National Research Facility - Community Statement of Need

Q1. Name of the facility

National facility for ultra-high field (11.7T) human MRI scanning

Q2. Please provide the name, institution and e-mail address of the Principle Author of the Statement of Need (the person who is coordinating and leading in the submission).

Professor Richard Bowtell, University of Nottingham (richard.bowtell@nottingham.ac.uk)

Q3. Vision/Quality: Present the science that will be enabled by the proposed National Research Facility. Applicants should provide evidence of the quality of research to be facilitated and the research areas which will be supported alongside why this facility is now needed and will be needed over the proposed 5 years of running. If the facility would enable cross-disciplinary research, please state which other council's remit(s) this would fall.(6,000 characters incl. spaces)

Vision: A national facility for ultra-high field human MRI scanning, bringing together the UK research community to realise the substantial benefits of 11.7T MRI and to exploit the advanced capabilities of an 11.7T scanner in ground-breaking studies which address crucial questions in biomedical research. This will impact on the portfolios of MRC, BBSRC and EPSRC.

Quality: Magnetic resonance imaging (MRI) and spectroscopy (MRS) provide powerful insights into the structure and function of the human body, enabling the study of anatomy, physiology and metabolism, dynamically and non-invasively, in health and disease. MRI and MRS underpin research programmes across the whole of biomedicine, from basic human biology and neuroscience to experimental medicine studies of the mechanisms of disease and therapies.

The development of MRI has followed a trajectory towards ever increasing magnetic field strength, driven by the increases in sensitivity and contrast offered by operating at high field. As stated in a recent MRC review

Ultra-high field (UHF) MRI represents the cutting edge of biomedical imaging in humans and is an area of intensive research and development internationally. Over the last decade, 7T MRI scanners have evolved significantly, as they have undergone the transition from bespoke research systems to clinical research tools within the reach of the broader imaging community……7T MRI has greatly enhanced the range of anatomical, functional and metabolic features that can be detected in vivo, particularly in the brain.

We now have more than 14 years' experience of 7T MR in the UK, and UK-based researchers have helped to establish the efficacy of 7T MRI. Through the UK7T Network, the UK's 7T sites have gained valuable experience of working closely together. Experience at 7T and recent technological advances, have led to considerable international excitement about the potential of UHF (> 7T) for human MRI. A small number of 9.4T scanners are producing impressive results, 10.5T and 11.7T scanners are poised to deliver and 14T scanners are being considered in Europe and China. This is similar to the situation that pertained just before MRI successfully moved to 3T, and later, 7T. For UHF to gain real traction a concentrated national-level effort is now needed to realise its full benefits. We believe that a step change in performance can be rapidly delivered at 11.7T, enabling swift advances in applied biomedical imaging, while the considerably larger costs, risks and timescale involved in developing a 14T scanner, make this an aspirational goal for the future. The potential gains offered by 11.7T are great, but technical advances in engineering, physics and computer science are required to deliver them. The world-leading, closely-knit

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UK research community is well-placed to undertake the coherent programme of work required to develop and exploit 11.7T.

Increased signal at 11.7T will translate into much richer information content in structural and functional imaging in the human brain and body. The signal-to-noise-ratio (SNR) of brain images will more than double from 7T levels, and sensitivity to key MRI markers of tissue properties also increases. This is particularly the case for sensitivity to myelin and iron, which are important markers of neurodegeneration and neurodevelopment. Higher field provides stronger BOLD (blood oxygenation level dependent) contrast that forms the basis of most functional MRI of the brain. BOLD contrast scales approximately linearly with field strength, leading to a near quadrupling of the BOLD contrast-to-noise ratio from 7 to 11.7T. This massive gain in sensitivity will allow brain activity to be probed in unprecedented detail, enabling reliable assessment of brain function at a mesoscopic level, bridging the gap between invasive electrophysiology and microscopy techniques and standard neuroimaging. As is evident from pre-clinical work, UHF also offers great benefits for studies of metabolism in health and disease using NMR signals from ^{1}H and other nuclei. Gains in SNR for MR studies involving other nuclei (e.g.^{13}C, ^{2}H, ^{23}Na, ^{7}Li and ^{31}P), are even greater than for ^{1}H and these benefits are amplified by the greater spectral dispersion at 11.7T. Increased spectral dispersion and slower longitudinal relaxation also improve the specificity and sensitivity of ^{1}H chemical exchange saturation transfer (CEST) measurements. These factors will produce a step change in metabolic mapping capability by reducing the acquisition time required for useful spatially-resolved measurements to a participant-tolerable duration.

These gains will lead to:

- Robust acquisition of fMRI data at 500-μm isotropic resolution, facilitating the characterisation of the laminar and columnar architecture of the human brain over extended cortical regions, and allowing the direction of information flow to be evaluated by comparison of laminar signals.
- Anatomical images with sub-100 μm resolution, providing histological levels of detail for identification of changes in brain architecture and microstructure in neurodegenerative diseases, and neurodevelopmental disorders.
- Improved measures of metabolism in the human body, transforming our ability to undertake non-invasive studies of human physiology, providing new insights into human biology and the mechanisms of disease and therapy.
- Development of new MRI technology, along with the image acquisition and processing methodology, needed to realise the full benefits of 11.7T, also yielding considerable benefits for MRI at lower field strengths.

Insights into brain structure and function will be of immediate benefit to researchers in neuroscience, neurology and psychiatry. New measures of metabolism and organ function from basic physiology to studies of disease will be of value across the biomedical community, including life science industry. Engineers, physicists and computer scientists will be engaged in the development of new UHF technology.

Q4. Users and Community Engagement: There must also be information and evidence on the level of community engagement and support that has led to the Statement of Community Need. The Statement of Community Need must be presented as a community backed document. A description of the UK communities that will benefit from the usage of this facility needs to be present, including the expected number and type of users (both academic and other stakeholders). Specific information should be provided on key research groups and their underpinning funding portfolio. Projected growth of the user base over the next 5 years should be indicated. (6,000 characters incl. spaces)

The UK holds a world-leading position in medical imaging research. The EPSRC medical imaging portfolio is currently £97.7M with similar levels of investment in this area by MRC and Wellcome. The researchers listed under Q.9 are directly supported (as PIs) by >£50M of current research funding from UKRI and Wellcome, with additional funding from a range of other sources (including EU, NIHR, Alzheimer's

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Research UK, BHF, CRUK, MND Association, Parkinson's UK, UK MS Society, Spinal Research and Versus Arthritis).

The drive to establish this national facility has been stimulated by recent advances in the physics and engineering that underpin high-field MRI, growing understanding of the efficacy of 7T MRI, and ongoing work to establish UHF MRI capabilities in other countries (e.g. plans for a 14T MRI scanner in Germany, and a concerted US effort to gain support for a 20T MRI scanner). An UHF MRI workshop (> 130 attendees) was held in Nottingham in January 2019 to promote community engagement in the development of an UHF facility. It brought together international pioneers of UHF MRI with potential developers and users of UHF MRI in the UK. This statement has been developed over a one-month period, based on input from ~90 researchers from 20 different organisations (see Q9).

UK communities to benefit from the facility include: neuroscientists, who will exploit the increased spatial specificity and sensitivity at 11.7T in interrogating brain structure and function; clinicians and life scientists (in academia and industry), who will use UHF MR to investigate disease mechanisms and therapies in the brain and body; physicists and engineers, who will develop and apply new techniques and hardware for UHF MR; computer scientists and mathematicians, who will exploit the previously unattainable spatial resolution and information content of 11.7T data.

Examples of science to be enabled, include (participating sites noted):

Assessment of brain function at a mesoscopic level: (i) establishing laminar-specific fMRI as a tool for investigating information flow in the cortex during task execution and for evaluating mesoscale connectivity, underpinned by improved understanding of laminar haemodynamics (*Birm, Cam, Gla, Nott, Oxf, Suss, UCL*); (ii) probing the evidence for columnar organisation in cortical areas outside the visual cortex (*Cam, Birm, Gla, Man, Nott, Oxf, Suss, UCL*); (iii) investigating changes in responses across laminae in neurodegenerative disease, specifically testing the hypothesis that Parkinson's and Huntington's disease affect deep layers of the cortex early in the disease course while Alzheimer's disease involves more superficial layers: combined with anatomical images this will provide mechanistic insights at the earliest stage of these diseases, when therapeutic intervention would provide greatest benefit (*Cam, Nott, UCL*).

Anatomical images with histological detail: (i) detection of microbleeds and their links to disease mechanisms including neuroinflammation, vasculopathy, trauma and neurodegeneration (*Cam, Liv, Mancs, Nott, UCL*); (ii) elucidation of neurodevelopmental disorders, including focal cortical dysplasia, and the earliest stages of neurodegeneration that are poorly seen at lower fields, using increased sensitivity to investigate the role of immune cells in neurodegeneration based on differential iron accumulation in microglia and macrophages (*Birm, Cam, Car, Ed, GSK, Imp, Liv, Man, Nott, UCL*); (iii) characterisation of sub-cortical structure for investigation of sub-nuclear pathology and improved targeting of therapeutic deep-brain stimulation (*Birm, Nott, UCL*); (iv) measurement of key structures (and physiological processes, such as vascularity and hypoxia), that underpin therapeutic success and clinical outcome in cancer, exploiting new contrast and theranostic agents (*Birm, ICR, Mancs, UCL*); (v) harmonising anatomical contrast at 11.7T to conventional histology through linked post-mortem MRI and microscopy (*Oxf*).

Improved measures of organ metabolism: (i) using ^{13}C-MRS and MRI to quantify endogenous metabolites and study the metabolism of exogenous ^{13}C-labelled metabolites (*New, Nott*); (ii) ^{19}F MRI for tracking perfluorocarbon-labelled cells in regenerative medicine studies and monitoring of neuroinflammation (*Cam, Gla, New*); (iii) using ^{31}P measurements to probe the mitochondrial redox potential through the NAD/NADH couple (resolvable in UHF preclinical systems, but so far challenging at 7T in humans), with particular application to psychiatric studies and investigation of cardiac disease (*Cam, KCL, Leeds, New, Oxf, Suss*); (iv) using ^{23}Na MRI to quantify cell volume fraction for evaluating atrophy in neurodegeneration, monitor therapy in cancer and investigate mechanisms of functional failure in multiple sclerosis (*ICR, Imp, Nott, Suss, UCL*); (v) exploiting increased spectral dispersion and sensitivity in 2-hydroxyglutarate measurements as a marker for isocitrate dehydrogenase mutation in tumours, particularly for assessing tumour heterogeneity (*ICR, Liv*); (vi) using CEST and deuterium metabolic imaging in measurements of normal and disturbed metabolism (*Cam, Car, GSK, Man, Nott, UCL*).

Developing new technology and methodology for MRI: (i) establishing national capability for UHF radio-frequency (RF) coil design and fabrication (*Bris, Gla, Nott, Sheff*); (ii) optimisation of pTx techniques,

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essential for imaging the head and body at UHF (*Cam, Car, KCL, Nott, UCL*); (iii) use of motion and field monitoring for prospective and retrospective correction of effects of movement in images and spectra (*Cam, Car, Nott, UCL*); (iv) investigating the effects of microstructure on contrast mechanisms (*Bris, Cam, Car, Nott, Oxf, UCL*); (v) using very high quality 11.7T data sets in conjunction with machine learning to augment data acquired at lower field via quality transfer (*Nott, Oxf, UCL*); (vi) developing 2D-MRS approaches for improved *in vivo* measurement of brain metabolites (*KCL, Man, Nott*).

Q5. National Importance and Context: A clear explanation of the existing UK and international landscape, in terms of the available facilities and equipment, and how the proposed facility will add value to this landscape. The Statement of Community Need should address existing capabilities of equipment and access to it and how an existing facility is a vital part of the landscape or how a new facility would enhance the landscape if none exist in this area. (4,500 characters incl. spaces)

The early years of MRI saw commercial manufacturers standardise operation at a maximum field of 1.5T. The UK played a leading role in the subsequent development of 3T scanners, with bespoke systems being developed in Nottingham and Oxford in the 1990's, before commercial systems became available in the early 2000's: the same UK sites also made important early contributions in demonstrating the potential of 7T field strength. Today, around 20% of the approximately 3,000 new scanner installations per annum operate at 3T, and with the recent CE approval and FDA clearance of the Siemens 7T Terra scanner for examinations of the head and extremities, sales of 7T scanners are accelerating and the range of applications of 7T MRI is rapidly growing.

At present, there are more than sixty 7T scanners worldwide. In the UK five 7T scanners are currently operational (in order of installation - Nottingham, Oxford, Cardiff, Cambridge and Glasgow), and two further installations are nearing completion in London (St Thomas' and Queen Square). The UK's 7T sites came together in 2016 to form the UK7T Network (funded by an MRC Partnership Grant) and this network has played an important role in UHF training, and in sharing expertise between sites, as well as in developing and harmonising sequences across 7T scanner platforms. The UK7T Network forms a successful model for multi-institutional collaborative work on high field MRI, which can be built upon to provide a management structure for a new national UHF MRI facility.

MRI scanners operating above 7T have been developed by a small number of individual sites internationally. There are three operational human 9.4T scanners in Europe (MPI for Biological Cybernetics, Tübingen, Germany; Maastricht, Netherlands) and the US (University of Illinois, Chicago), and one is under development in China (Institute of Biophysics, CAS, Beijing). Minnesota operates a 10.5T scanner and three 11.7T scanners are expected to become operational in the next two years (NIH, USA; Neurospin, Saclay, France; Gachon Medical University, Korea). Several national-level initiatives for developing UHF scanners are planned. In the US, a concerted effort to gain funding for a 14T scanner is underway, with the ultimate aim of producing a 20T scanner for the human brain. Germany and the Netherlands have both formed national consortia to develop 14T MRI systems (neither yet funded). We are also aware of at least two groups in China (Shenzhen Institutes of Advanced Technology & Peking University) who have received funding to begin the development of human 14T projects. In the pre-clinical domain, small-bore 9.4T and 11.7T imaging systems are in widespread use, with smaller numbers of systems operating up to 21.1T. There are good links between these sites and the UK research community.

In developing plans for a national UHF scanning facility in the UK, we have considered the optimal field strength in detail and have selected 11.7T, as it offers a significant increase over 7T in sensitivity for anatomical and functional MRI, as well as providing major benefits for spectroscopic measurements of metabolism and kinetics, based on ^{1}H and a range of other nuclei. An 11.7T scanner can be built around a magnet that uses the well-established NbTi wire technology that is employed in lower field scanners (although requiring pumping to achieve a wire temperature of ~2K). Such a magnet could be constructed in less than two years. By harnessing the collective effort of the UK MRI research community, we can therefore develop a powerful and versatile UHF scanner, that can be applied to studies of the brain and body within three-years of the start of funding. In contrast, a 14T scanner, although providing additional gains in sensitivity, would require more complex NbSn magnet technology, which is yet to be incorporated in standard human MRI scanners. Therefore, the cost, lead time and risk of failure involved in developing a 14T scanner are all significantly higher, and the time required to develop a working system would be greater than 5-years. The opportunity it offers rapidly to gain new insights into key clinical and scientific questions, combined with the lower risk, makes 11.7T the optimal choice for the UK.

The development of an ultra-high field MRI scanner facility operating at 11.7T will provide the UK research community with the opportunity rapidly to capitalise on the benefits provided by a step-change in field strength.

Q6. Impact: What potential impact will the proposed facility have on the research community, across the range of types of impact (scientific/academic, people, economic, skills and training, socio-economic etc.), and is there a clearly thought through pathway for expanding the user base and accelerating the identified impacts. For further guidance, please refer to:
http://www.epsrc.ac.uk/funding/howtoapply/preparing/impactguidance/ - please note this directed to an EPSRC audience and this needs to cover biomedical as well as EPSRC(3,000 characters incl. spaces)

A national facility for UHF (11.7T) MRI is needed to maintain the UK's position at the international forefront of research in the development and application of biomedical MR. It will form a focus for international collaboration, with direct links to the leading international sites who also aspire to develop an UHF MRI scanning capability, as well as drawing in collaborators without access to UHF technology in their own countries. The facility will attract and retain world-leading scientists in the UK – this would include clinicians, physicists, engineers, clinical scientists and neuroscientists. It will also provide a focus for training of researchers in the engineering, physics and application of UHF MRI, benefiting the wider MRI research community, including the UK7T Network. The contributors to this statement (Q9) collectively have an extensive network of multi-disciplinary collaborations within academia, industry and charities, which will be leveraged to expand the user-base of the facility.

As a platform for world-leading biomedical studies, the facility will have significant societal impact via provision of better understanding of brain function and anatomy in health and disease, along with new insight into normal and disturbed metabolism and physiology throughout the human body. It will also support pharma R&D by providing a flow of sensitive and specific biomarkers of disease that allow early interrogation of pharmacological response and so provide improved understanding of drug mechanisms.

The cutting-edge developments in MR technology, required to realise the benefits of the elevated field strength, will open up new opportunities for commercialisation, and, in many cases, these developments will also be applicable at 7T and lower field strength, so providing far-reaching benefits for research and clinical studies. Enhancing the UK's capability in RF hardware development will have significant enabling impact for MR research in the UK, potentially stimulating the development of new SME's, as has occurred in Germany and the Netherlands. Wide impact could also arise through use of ultra-high-resolution 11.7T data to augment lower-field measurements via machine learning. The improved understanding of microstructure, anatomy and physiology that 11.7T MRI/S will provide will also underpin improved acquisition, analysis and interpretation of lower field data.

UK industry has a leading role in the development and supply of magnets for MRI, and until recently had supplied all magnets for human MRI scanners operating above 7T. This document has been developed in discussion with Tesla Engineering Ltd, who have provided information on magnet characteristics. Tesla employs 150 staff who are engaged in UHF MR developments, and the associated supply chain underpins a significant number of specialist engineering jobs in the UK. The development of an 11.7T magnet for use in a national facility would provide a significant stimulus to the magnet industry.

Q7. The potential facility: A description of the type of facility service proposed and its primary function, including an indication of what the facility should provide to be of maximum benefit to the research community (what technologies and capabilities should be available, what services should it provide, what type and number of staff would it need). How will the facility include a move towards some element of cost recovery and sustainability.(6,000 characters incl. spaces)

We will develop an 11.7T MRI scanner that can be exploited by the UK research community in a range of studies, particularly for experimental medicine and neuroscience. Through a collective national effort, we will develop a state-of-the-art scanner that is optimised for operation at UHF, integrating recent enabling technical developments into the design, including open architecture, high-density RF receive arrays, pTx capability, and motion and field monitoring. The specification of the scanner will be developed with the community through a robust procurement process, preceded by an initial design phase. Elements of this design will facilitate the future development of more versatile scanners operating at lower field and help to shape the future development of even higher field scanners (14 and 20T).

The scanner will utilise an 11.7T magnet with a large enough bore (830mm) to accommodate gradient and RF coils that allow measurements to be made in the body, as well as in the brain. A gradient coil (610mm inner diameter) capable of producing gradient strength/slew rate of at least 80mTm^{-1}/200 Tm^{-1}s^{-1} will be incorporated, and an insert head gradient coil to provide significantly higher gradient performance for neuroimaging studies (e.g. for high-resolution, tractography) will be developed. A minimum of 16 ^{1}H transmitter (Tx) channels (2kW per channel) will be used to achieve homogeneous excitation at 500MHz by exploiting parallel transmit (pTx) methods. At least 128 receiver (Rx) channels will be available, ideally configurable across different resonance frequencies, to facilitate a range of multi-nuclear studies. 32kW of reconfigurable RF power would be available for X-nuclei studies. The system would initially be supplied with 16Tx/32Rx ^{1}H RF head and body array coils, along with combined ^{2}H/^{1}H, ^{23}Na/^{1}H and ^{13}C/^{1}H RF head coils. Additional multi-nuclear RF coils would subsequently be built or purchased, to support a wider range of studies. An optical camera for monitoring head motion and a field camera for measuring spatiotemporal variation of the fields in the magnet will be incorporated. Capability for monitoring physiological information synchronised to scan acquisition will be provided, as well as standard peripheral devices for fMRI studies (video, audio and vibrotactile stimulus presentation systems and response boxes).

In addition to the space required for housing the scanner and its control/equipment rooms, the facility will require patient-friendly reception and waiting areas, as well as rooms for behavioural and electrophysiological testing. It would be expected that the national facility would be associated with an existing imaging centre with experience in managing high-end medical imaging scanners, and in close proximity to a university hospital. This would mean that the necessary ancillary facilities and support structures (including those required for data storage and transfer, quality assurance, clinical research support and governance and potentially for RF coil development and testing) could build upon existing structures and systems. The new facility would also require office space for hosting visiting researchers over both, medium- (e.g. 3 months to implement and test a new sequence or RF coil) and short-term visits (e.g. a one-day visit to scan multiple subjects). A key role of the host site will also be to enable patient studies, through provision of appropriate local facilities and links to local clinical collaborators with access to patient groups. The network of NIHR Biomedical Research Centres (and key clinical academic centres in the devolved nations) offers a natural engagement mechanism for this activity.

Enabling the UK research community to realise the full benefits of the UHF scanner, will require the Facility to provide expert staff support. Various roles will be phased in over 5 years (see Q8). A facility manager is needed to manage the specification and ordering of the system, and its subsequent installation, testing, and operation. Two postdoctoral research assistants (PDRAs) are needed to develop, test and manage RF coil hardware over the 5-year period. It is expected that these PDRAs will form part of a wider, cross-institutional collaborative effort in RF coil development. Once the system is installed, three PDRAs will work with users to develop and optimise sequences for functional imaging, anatomical imaging and spectroscopy. Research radiographer support will be later needed to run studies based on established sequences.

Several models could be used for funding the operational costs of the facility during its early phase of operation (Q8): a multi-institutional programme grant alongside an infrastructure award could fund the development of the system, with this activity utilising a significant fraction of the time on the scanner; or this development could be proportionally funded by multiple academic institutions (in conjunction with funders) in return for involvement in the development programme and early access to the scanner.

Q7. The potential facility: A description of the type of facility service proposed and its primary function, including an indication of what the facility should provide to be of maximum benefit to the research community (what technologies and capabilities should be available, what services should it provide, what type and number of staff would it need). How will the facility include a move towards some element of cost recovery and sustainability.(6,000 characters incl. spaces)

In the longer term we envisage recurrent costs to be covered by access fees paid through grant funding (in line with most UK research scanning facilities). Based on the current cost of 7T scanning (~£700 per hour), a charge of £1,000 per hour is realistic for an 11.7T scanner. At this rate, 16 hours of fully funded scanning per week over 48 weeks per year would cover the estimated core operating costs of the facility (excluding any direct funding of staff). This would leave significant capacity on the scanner for continued development work, maintenance and for subsidised/pump-prime activity.

A Steering Committee, comprised of representatives from multiple institutions (including clinicians, neuroscientists and physicists), industry and funding bodies, will set and oversee the parameters of the Facility's operation. An Operational Committee composed of active developers/users of the Facility, would meet more frequently to manage its operation. A joint Safety Committee would also be established with the UK7T Network. The work of these committees would be informed by input from an International Advisory Board, including representation from international sites with experience of human scanning above 10T and associated safety issues.

Q8. Indicative resources: Outline indicative costs over 5 years of operation. This should be split into capital requirements and yearly recurrent costs.
If there are existing UK capabilities or equipment that the proposed facility could utilise, the Statement of Community Need should describe both:
• The costs of supporting the facility if the existing capabilities or equipment did not exist, and
• The costs of the facility if it were to use existing capabilities and equipment.
(3,000 characters incl. spaces)

The information provided here is based upon indicative costings from magnet and system manufacturers (the latter including the cost of taking responsibility for system integration), and on a design feasibility study for a building to house the scanner on a university site. Magnet bore sizes of 830mm and 900mm were considered, and while 900mm would give some additional flexibility, the community do not believe it will give enough scientific benefits to justify an additional >25% cost over 830mm. Lead-time for 830mm magnet delivery is 18-20 months from order, with a similar lead time for the integrated system. Estates work would be delivered in parallel. Annual recurrent costs for maintaining the magnet and system are assumed to commence in Years 3 and 4, respectively. No institutional/industry contributions are yet included, and we anticipate additional value could be extracted through a robust procurement process.

Capital Requirements

11.7T Magnet with 830 mm bore including installation and He for cool-down 550 tonne iron shield to confine 5 G field to 8.5 m axially/ 4.5 m radially	**£7.65M**
Integrated system, incl. 16Tx and 128 Rx ^{1}H RF channels + head coil & body array X-nuclei RF 2Tx 3 head coils at least 80mTm^{-1}/200Tm^{-1}s^{-1} whole-body gradient system Head insert gradient coil Field and optical cameras	**£12.1M**
> 400 m^2 building to house the magnet, equipment and associated activities	**£2M**
Total Capital Requirements	**£21.75M**

Yearly Recurrent Costs	**Annual**	**Period**	**Total Yrs. 1-5**
System			
Magnet maintenance	**£130k**	Years 3-5	**£390k**
Integrated system maintenance	**£290k**	Years 4-5	**£580k**
RF Coil development	**£90k**	Years 1-5	**£450k**
System Total Recurrent			**£1.420M**

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Indicative Staff Requirements

Facility Manager	**£65k**	Years 1-5	**£325k**
RF-focused PDRAs	2 x **£51k**	Years 1-5	**£510k**
fMRI PDRA	**£50k**	Years 3-5	**£150k**
Anatomical imaging PDRA	**£50k**	Years 3-5	**£150k**
Spectroscopist PDRA	**£50k**	Years 3-5	**£150k**
Research Radiographer	**£61k**	Year 5	**£61k**

Salary Total Recurrent **£1.346M**

Directly Incurred Costs **£1.419M**

Total Recurrent Costs over 5 years **£4.185M**

Total Costs Capital + Recurrent over 5 years **£25.935M**

Q9. Authors and Community Engagement: A list of who was directly involved in writing the Statement of Community Need (name, institution / company and research interests).(4,500 characters incl. spaces)

Colour indicates: Clinician; Neuroscientist; Imaging/Clinical/Computer Scientist; Black: Physicist/Engineer

Bold: Primary Contributor

University of Birmingham [Birm] **Bagshaw** (*structural/functional imaging, novel contrasts*); **Peet** (*multi-modal MRI, children's cancer);* Fernandez-Espejo (*structural/functional imaging, novel contrasts*); Mayhew (*structural/functional imaging, novel contrasts, ASL*); Noppeney (*structural/functional imaging*)

University of Bristol [Bris] **Kauppinen** (*relaxometric contrasts for microstructural imaging*); Coulthard (*ageing and dementia*)

University of Cambridge [Cam] **Kourtzi** (*laminar imaging, GABA/glutamate MRS, myelination, functional & structural connectivity*); **Rodgers** (*UHF, 31P spectroscopy, body*); **Rowe** (*dementia, parkinsonism, cognition & neurochemistry*); Bullmore(*development, psychosis, addiction mechanisms: chemistry & circuits*); Gilbert (*oncology, diagnostics & experimental therapies*); Menon (*brain injury, neurochemistry, multinuclear MRS*)

Cardiff University [Car] **Wise** (*brain metabolism, quantitative fMRI, multinuclear*); Jones (*brain tissue microstructure, diffusion, MR histology*); Harrison *(immuno-psychiatry, brain functional & structural MRI);* Kolasinski (*somatosensory & motor function*); Murphy (*cerebrovascular MRI methods*)

University of Edinburgh [Ed] **Marshall** (*blood flow, metabolism, accelerated imaging*); Whalley (*neuropsychiatric disorders*)

University of Glasgow [Glas] **Goense** (*investigating neural circuits in sensory cortex*), **Gunamony** (*UHF RF coils & hardware development* - MR CoilTech Ltd).

GSK: Murphy (*quantitative imaging, imaging for pharmaceutical R&D*)

Imperial College [Imp] **Bangerter** (*multinuclear and quantitative MRI, pulse sequences*); Matthews (*neurophysiology, neuropathology, vascular reactivity, neuroinflammation*)

The Institute of Cancer Research [ICR] **Leach** (*oncology imaging, cancer evaluation, function & metabolism*); Kho (*radiology, prostate cancer*); Messiou (*radiology, sarcoma, myeloma*)

KCL **Williams** (*neuroimaging in psychiatry and neurology, functional & metabolic contrast*); Barker (*sequence development, clinical application*); Catani (*diffusion tensor imaging & neuroanatomy*); Malik (*pTx techniques & applications, RF safety*); Mehta (*pharmacological MRI*)

University of Leeds **Schneider** (*cardiac diffusion MRI, cardiac MR spectroscopy);* Dall'Armellina *(cardiologist: cardiac diffusion MRI, 4D flow*); Plein *(cardiac perfusion, cardiac metabolism*)

University of Liverpool [Liv] **Poptani** (*high field MRI/MRS: biomarkers for cancer treatment response & cell tracking*); Das (*UHF MRI for brain tumour treatment response*); Keller (*epilepsy & neurodegeneration, novel MRI biomarkers*); Kemp (*MRS in metabolism & cell physiology*); Meyer (*fMRI, multisensory perception & learning*); Wuerger (*fMRI imaging, colour vision, multi-voxel pattern classification*)

University of Manchester [Man] **Parkes** (*quantification of brain physiology, PET-MR*); Montaldi (*medial temporal lobe circuits, neurodegeneration*); O'Connor (*imaging biomarker validation, tumour physiology*)

Newcastle University [New] **Blamire** (*neuromuscular imaging, brain injury, novel MR contrasts*); **Thelwall** (*multinuclear MR imaging and spectroscopy*); Cousins (*psychiatry, bipolar disorder, lithium treatment*); Kaiser (*neuroinformatics, network structure & function*); Taylor (*old age psychiatry, dementia*);

University of Nottingham [Nott] **Auer** *(neurodegeneration, cancer, stroke, depression, & pain*); **Bowtell** (*UHF, MR hardware development, susceptibility contrast*); **Francis** (*UHF, novel sequence development, fMRI*); **Glover** (*RF hardware, pTx RF pulse design, compressed sensing*); **Gowland** (*novel and quantitative contrasts, UHF, safety*); **Hall** (*personalised medicine, MRI for respiratory disease*); **Morris** (*UHF, multinuclear MRS, DNP*); Aithal (*metabolic imaging & quantitative MRI in liver disorders);* Dineen (*quantitative imaging techniques for characterising brain diseases*); Greenhaff (*novel MR techniques in ageing, exercise and health*); Krumbholz (*auditory neuroscience, cortical micro-circuitry, auditory*

Q9. Authors and Community Engagement: A list of who was directly involved in writing the Statement of Community Need (name, institution / company and research interests).(4,500 characters incl. spaces)

impairment); Patel (translational cancer research, melanoma, immunotherapy); Scammell (*osteoarthritis; chronic pain; bone injury, cartilage, muscle*); Sotiropoulos (*connectomics, diffusion MRI analysis, machine learning*)

University of Oxford [Oxf] **Jezzard** (*pulse sequence development, physiological MRI, cerebrovascular MRI*); **Tyler** (*cardiac MRI, hyperpolarization, 13C / 31P spectroscopy*) ; Johansen-Berg (*brain plasticity & recovery from damage*); Miller (*recon, sequences, microstructure, modelling*)

University of Sheffield [Sheff] **Wild** (*non-proton MRI, hyperpolarised methods, RF hardware*); Hoggard (*neuropathy, ataxia*); Wilkinson (*neuroimaging*)

University of Sussex [Suss] **Cercignani** (*multi-modal quantitative MRI - translation to clinical applications*); Colasanti (*effects of neuroinflammation & mitochondrial dysfunction on mental health*); Critchley *(mind-body interaction & effects on mental health*)

Tesla Engineering Ltd: Pittard (*magnet technology*)

UCL: **Alexander** (*image analysis, machine learning, pattern recognition, computational modelling);* **Callaghan** (*Laminar level integration of structure & function; sequence development*); **Gandini Wheeler-Kingshott** (*reduced FOV imaging; ^{23}Na quantification & functional imaging);* **McColgan** (*Huntington's disease- layer specific quantitative MRI);* **Parker** (*novel contrasts, BBB, diffusion, perfusion, multinuclear*); **Shmueli** *(novel contrast, electromagnetic tissue properties mapping*); **Weil** (Parkinson's dementia); Arridge (*image reconstruction, inverse problems, deep learning*); Atkinson (*body, cancer, motion correction*); Drobnjak (*image analysis; modelling*); Duncan (epilepsy); Kok (*functional imaging of cortical layers & columns during perception*); Lambert (*early Parkinson's disease);* Maguire (*hippocampal subfields, laminar imaging, memory disorders*); Price (*predicting & explaining language outcomes, recovery after stroke*); Punwani *(cancer, multinuclear, microenvironment, body*); Schott (*dementia / posterior cortical atrophy*); Tabrizi (*Huntington's disease – clinical trials*); Zhang (*computational imaging, image reconstruction, modelling*)