January 15, 2024

DRD-UK Consolidated Grant Submission 2025-2029

On behalf of University of Birmingham, University of Bristol, Brunel University London, University of Cambridge, University of Edinburgh, University of Glasgow, Imperial College London, King's College London, University of Lancaster, University of Leicester, University of Liverpool, University of Manchester, University of Oxford, Queen Mary University of London, STFC Particle Physics Department, STFC Technology Department, Royal Holloway University of London, University of Sheffield, University of Sussex, University College London, University of Warwick.

The full author list is provided at the end of the document.

Abstract

An international organisation for strategic R&D activities is being setup, under the auspices of ECFA and hosted by CERN, to serve the needs of the future experimental programmes in particle, particle astro-physics and related nuclear physics areas. The necessary national infrastructure, training and industrial support will form part of this activity. The UK is fully engaged in this process and is organising its activities, in alignment to the international DRD collaboration and major international partners. This submission describes the DRD-UK collaboration areas, listing the UK projects with which the institutes have engaged and for which effort is requested in the group submissions. A request for maintenance and operations funds is made, including travel, training and industrial engagement activities.

Contents

1 Introduction to DRD

Particle physics detector R&D is entering a new era with the major projects of ATLAS and CMS Phase II now in their construction phase. R&D for the next decade is focussed on a set of medium and smaller scale projects with more diverse aims and will potentially lay the path for a major future collider project on the 20+ year horizon. Consequently, an international programme of strategic R&D in detector systems is being setup. The UK community (particle, particle astro-physics and relevant nuclear physics) is fully engaged in this process, which it has helped shape, and provides several of the international leaders of the DRD process and collaborations.

The costs involved in developing cutting-edge technologies are rising while the field remains – by commercial standards – a low-volume, niche market. Increasingly, costs can be met only through a significant pooling of resources. The new DRD structures will have the necessary critical mass to meet these challenges while ensuring that creativity is maintained. These long-term strategic funding programmes will sustain research and development in order for the technology to mature and to be able to deliver the experimental requirements. This strategic R&D programme will:

- Provide UK and international coordination to identify and target common technological goals that will underpin the next generation of experiments facilitating long-term developments.
- Provide and coordinate instrumentation training and skill development for the next generation of experimental particle physicists, engineers and technical staff.
- Construct and support specialised facilities (design, build and test) supporting international capability in detector development and construction,
- Provide methods of establishing meaningful longer-term relationships with industrial partners.

The DRD collaboration aims to develop a programme over the next years to meet these goals. In this new international framework the UK is well placed (infrastructure, expertise, leadership) to further build, or in some cases rebuild, strong international leadership if supported through appropriate investment.

1.1 Organisation

The DRD Collaborations, see Fig. 1, cover areas of relevant R&D, with UK involvement in all. The formation follows from a three year process following the European Particle Physics Strategy recommendation with a roadmap [1] and implementation document [2] produced. A Detector Research and Development Committee (DRDC) has been put in place. The operational model will be similar to CERN experimental collaborations, thus allowing strategic priorities to be determined and cross-institution and international collaboration to be performed.

These DRD collaborations will address the needs of strategic R&D to underpin future experimental programmes. These will build upon and expand from the success of CERN RD collaborations [3], such as RD50 (which underpinned most of the silicon developments that enabled LHC detctors and beyond, and the UK had the long-term co-spokesperson) and RD53 (where a common ATLAS/CMS Upgrade II pixel chip basis was developed).

The DRD collaborations are expected to ramp-up over the first three-four years cycle. A UK structure has been setup to coordinate the activities. A steering board has been appointed with representatives from each of the 20 UK particle physics groups and UK coordinators appointed for the DRD-UK collaborations (see Appendix B). UK community meetings have been held and the coordinators are working with the international community to shape the overall projects.

1.2 UK goals

In the past years, particle physics detector system construction has been a significant UK strength with major international projects having been delivered and currently in construction. However, the development of new technologies has lagged behind other leading nations in some important areas. The extensive expertise and infrastructure in the UK, established through our involvement in major build and development programmes, can be leveraged to enable a fast and cost-effective rebuilding of technology R&D leadership. The DRD collaborations provide the opportunity for the UK to coordinate and target its R&D programme on the key technologies in which it wishes to play a leading role for the next decades, developing appropriate infrastructure and working with UK industry. Establishing this generic R&D was a recommendation of the recent STFC Strategic review of particle physics [4]. Training in instrumentation and industrial engagement can be further strengthened in the UK, and these are both areas that can benefit from this initiative, along with managing the future environmental impact of the field. EDI will also be considered.

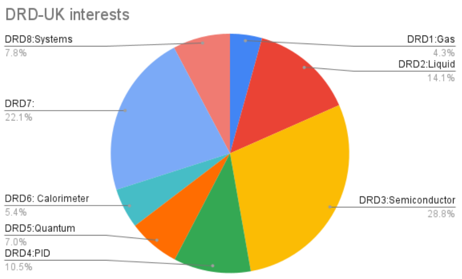

Figure 1: DRD-UK activity.

The capability to design, develop, and scientifically exploit advanced detector technologies underlies practically all STFC experimental research. Sustaining such capability requires access to appropriate laboratories and facilities, and a well-trained workforce across all career levels. The DRD-UK programme will give the opportunity for students to develop a skill set for experimental particle physics and of benefit to the UK economy.

Detector technology should be a key impact-generating output of the STFC research programme, and there is proven scope for interdisciplinary and industrial use of both particle physics detectors and the related data-processing systems. The international coordination of activities gives the opportunity for UK industry to reach a wider pool of researchers from which future orders for the experimental programme will emerge.

The UK programme will be led by the demands of future experiments with strong UK interest, and PIs of future UK projects are engaged in the process.

2 DRD-UK collaborations overview & workplan

2.1 DRD-UK 1: Gaseous Detectors

Contributing institutes: Birmingham, Cambridge, Imperial, Liverpool, Manchester, Warwick, York, STFC ISIS, STFC PPD

Gaseous detectors such as MultiWire Proportional Chambers, Time Projection Chambers, Resistive Plate Chambers and Micropattern Gaseous Detectors are part of every major (astro-)particle physics experiment today. Future cutting-edge experiments impose new challenges that require the following indispensable R&D activities in the UK:

- [**MicPattern**] Development and optimisation of micropattern detectors across a range of pressures, using existing unique facilities, e.g., for glass-GEM fabrication (WP8);
- [**EcoGases**] Identification of novel low-GWP gas mixtures benefiting from synergy with ongoing activities at CERN for LHC experiments and beyond (WP1, WP6, WP7);
- [**DetModel**] Advancement in detector simulations crucial for guiding the R&D activities across the full spectrum of DRD1 and especially low-GWP gasses (WG4);
- [**Infrastruct**] Development and maintenance of an experimental platform for gaseous detector testing benefitting from ongoing developments for DUNE (WP4, WP8);
- [**Readout**] The development and characterisation of the next generation of optical & charge readout systems (WP1, WP5).

Industrial partners include e.g., glass and glass coating industries, BOC/Linde, precision vacuum vessel manufacturers. *Beneficiaries* range from low-background and rare-event experiments such as DarkSphere and MIGDAL, over large-scale low-rate experiments like DUNE, to large-scale, high-rate experiments like ANUBIS or FCC detectors.
The extensive range of future applications reflects the wide applicability and indispensability of gaseous detectors and underlines the UK's involvement on all crucial R&D fronts.

2.2 DRD-UK 2: Liquid Detectors (neutrinos and dark matter)

Contributing institutes: Edinburgh, Imperial, King's, Liverpool, Manchester, Oxford, Sheffield, STFC PPD, Sussex, University College London, Warwick

Liquid Detectors, using noble element, liquid scintillator or water Cerenkov, are used for Dark Matter searches, neutrino physics and neutrinoless double beta decay. The UK DRD2 effort aims to increase, improve and combine the light signals recorded, underpinned by ultra-low background developments. Indeed, increased light detection and reduction of both energy thresholds and backgrounds would be transformative for future neutrino and dark matter experiments, which requires R&D efforts to develop new and improved solutions for light detection, hand-in-hand with improved background rejection techniques. A step change in technologies to measure and control trace radioactivity and particulate contamination is also essential.

1. **Development and characterisation of light sensors.** Increasing the quantum efficiency in the VUV wavelength range and optimizing the sensor integration for maximum efficiency would offer enhanced light detection capabilities. The development of characterisation facilities for these sensors in the VUV wavelength range will be crucial to assess the performances.

2. **Increase light collection and light detection efficiency over a broad wavelength range.** Combining new or traditional light sensors to light collection devices such as new types of fibre, metalenses or dichroic cones and filters would offer enhanced light signals. The development of efficient and scalable wavelength shifters would also strengthen the use of light sensors optimized for the visible.
3. **Development of charge-to-light and charge+light readouts.** The ionisation charge signal produced in noble element detectors underpins detector capabilities. Improving this signal detection, by conversion and amplification to light signals would offer lower energy thresholds and better energy resolution. Alternatively, leveraging a high granularity direct charge readout combined to an efficient light readout would offer 4D imaging capabilities.
4. **Background reduction with improved material screening techniques and use of novel low-background materials.** Liquid detectors for dark matter and neutrino physics will require a step change in radiopurity of materials and methods used for detector construction and assembly. This sub-task will directly address this need by focusing on an R&D required to improve the sensitivity of the current radio-assaying and cleanliness control facilities in the Boulby Underground Laboratory and surface labs by a factor of 10-100. The main focus will be on enhancing the sensitivity of HPGe gamma-spectroscopy, ICP-MS assays, radon emanation and surface screening.

The UK programme builds on previous investments in world-class facilities at the Boulby Underground Laboratory, which will boost the existing industrial engagement with companies such as MIRION (Canberra), Agilent, XIA, Calder Lead. Developing UK global leadership in light detection for liquid detectors and collaborating with international partners will improve the prospects for the UK hosting world-leading large-scale science projects in this area.

Expected beneficiaries: DUNE, DarkSide-lowMass, Argo/GDMAC, XLZD, SNO+ upgrades, LiquidO, LEGEND, NEXT, Positron-Electron Tomography imaging.

2.3 DRD-UK 3: Semiconductor detectors

Contributing institutes: Birmingham, Bristol, Cambridge, Edinburgh, Glasgow, Imperial, Lancaster, Liverpool, Manchester, Oxford, Queen Mary, Sheffield, STFC PPD, STFC TD, Warwick

Silicon detectors play a crucial role in particle physics experiments requiring the reconstruction of charged particles. They have grown to be the technology of choice for both the reconstruction of displaced vertices and in the momentum measurements carried out by larger tracking systems. Widespread adoption of silicon has also begun in the neighbouring fields of calorimetry, time of flight and time projection chambers.

Over the past decade or so there has been a significant diversification in silicon detector technologies. Integration of the sensing elements with commercial CMOS processes has spawned entire families of monolithic devices, optimised for charge collection and significantly enhancing their tolerance to high radiation environments. The move towards smaller technology nodes comes with an associated rise in cost, necessitating a greater degree of international co-ordination. In parallel, the implementation of highly doped structures in traditional planar devices has extended their timing abilities well towards the picosecond range, using impact ionisation to multiply collected charge. Progress within the international community proceeds along these interrelated fronts, with the DRD3 proposal covering:

1. **Monolithic CMOS devices.** The development of high-performance tracking detectors where the sensing node is fabricated alongside the readout electronics in commercial CMOS processes.

2. **4D tracking systems.** The development of sensors with response times on the order of 10 ps, opening a new world of possibilities spanning high-rate experimental conditions with integrated Particle Identification through Time-of-Flight.

3. **3D stacked detectors.** The development of re-configurable CMOS detectors using multiple highly-interconnected ASICs, each implementing a layer of analogue or digital functionality independently

4. **Extreme radiation tolerance.** The development of sensors able to withstand extreme radiation environments, such as those found in high rate experiments such as the HL-LHC/FCC.

The UK is world-leading in the design and construction of silicon vertex and tracking detectors - including for example the ATLAS SCT, ITk strips and pixels, LHCb VELO and VELO Upgrade. UK contributions have spanned the complete detector chain, covering: sensor design, ASIC development, mechanics and cooling, DAQ and simulations. This has in many cases proceeded hand-in-hand with UK commercial partners, either fabricating devices (cf. Micron semiconductors and Teledyne e2v) or selling to sectors ranging from electron microscopy to x-ray diffraction (cf. Quantum Detectors). Despite this, the UK community is at risk of abdicating international leadership through the lack of R&D funding opportunities and the limited job and training opportunities for those developing silicon detectors.

Expected beneficiaries: ALICE-3, LHCb U2, EIC, Belle-3, ATLAS, CMS, HIKE, Mu3e Phase 2, experiments at proposed facilities (muon collider, ILC/CLIC/C3, CEPC/FCC), x-ray spectroscopy, electron microscopy

2.4 DRD-UK 4: Particle identification

Contributing institutes: Birmingham, Bristol, Cambridge, Edinburgh, Imperial, Leicester, Oxford, STFC PPD, Warwick

Particle identification (PID) is critical for many experiments, where separating between different charged-hadron species is key to suppressing experimental background. The UK has a strong history of developing and delivering PID systems for particle physics experiments (LHCb RICH, NA62 KTAG). The UK is also leading efforts to develop PID detectors for the next generation of experiments (Cherenkov detectors for LHCb and HIKE and time-of-flight for LHCb). Particle identification will also be necessary to fully exploit the large data sets taken at the Z pole by future e^+e^- experiments with UK design leadership. Advances in material science may also allow the development of entirely new PID systems for future experiments based on novel, meta-material, radiators which could provide interesting alternatives to fluorocarbon gas or aerogel radiators.

DRD-4 activities cover both specific solutions for PID and the more general need to develop new generations of fast-timing photon-detectors that can be tiled to cover large areas, and can withstand the extreme rates expected in future experiments. These technologies also have applications in calorimetry systems and dark matter detectors.

UK groups involved in DRD-4 are working closely with a variety of industrial partners (including Photek Ltd in the UK) to develop photon detectors that meet the challenging needs of future experiments.

Expected beneficiaries: LHCb U2, HIKE, CEPC/FCC

2.5 DRD-UK 5: Quantum sensors and technology

Contributing institutes: King's, STFC RAL, Oxford, Birmingham, Liverpool, Imperial, Cambridge, Lancaster, Sheffield, Royal Holloway, University College London, National Physical Laboratory.

Quantum sensors register a change of quantum state caused by the interaction with an external system with commensurate low energies sensitivity. Significant activities are ongoing through the Quantum Technology for Fundamental Physics (QTFP) Programme with aims such as the search for light Dark Matter, Gravitational Waves in an unexplored frequency range, and studies in the neutrino sector.

One current focus is the development of large-scale atom interferometry projects. R&D efforts are underway for elements such as Ultra-High Vacuum (UHV) and Laser-Stabilization (LS) systems in collaboration with UK industry partners (Torr Scientific, Kurt J. Lesker) The QTFP programme has catalysed the development of ultra low noise technologies in the microwave regime (phase coherent low noise parametric amplifiers, power sensors, and qubit arrays). Practical utilisation of cryogenic electronics for fundamental physics and R&D on cryogenic multiplexing and control electronics comes within the remit of DRD5.

More speculatively significant opportunities may exist beyond QFTP with applicability to HEP detectors these include such disparate areas as low dimensional materials (nanodots, atomically thin monolayers) for scintillating materials or gaseous detectors, nanoengineered semiconductor devices, nanophotonics and optical tracking TPCs.

Expected beneficiaries: dedicated experiments such as AION, QSHS, QTNM, with potential benefits across conventional high energy physics systems

2.6 DRD-UK 6: Calorimeters

Contributing institutes: Birmingham, STFC PPD, STFC TD, Sussex

Calorimeter R&D for future experiments has gained significant energy in recent years. In the UK the focus is in two distinct areas, that push the boundaries beyond currently running experiments: the MAPS-based digital calorimeter (DECAL) and the scintillator-based dual-readout calorimeter. Specific projects are detailed in Section C.6.

One of the limitations of the resolution of energy measurements at high-energy physics experiments are Landau fluctuations of the deposited energies for calorimeters with thin absorbers. A DECAL reduces the importance of this contribution to the energy resolution by counting the number of particles traversing each sensitive layer rather than measuring their deposited energies. To avoid saturation effects, high transverse segmentation is required. Using a dense, passive absorber such as tungsten allows a very compact longitudinal design, reducing the cost of subsequent detectors and detector solenoid, as well as ensuring a minimal transverse shower extent due to its small Molière radius. The UK is involved in the EPICAL-2 project and the analysis of existing testbeam data of the DECAL activity in the ECFA DRD6.

Another crucial area of R&D is the testing SiPMs and optical fibres coupled with SiPMs for extracting signals from a calorimeter detector. The UK has involvement in this area of R&D, both in hardware and simulation, through its participation in the IDEA collaboration, which has built and tested a dual-readout calorimeter prototype at CERN. SiPM readout can be used both for dual-calorimeter prototypes for future collider experiments, as well as for upgrades of calorimeters for high intensity kaon and future forward physics facility experiments.

Expected beneficiaries: FCC, HIKE, Forward Physics Facility

2.7 DRD-UK 7: R&D Collaboration for Electronic Systems

Contributing institutes: Birmingham, Bristol, Imperial, Manchester, Oxford, Royal Holloway, STFC PPD & TD, Warwick

As documented in the ECFA R&D Roadmap, High-Performance electronic systems are a key aspect of all future detector projects. Major electronic systems have become too complex for any single institute to implement alone, as they often require expertise in disparate technologies. Along with complexity, the cost of the necessary developments is high and continues to increase. Accordingly, the delivery of new detectors will require a greater level of coordination and cooperative working within the field. The DRD7 collaboration will provide the platform to support this approach.

DRD7 will develop and demonstrate new hardware, firmware, and software concepts relevant to the requirements of medium- and long-term detector projects. In addition, it will facilitate access to expertise, tools, and industry vendors in support of the entire DRD programme, and act as a focal point for development of future common standards and approaches.

DRD7 will initially include R&D projects in six development areas:

1. Data density and power efficiency
2. Intelligence on the detector
3. 4D and 5D techniques
4. Extreme environments
5. Backend systems and commercial-off-the-shelf components
6. Complex imaging ASICs and technologies

The UK has many decades of experience and leadership in the design and build of electronic systems and is home to the EUROPRACTICE Microelectronics Support Centre[1], putting the UK in a position to contribute strongly to DRD7 as part of co-developments with CERN and the international DRD consortia.

UK institutes are fully engaged with the establishment of projects within DRD7 development areas and are currently organising their activities in alignment with international partners. Coordinated national level activity across these areas will enable the UK to strengthen existing leadership in some areas and foster or regain leadership in others.

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[1] `http://www.msc.rl.ac.uk/msc/Services/EUROPRACTICE/index.html`

2.8 DRD-UK 8: Challenges of large scale systems

Contributing institutes: Bristol, Liverpool, Manchester, Oxford, Sheffield

The UK has a long and successful history of developing, constructing and commissioning large-scale detector systems for high-energy physics. The HEP community has considerable expertise in critical areas such as mechanics, services and integration, and has developed successful collaborations with UK industries as well as academics in other fields.

Future HEP experiments - from neutrino physics to the FCC-hh - will require more granularity (hence more services including readout, power and cooling) and/or lower mass in order to reach their physics goals. For example, tracking detectors at a Higgs factory are likely to be multi-Gpixel CMOS silicon devices with power-hungry front-ends but material budgets that are an order of magnitude lower than that for LHC tracking detectors.

The main tasks in this area therefore include the push for lower mass detector systems, through novel mechanical design, construction and materials, and innovative, robust (and low-mass) solutions for providing cooling and other services in the active volume. In both of these areas there are huge opportunities to collaborate further with local industry and other fields of academia.

We will also look at the latest technological developments to enhance our general tools, from evolutionary improvements of widely-used software for design and simulation, to increased use of AI to perform optimisation of system designs, and more reliance on robotics for precision, repetitive or hazardous tasks.

Expected beneficiaries: all large scale detector systems

2.9 Industrial engagement, infrastructure and training activities

Contributing institutes: All

Industry and infrastructure

DRD-UK offers a unique opportunity for establishing a combined UK particle physics engagement programme with UK industry, unlocking unrealised potential in skills and innovation to meet the aims of the recent DSIT Policy paper on CERN engagement [5]. With this in mind we seek to:

1. Establish an industry programme board, to provide oversight and advice on the DRD-UK programme and deepen links. Travel funding is requested in this bid for this activity.
2. Develop a common technology requirement roadmap, to identify key common technology developments that are possible with industry. Harness and strengthen the existing UK links with the establishment of a "trusted trader" style database of UK companies accessible by all UK particle physics staff.
3. Provide seeding and underpinning funding for technology trials with/for industry. This will enable technology proof of concept projects. This will be subject to future bids, but first stage funds are requested here for fabrication of common interest, as described in Sect. 3.

An international survey has been conducted through ECFA on the available major infrastructure for particle physics. This has identified the significant facilities that underpin instrumentation development. Existing major UK infrastructure of relevance includes the Diamond light source, ISIS neutron and muon source, Birmingham Cyclotron and Boulby underground laboratory. The lack of UK facilities for R&D silicon detector fabrication is a notable omission compared with international competitors and DRD-UK through STFC has engaged with the DSIT UK government consultation on the UK semiconductor strategy [6].

Training

We will establish an instrumentation training programme for existing STFC students and seek a Centre of Doctorate Training linked to the DRD projects and UK experimental programme. Funds for the school are requested in Sect. 3, while the CDT will be subject to future bids. A longer term aim will be the establishment of UK instrumentation fellowships, to complement the existing Rutherford fellowships.

The CDT will train the next generation of leaders in large-scale fundamental science instrumentation, and we will work with STFC to realise this objective. The UK Industrial community will be involved from the outset (using the structures discussed above), and co-funding sought with private sector partners. In addition to R&D intensive firms, companies in the areas of public engagement, communication and managerial skills will be engaged.

We will build on existing long-term UK experience running multi-site graduate training schemes. The programme will consist of: a mix of online and face-to-face lectures and courses on a variety of subjects tailored to PhD students doing instrumentation work; residential laboratories and workshops focused on hardware; networking events; soft-skills training; and industry placements. The successful HEP Summer School provides a template for the DRD-UK residential component, and this instrumentation school will complement this. The existing instrumentation course and RAL detector lectures will be incorporated, and the residential school will run every two years.

3 M & O request and effort

All UK particle physics groups and additional institutes engaged in relevant technology development are committed to the DRD initiative. There are xxx authors on the proposal, and the effort they plan to dedicate to DRD is given in table 1. Requests for funds for specific high-priority R&D projects will be requested through the STFC early-stage research call, and potentially other avenues, in coordination with STFC. Elements of the programme with the potential to reduce the environmental footprint of particle detector systems have also been identified, and dedicated funds to pursue R&D programmes in these areas will also be sought.

The community has been formed through preliminary meetings of the collaborations internationally and in the UK. This is already bearing fruit through establishing increased links between R&D activities in UK universities, laying the way for strategic discussions. Future UK detector project PIs have presented to the monthly DRD-UK steering meetings. A dedicated half-day meeting is planned after the IOP meeting in April. All eight international DRD collaborations plan regular workshops. Consequently we request travel funds to support networking and engagement, and support international DRD leadership positions associated with the R&D activity. The travel costs given may appear low given the large attendance (exceeding 500 for largest activities) at the kick-off meetings. However we assume i) attendance will be in line with previous RD collabs at regular meetings ii) 50% of travel will be combined with experiment activity and claimed through that. The estimate is based on UK attendance at previous RD50 (now DRD3) meetings, the largest single activity, scaled for the fractional UK activity in the new collaborations. The costs assumed per trip (£400 short, £1000 long) have been compared with LHC experiments. A small component of travel funding has been allocated for DRD-related testbeam and irradiation activities, with most of this typically being experiment funded. We do not anticipate DRD-UK LTAs currently. Short term travel is estimated at £29k/annum and long-term at £76k/annum.

As described in Sect. 2.9 an instrumentation training programme will be established. The primary costs will be for the residential component of the programme. We anticipate a cohort of 35 students for this, from students engaged in experimental programmes, estimated from discussion with the steering board. This will be supported by seven staff who will give lectures and supervise the hands-on workshops. Including accommodation, food, travel and administrative costs the one-week school is estimated at £57k, and will run twice during the CG period. Instrumentation for the programme is budgeted at £35k for the first cohort, reducing to £11k for updates and expansions for further iterations.

Funds are requested to support the engagement with industrial partners. Funds for the industry programme board are requested for supporting the travel of five industrial members and five UK academic visits to UK industry at £4k per annum. Technical support for the UK company database and UK website is requested at a nominal £0.5k/annum. The industrial fabrication fund is available for all DRD activities, with prioritisation decided by the steering board. Costs at £50k are estimated at the level of one semiconductor fabrication run every two years, and matching industrial funding will be sought where appropriate.

Staff effort of 1.5FTE/yr is requested for the participation of STFC Technical Division in this programme, where TD is playing a particularly major role in DRD7 and chip aspects of DRD3. These funds are to support the development of the first coordinated UK activity on the development of new CMOS sensors (DRD3.1) and a novel System-On-Chip for the front-end systems of future experiments (DRD7.1). CMOS activities are considered a high priority by the full UK community, and the front-end chip is proposed and led by TD.

Several of the international DRD collaborations have indicated that they will levy membership fees, at approximately 2k CHF per annum per institute, to establish funds to support common activities and administrative costs. As these are at an early stage of being established we do not request these funds here, and will expect institutes to bear these costs from their CG awards for the collaborations with which they wish to engage.

4 Summary

DRD is an international organisation for strategic R&D activities that will underpin the future experimental programmes in particle, particle astro-physics and related nuclear physics areas. The full UK community has engaged with the process, understanding the potential that establishing a combined UK programme can have. This is already creating synergies and laying the ground for strategic UK decisions to be taken, though dedicated funding will be required to realise these. This document provides the first overview of activities planned for the next period. A request for funds is made to support travel, training and industrial engagement.

Appendices

A DRD-UK Effort

	DRD Collaboration								
Institute	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**
Birmingham	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Bristol	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Brunel	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Cambridge	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Edinburgh	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Glasgow	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Imperial	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
King's	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Lancaster	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Leicester	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Liverpool	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Manchester	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Oxford	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
QMUL	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
RAL PPD	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
RAL TD	—	—	3.0	—	—	—	3.0	—	—
RHUL	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Sheffield	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Sussex	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
UCL	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Warwick	—	—	X.Y	X.Y	—	X.Y	—	X.Y	X.Y
Total	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y

Table 1: Effort expressed in FTE staff years dedicated to work in the DRD collaborations, as requested in the group CG submission or funded by other sources. Student effort is not included.

B Coordination Roles

B.1 DRD-UK steering board members

The UK DRD steering board is composed of one member per UK particle physics group. The current members are listed below. The term of all positions is three years. The PI is elected by the members of the steering board. The steering board members are the group leaders of the institutes or a member selected by the group leader. The M&O funds will be held at RAL and overseen by the budget holder.

In addition the University of Leicester space science research centre is contributing and is represented on the steering board by the University of Warwick.

Institution	Representative
Birmingham	ALLPORT, Philip
Bristol	GOLDSTEIN, Joel
Brunel	KHAN, Akram
Cambridge	WILLIAMS, Sarah
Edinburgh	GAO, Yanyan
Glasgow	BATES, Richard
Imperial	TAPPER, Alex
King's	DI LODOVICO, Francesca
Lancaster	O'KEEFFE, Helen
Liverpool	VOSSEBELD, Joost
Manchester	PARKES, Chris (Project lead)
Oxford	BORTOLETTO, Daniela (Board chair)
QMUL	HOBSON, Peter
RAL PPD	WILSON, Fergus (RAL Budget Holder)
RAL TD	FRENCH, Marcus
RHUL	BOISVERT, Veronique
Sheffield	VICKEY, Trevor
Sussex	HARTNELL, Jeffrey
UCL	THOMAS, Jenny
Warwick	RAMACHERS, Yorck

Table 2: Members of the DRD UK Steering board.

B.2 DRD-UK Coordinators

Each DRD collaboration has a set of UK coordinators. The coordinators are selected by the PI after discussion with members of the relevant community.

Area	Coordinator
DRD-1 [Gas]	BRANDT, Oleg; MAJEWSKI, Pawel;
DRD-2 [Liquid]	GUENETTE, Roxanne; MONROE, Jocelyn; SAAKYAN, Ruben; SCOVELL, Paul;
DRD-3 [Si]	DOPKE, Jens; GONELLA, Laura; HYNDS, Daniel; VILELLA FIGUERAS, Eva
DRD-4 [PID]	BLAKE, Thomas; ROMANO, Angela
DRD-5 [Quantum]	BUCHMULLER, Oliver; DAW, Ed
DRD-6 [Calo]	SALVATORE, Fabrizio; WATSON, Nigel
DRD-7 [Electronics]	FITZPATRICK, Conor; FRENCH, Marcus; POTAMIANOS, Karolos; PRYDDERCH, Mark; ROSE, Andrew
DRD-8 [Systems]	GOLDSTEIN Joel; VIEHHAUSER, Georg
Training	LAZZERONI, Cristina; BATES, Richard
Industry Engagement	FARROW, Richard; CASSE, Gianluigi

Table 3: Coordinators of the DRD UK activities.

C DRD activity lists

Each task is given a DRD-UK reference number and these appear in the consolidated grant cases of institute bids for posts working on these topics. Some tasks may also have international reference I-DRD numbers, these are included below where appropriate to make links clear, but do not appear in the consolidated grant bids.

C.1 Task List for DRD-UK 1: Gaseous Detectors

No.	**Name**	**Description**
1.1	MicPattern	Develop and characterise novel gaseous micropattern detectors. *Deliverables:* (a) Optimised glass ThGEMs geometries for high light/charge gain, (b) Optimised stack of glass GEMs for high dynamic range operation in low pressure TPCs with light and charge readout, (c) Novel glass GEM geometries for high-rate, high-occupancy calorimetric applications. *Beneficiaries:* Direct Detection (DD) Dark Matter (DM) searches, calorimetry at future collider (FCC-ee) & fixed target experiments. Industry links: glass and glass coating manufacturers.
1.2	EcoGases	Identify novel low-GWP gas mixtures for high-field applications. *Deliverable:* ideal novel gas mixture following criteria of: (a) low-GWP, (b) non-flammability, (c) ageing stability, detector performance at (d) atmospheric pressures, (e) up to 10 bar (f) down to 0.1 bar. *Beneficiaries:* large-scale detectors at HL-LHC (ANUBIS, CODEX-b), FCC, fixed target, ν detectors, DD DM detectors, n detectors. Industry links: BOC/Linde.
1.3	DetModel	Dissimination, maintenance and improvement of detector modelling and simulation programmes (e.g., Garf++, Magboltz) *Deliverables:* (a) Simulation workshops for UK-DRD1 students and junior researchers. (b) Dissemination of expertise on gas detector simulations within UK-DRD-1 and guiding detector performance studies. *Beneficiaries:* most gaseous detector applications.
1.4	Infrastruct	Delivery and maintainance of testing/performance evaluationplatforms for gaseous detectors. *Deliverables:* (a) Ability to test the performance of novel gas mixtures to further augment gaseous detectors e.g. TPCs, (b) Ability to benchmark highly granular optical TPC readout for resolution at the diffusion limit (c) Ability to prototype a calibration system. *Beneficiaries:* ν detectors, rare-event experiments, DD DM searches.
1.5	Readout	Develop and characterise novel optical and charge readout architectures, including calibration in the primary context of TPCs, MPGDs, and RPCs. *Deliverables:* (a) Characterisation of TPX3cams for gaseous detector applications e.g. TPCs, (b) Survey ASICs currently available for gas detectors readout and influence the future generation, (c) Low cost charge readout systems for low occupancy detectors, (d) Ultra-low noise electronics for rare event TPCs. (e) Develop a readoutsystem capable of 3D and 4D tracking combined with particle ID, *Beneficiaries:* ν detectors, DD DM searches, rare event experiments, future colliders like FCC-ee and fixed target experiments.

C.2 Task List for DRD-UK 2: Liquid Detectors (neutrinos and dark matter)

No.	Name	Description
2.0	Coordination	Coordination tasks for DRD 2 in the UK and in the international collaboration.
2.1	Light sensor optimisation	Light sensor optimisation for VUV photon detection Detector integration optimisation for VUV photon detection. Development of characterisation facilities for VUV.
2.2	Increase light collection	Development of better scalable wavelength shifters, reflectors and fibres. Development of optimized light collectors and concentrators.
2.3	Increase light yield in nobles	Understanding Microphysics of noble liquid (NL) response. Characterizing and Modelling NL light emission and transport. Characterizing Properties of Xe-Ar mixture.
2.4	Increase light in Scintillators	Optimization and full characterization of hybrid, opaque and novel scintillators. Achieve high isotope loading factors in water and scintillator.
2.5	Charge-to-light	Granular S2 light production/detection. Optimisation and characterisation of charge amplification structures. Demonstration of the scalability of the technologies developed in this task.
2.6	Charge readout (pixels)	Design a fC charge sensing pixel readout optimized for low energy detection minimized power consumption. Design of a scale-up pixel readout with $\mathcal{O}$(100 million) channels. Design of an architecture capable of capturing multi-modal signals.
2.7	Background reduction (radiopurity)	Develop radiopurity screening and control system applicable across a wide range of rare event search experiments (neutrino, dark matter, etc). Necessitates close collaboration with industry: MIRION, Agilent, XIA, Lead Shield Engineering, Calder Lead. Increase sensitivity of Boulby and RAL based radio-essay systems: 1-10 μBq/kg for HPGe, 0.1-1 ppt for ICP-MS, 5 μBq for Rn emanation, 0.5-1 mBq/m^2 for surface screening. Develop tools for background evaluation based on radiopurity assays: high-stat simulations of highly shielded detectors, new statistical inference tools. Development of integrated material data bases, work flows to optimise screening throughput, protocols for clean manufacture and cleanliness control.

C.3 Task List for DRD-UK 3: Semiconductor detectors

No.	Name	Description
3.0	Coordination	Coordination tasks for DRD3 in the UK and in the international collaboration.
3.1	High granularity, rad-hard CMOS sensors	This task will explore the development of fully functional monolithic sensors in commercial CMOS technologies with large volume, low-cost production. UK expertise in CMOS imaging technologies will be used to target high granularity (down to 25x25 μm^2) and high radiation tolerance (towards 10^{16} n$_{eq}$/cm^2) in one device, with a modest time resolution (hundreds of ps) [I-DRD3 WP 1.1, 1.4]. Beneficiaries: Vertex and tracking detectors for upgraded and upcoming experiments (ALICE-3, LHCb-2, EIC, CEPC, Belle-3, ATLAS, CMS); developments towards future e+/e- colliders, muon and hadron colliders.
3.2	Sensors for 4D-Tracking	This task is concerned with the development of sensor technologies to achieve high time resolution combined with high spatial resolution, fill factor, and radiation hardness. In addition to further the development of 3D sensors and LGAD technology [I-DRD3 WP 2.2, 2.3], it will pursue innovative solutions in the form of monolithic sensors to reach timing resolution in the order of 10s of ps, better than 99% fill-factor, 10s of μm spatial resolution, and radiation tolerance towards 10^{15} n$_{eq}$/cm^2 [I-DRD3 WP 1.2]. Beneficiaries: Upgrades of LHCb, HIKE, ATLAS and CMS timing detectors, EIC, CEPC; demonstration of technology for use at the proposed future muon and hadron colliders.
3.3	3D Stacked, Reconfigurable CMOS Sensors	Commercially available 3D stacked CMOS sensor technology will be explored to develop monolithic sensors with a high level of reconfigurability that could be deployed in both tracking and electromagnetic calorimetry detectors. Exploiting the higher achievable digital logic density and the stitching capability of the process, this development aims at the realisation of a large area, 3D stacked CMOS sensor as a cost-effective solution to equip large detector systems at future collider experiments [I-DRD3 WP 1.3, 1.5]. In addition, 3D stacking technology distinctive advantages in terms of signal and power distribution will be capable of underpinning larger and faster detectors for X-rays and cryo-electron microscopy. This activity has synergies with DRD6 and DRD7. Beneficiaries: Tracking and calorimeter detectors at future e+/e-, muon and hadron colliders; X-rays spectroscopy, electron microscopy.

3.4	Sensors and electronics for Extreme Fluences	This task will develop UK expertise and infrastructure for the development of sensor and ASIC technologies towards the ultra-high fluence environments expected at the FCC-hh. An ambitious programme of measurements will be undertaken to map the evolution of silicon sensor properties with progressively higher proton and neutron fluences, towards the ultimate target of testing the operation of detectors at $10^{18}\ \mathrm{n}_{eq}/\mathrm{cm}^2$ [I-DRD3 WP 3.2, 3.3, 3.4]. Dedicated test structures will be fabricated at UK companies (e.g. Te2v, Micron). ASICs performance will be studied up to a few Grad dose. The potential of diamond detectors will be investigated by demonstrating fabrication of 25 µm base length cubic cell 3D diamond devices [I-DRD3 WP 6.1] to be tested up to 10^{16} - $10^{18}\ \mathrm{n}_{eq}/\mathrm{cm}^2$ [I-DRD3 WP 3.1, 3.3, 3.4]. The UK retains a leading position in the fabrication of diamond sensors through ElementSix Ltd UK, one of two companies worldwide to produce detector grade diamond, and unique worldwide capability to process 3D graphitic wires in diamond. The proton irradiation facility at the MC40 cyclotron of the University of Birmingham will be further developed to provide fluence and TID in the range required for this task. In addition, a neutron irradiation line will be developed at the new Accelerator Driven Neutron Facility (ADNF) in Birmingham. Radiation hardness is key to many DRD3 and DRD7 activities. Beneficiaries: Detectors, Front-end ASICs and DAQ at future hadron colliders.
3.5	Simulations	The proposed developments of new technologies within the DRD3 UK activities will be supported by effort on simulations. UK expertise will progress TCAD simulations of CMOS processes to optimise pixel charge collections properties and inform design activities. This work will include the implementation of newly measured semiconductor properties into TCAD and MC simulation tools, and the development of radiation hardness models for extreme fluence [I-DRD3 WP 4.2, 4.3, 4.4]. In addition, this task will work on full detector simulation studies, focussing on design parameters and performance metrics, to evaluate the impact of the developed technologies on the physics programme at future colliders and aid further R&D and technology selection. Beneficiaries: solid state detector developments for future experiments.

C.4 Task List for DRD-UK 4: Particle identification

No.	**Name**	**Description**
4.0	Coordination	Coordination tasks for DRD4 in the UK and in the international collaboration.
4.1	Design for future experiments	Design of PID systems based on Cherenkov/TOF techniques for future experiments [I-DRD4 WP 4.3, 4.4]. Activities in this package include the design and simulation of new detectors, the development of lightweight mechanical supports, and the development of techniques for measuring the optical properties of optical components. Deliverables: conceptual designs for and evaluation of prototype detectors for future experiments. Beneficiaries: LHCb, HIKE, PID at future experiments (e.g. FCC).
4.2	Novel radiators	Development of novel radiators for future PID detectors; including metamaterials with customisable refractive index properties [I-DRD4 WP 4.3]. Activities in this package involve the simulation of properties of new types of radiator material (such as photonic crystals and materials embedding nanospheres), and testing of sample materials. New types of radiator material could be used in PID detectors providing replacements to e.g. fluorocarbon gases in future experiments. Deliverables: design and characterisation of small-scale material samples. Beneficiaries: LHCb, PID at future collider and fixed-target experiments. This R&D has synergy with EPSRC funded research taking place at a number of UK Universities.
4.3	New photon detectors	Study and development of novel photon detectors for Cherenkov/TOF applications in future experiments. This package focuses on the development of new solid-state (SiPM) and vacuum-based (MCP-PMT) photon detectors [I-DRD4 WP 4.1, 4.2] to meet the challenging requirements of future experiments. Activities in this package include: development of SiPM arrays with mm-scale pixelation, picosecond time resolution and improved radiation hardness; design solutions for cooling of SiPMs in high-radiation environments; development and qualification of fast-timing vacuum tubes (MCP-PMTs, PMTs with transmissive diamond dynodes) with extended lifetimes and high-rate capabilities; studies of large-area vacuum photon detectors (e.g. LAPPDs); development of optimised photocathode materials; development of associated read-out electronics. Deliverables: characterisation and validation of prototype photon detectors, design of readout electronics for fast-timing, advancement in existing technology. Beneficiaries: LHCb, HIKE, Belle 2, PID and calorimetry at future experiments. Industry: these activities involve industrial partners in the UK (Photek Ltd) and worldwide, who are interested in establishing collaborations to develop technologies that fulfil the new requirements and fill market gaps.

No.	**Name**	**Description**
4.4	Accelerated computing for PID	Development of novel simulation and reconstruction algorithms for PID applications in future experiments [I-DRD4 WP 4.3, 4.4]. This package is focused on new software challenges that arise in the extreme conditions expected at future experiments. The accuracy and precision, necessary for control of statistical and systematic uncertainties, calls for in-depth validation of simulations, and larger volumes of simulated data. Deliverables: optimised reconstruction algorithms for PID with large multiplicities and combinatorics in the available processing time; development of general software frameworks and tools dedicated to PID and other imaging detectors. Beneficiaries: LHCb, HIKE, Belle 2, PID at future experiments. Industry: Graphcore.

C.5 Task List for DRD-UK 5: Quantum sensors and technology

No.	**Name**	**Description**
DRD-5.0	Coordination	Coordination tasks for DRD 5 in the UK and in the international collaboration.
DRD-5.1	Widget	R&D for high-flux atom interferometry is being conducted to support the needs of the AION and MAGIS experiments. This work also directly impacts the development of optical atomic clocks and quantum computing platforms that utilize neutral atoms. Additionally, ongoing R&D efforts are leveraging expertise from National Particle Physics Labs, such as RAL and Daresbury, to streamline the design and production process for key components of Cold Atom Quantum Laboratories. Notably, AION has centralized the design and production of essential components like Ultra-High Vacuum (UHV) and Laser-Stabilization (LS) systems. This collaboration closely involves the UK industry.
DRD-5.2	ULN-Coherent	R&D for ultra-low-noise phase coherent microwave amplifiers in the frequency band 1-100 GHz. Such devices drive the sensitivity of searches for axions and other hidden sector dark matter, of measurements of the neutrino mass in tritium end point experiments employing cyclotron radiation, and in neighbouring field applications in quantum measurement and quantum computing.
DRD-5.3	ULN-Incoherent	R&D for sensor classes that directly measure temperature or energy and thereby avoid the standard quantum limit. Sensor classes include bolometers and a broad class of other energy detectors. Applications include searches for hidden sector dark matter including axions and any other application requiring wideband low noise electronics at ultra low temperatures.
DRD-5.4	Qubit sensors	R&D for the application of various classes of qubit devices to ultra sensitive readout. Applications include cryogenic thermometry, readout of resonant cavity structures used for axion and other dark matter searches, readout of detectors for reactor neutrinos and microwave readout of tritium endpoint experiments.
DRD-5.5	CryoMulti	Development of all-cryogenic electronics for multi-channel multiplexing. Segmented detectors require the multiplexing of many channels that might be better carried out at cryogenic (ie millikelvin) temperatures. Superconducting multiplexing circuits capable of ultra low temperature multiplexing would be developed in this work package.

No.	Name	Description
DRD-5.6	CryoFPGA	Field programmable gate arrays have seen extensive use in physics experiments requiring fast real time deterministic electronics for many purposes. Cryogenic field programmable electronics is being developed for quantum computing applications. In this package we aim to exploit commercially available cryogenic field programmable electronics for physics purposes such as feedback control to stabilise a quantum system in its ground state without recourse to a room temperature electronics chain.

C.6 Task List for DRD-UK 6: Calorimeters

No.	**Name**	**Description**
6.0	Coordination	Coordination tasks for DRD 6 in the UK and in the international collaborations.
6.1	Sensor Requirements	Requirements for a CMOS MAPS-based sensor optimised specifically for calorimetry depend on target application and include need for multiple thresholds per pixel, means of reducing power consumption at source ($\sim$ 10mW/cm^2 today) by at least an order of magnitude, sensor size and stitching technologies to instrument $\sim$ 2000 m^2 for a calorimeter. For Dual-Readout calorimetry, establish attenuation length and response in frequency of fibres; measurement of time resolution and time precision of state-of-the-art SiPMs; measure of bias voltage, quantum efficiency, gain of SiPMs coupled to FERS readout. Deliverable: Requirement specification for calorimetry optimised CMOS MAPS-based sensor; characterised SiPMs and their coupling to optical fibres. Beneficiaries: future PP projects requiring compact EM calorimetry.
6.2	Power mitigation	Develop set of alternative strategies that can be deployed instead of/in parallel with any sensor, including evaluation of passive cooling using tungsten absorber layers, impact of power cycling on performance (duty cycle depends on target application). Deliverable: portfolio of mitigation strategies to be deployed, depending on target application. Beneficiaries: future PP projects requiring compact EM calorimetry.
6.3	Interaction modelling	Extend calorimetry data-taking campaign using the EPICAL-2 prototype (and any other sensors available before 2029). Use improved beamline instrumentation to complement existing data from DESY and the SPS, we will benchmark GEANT4 physics models using uniquely granular detector and tune microscopic parameters in AllPix2. Improved models will allow optimal clustering and pattern recognition using existing tools to enhance linearity and resolution. Modelling of a dual-readout calorimeter in Geant4 using SiPMs+FERS and comparison with results from current test beam campaigns. Modelling of a possible Large Angle Veto calorimeter (a la NA68) for future high-intensity kaon experiments. Deliverables: algorithms, benchmarked and tuned simulation models and CMOS sensor modelling capability. Beneficiaries: developers of high-performance calorimetry, GEANT4 users, future PP detector designers.

C.7 Task List for DRD-UK 7: Electronics and data handling

No.	Name	Description
7.0	Coordination	Coordination tasks for DRD 7 in the UK and in the international collaboration.
7.1	Radiation Tolerant RISC-V System-On-Chip	Develop both a technology and design platform to meet the challenges and opportunities of future Front-End Systems, introducing greater flexibility for ASICs to reduce the number of variants and enabling more rapid development based around the SoC approach. (a) Investigate strategies such as Watchdog circuits for SEU tolerant processors and SoC blocks (DMA, memory, etc); (b) Evaluate the SoC methodology promoted by CERN and provide feedback. Investigate integrating SoC with timing and synchronisation systems; (c) Verify RISC-V operation from an user perspective and feedback into SoC specifications. Related to I-DRD 7.2.b. Beneficiaries: Future Front-end ASICs & systems.
7.2	Virtual Electronic System Prototyping	Related to I-DRD 7.2.c. developing a scalable, flexible toolchain to enable simulation of detector readout systems from particle interaction in the detector to digital data output, thereby aiding in the design, optimization, and analysis of future detector systems in high-energy physics experiments. As a Virtual Framework User, we will evaluate the framework from the user perspective and provide feedback, with the option of greater participation later. Beneficiaries: Future Detector Systems.
7.3	COTs Architectures *DAQOverflow*	Identify experiment-agnostic common TDAQ activities, define generic benchmarks to allow easy comparison of cost/energy efficiency for various compute architectures for the purposes of back-end/trigger processing. Make generic algorithms/tools available for various architectures as a repository of 'best practice'. (a) Determine relevant figures of merit (Cost/Energy per unit of work); (b) Collect and review reference implementations and examples; (c) Benchmark these on existing CPU/GPU/FPGA resources; (d) Host these through a documented repository of firmware and software Related to I-DRD 7.5.a. Beneficiaries: Future Detector DAQ systems.

No.	**Name**	**Description**
7.4	No Backend	Investigate and develop 100Gb Ethernet based links for data readout from more complex front end ASICs to DAQ, benefiting HEP experiments requiring high/concentrated data readout bandwidth. (a) Design and develop the building blocks necessary for implementing Ethernet up to 100Gb on Front-End ASICs; (b) No Backend Approach – Demonstrate of a full 100GbE system with current and emulated Front-End ASICs, COTS and smart switches, commercial NICs and custom Back-End boards, and custom Software; (c) Smart-Switch for Future Data Readout – Design a COTS-based high-density switch bridging the detector environment to the COTS/DAQ world Related to I-DRD 7.5.b. Beneficiaries: Future Front-end ASICs & DAQ.
7.5	Silicon Photonics Transceiver	Assembly and evaluation of Photonic Transcivers developed within the I-DRD 7.1.a collaboration. Irradiation of proyotypes along with characterisation pre and post irradiation. Beneficiaries: Future Front-end DAQ systems.

C.8 Task List for Industrial engagement, infrastructure and training activities

No.	**Name**	**Description**
9.0	Coordination	Coordination tasks for industrial engagement, infrastructure and training activities related to DRD 1–8 in the UK and in the international collaboration.
9.1	Industrial Engagement	Engaging with UK industrial partners and serving on the industry training board.
9.2	Industry Database	Establishing and coordinating a database of trusted UK industrial partners.
9.3	Technology Roadmap	Develop a common technology requirement roadmap for UK industry.
9.4	Infrastructure	Common/shared tools, equipment, and general infrastructure that deliver instrumentation research. To maximise return on investment the DRD will coordinate the use of these common tools. Also we will coordinate UK-wide training of the experts who will operate the equipment. We will set up a web-based interface to aid the information sharing and create a UK pool of high-end research equipment and expert users.
9.5	CDT	Establish and run an instrumentation Centre of Doctorate Training linked to the DRD projects. We will establish and run a graduate programme, consisting of: a mix of online and face-to-face lectures on a variety of courses tailored to PhD students doing instrumentation work; residential laboratories focused on hardware; networking events; and industry placements. The CDT will seek matched funding from the typical science and engineering research companies, our ”industrial partners”, and also from companies who benefit from scientists with transferable skills; for example science communication companies, management companies and venture capital and investment companies. The topics of individual PhD work will be driven by the individual research lines in the DRD-UK programme, creating a synergy and a positive feedback effect between research and training.
9.6	Summer School	Establish and run a Summer School Series. To strengthen the UK instrumentation training of the new generations, and foster a network of UK experts, we propose an Instrumentation Summer School Series to run bi-annually linked to all the aspects of the UK DRD programme. The Schools in the Series will be residential with a duration of around 2 weeks, hosted in turn by the different institutes of the DRD network. It will include laboratory sessions, tutorials, Q&A, visit to local experimental facilities, and an opportunity to network with industrial partners during dedicated industry sessions.

References

[1] ECFA Detector R&D Roadmap Process Group, *The 2021 ECFA detector research and development roadmap* , Geneva, 2020. doi: 10.17181/CERN.XDPL.W2EX.

[2] ECFA Detector R&D Roadmap Process Group, *The 2022 ECFA detector research and development roadmap implementation plan* , Geneva, 2022. https://indico.cern.ch/event/1197445/contributions/5034860/attachments/2517863/4329123/spc-e-1190-c-e-3679-Implementation_Detector_Roadmap.pdf.

[3] *CERN RD Collaborations*, https://scientific-info.cern/archives/history_CERN/Exp-Programme-04#RD.

[4] STFC Review panel, *Strategic Review of Particle Physics* , 2022. https://www.ukri.org/wp-content/uploads/2023/01/STFC-03012023-SRPP-Final-Report_Dec-22.pdf.

[5] Department for Science Innovation and Technology, *UK Strategy for Engagement with CERN* , UK, 2023. https://www.gov.uk/government/publications/uk-strategy-for-engagement-with-cern-unlocking-the-full-potential-of-uk-membershi

[6] , *Department for Science Innovation and Technology* , UK, 2023. https://assets.publishing.service.gov.uk/media/646626780b72d3001334476d/national_semiconductor_strategy.pdf.

DRD-UK Collaboration

All staff and students working on detector development should be added, not only those bidding for CG effort.

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G. Barker[21], T. Blake[21], M. O'Flaherty[21], M. Kreps[21], X. Lu[21], A. Mitra[21], K. Potamianos[21], Y. Ramachers[21], B. Richards[21], M. Spangenberg[21],
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