e.g. supplying the token system for the Scottish railway network, and with the UltraCane Mobility Aid.

*Stages **D(ii)(iv)** through to stages **T(i)(ii)***: Battery Technology impact (m) has arisen from the application of our research and IP in polymer gel-electrolytes, starting with stages ***D(ii)*** and collaboration ***D(iv)*** through the EPSRC IRC in Polymer Science and Technology at UoL (1984-94). Impact has progressed to stages ***T(i)*** and ***T(ii)***, with both a licensing agreement established with the battery company PolyStor, and the formation of a spin-out company, Leeds Lithium Power.

c. Strategy and plans

STRATEGY: To realise new impact from our research, we follow both bottom-up (research-driven) and top-down (user or sector-driven) strategies to:

- Regularly monitor our latest research activity for future application and impact potential.
- Engage industry and other stakeholders early, in the design of new research activity and to guide new research directions and priorities.

This maintains an active portfolio of technology applications across all the sectors for impact **(1)-(5)**. For each new application, we utilise all the appropriate stage (***D***) routes and opportunities (see section **b.**) for technology and application development. At present our efforts focus on Healthcare **(1)** and Digital Technology **(3)** through the HEIF Sector Hubs that support these areas, and on Chemicals **(2)** and Imaging **(4)** through early stage industrial partnership and collaboration.

EXECUTION: The strategy is executed through our Research and Innovation (R&I) Committee, comprising the Director of R&I (DoR&I) as Chair, Head of School, Heads of research groups. This Committee has responsibility for delivery of the impact strategy and plans. It provides monthly communications to all UoA staff on the latest stage (1) opportunities for research application and exploitation, and regular updates from UoL RIS. The DoR&I sits on the Faculty-level R&I Committee, providing input to and communication from the higher level University strategy for impact. The current DoR&I, who has 14 years of experience working at a senior level in industrial R&D with Hewlett-Packard, provides advice for UoA staff on impact, communication and support for taking up stage (***D***) opportunities, and facilitates links to the appropriate staff in UoL RIS, to progress impact generation from our research. We have established an Industrial Advisory Board and two Technology Officers have also been employed in research groups in the UoA, to engage end-users early and to identify specific industry opportunities and potential market sectors for emerging research, leading, for example, to a new collaboration with Hitachi on spintronic devices.

d. Relationship to case studies

Our case studies evidence completed paths through our two-stage (***D*** then ***T***) approach to impact:

***Case Study 1*: *Renishaw Raman Microscope*:**
Economic impact has arisen through the world's best-selling Raman microscope. The impact grew from early stage-collaboration between the MNP group and the Spectroscopy Division of Renishaw PLC, leading to their current Raman products. (Impact path ***D(ii)*** and ***D(iv)***, followed by ***T(i)***.)

***Case Study 2*: *Pharmaceutical Company Avacta*:**
Economic impact has arisen through a successful University of Leeds spin-out company Avacta. Their commercial pharmaceutical analysis and characterisation system (the Optim 2) is based on MNP group research and IP in spectroscopy/imaging and microfluidics. (Impact path ***D(ii)*** and ***D(iv)***, followed by ***T(ii)*** and including staff transfer of Smith who moved to become CEO of Avacta.)

***Case Study 3*: *Lightweight, high-impact polymer composites*:**
Economic impact has arisen from the application of SMP Group research and IP in materials processing (hot compaction), leading to lightweight, high impact polymer composites, used in anti-ballistic body armour, sports goods (Nike, Bauer), lightweight luggage (Samsonite), audio speakers (Wharfedale) and radar covers for helicopters (Westland). (Impact path ***D(ii)***, followed by ***T(ii)*** (creation of Vantage Polymers), then ***T(i)*** (transfer to BP Amoco, now Propex Fabrics).