

**EPSRC UKRI Mid-Term Review Report, June 2020**

<b>Business Lead:</b> QinetiQ Ltd
<b>Academic Lead:</b> University of Exeter
<b>Project Title:</b> The Tailored Electromagnetic and Acoustic Materials Accelerator (TEAM-A)
<b>Grant reference:</b> EP/R004781/1
<b>Sector:</b> Information Technologies

**Project Delivery and Progress**

This five-year Prosperity Partnership (PP) programme continues to build upon the successful relationship that exists between the University of Exeter and QinetiQ. TEAM-A is developing advanced materials that can be used to control and manipulate the propagation of electromagnetic and acoustic energy in a highly tailored, bespoke fashion, and focuses to develop innovative techniques for their cost-effective manufacture. The ultimate aim of TEAM-A is a sustainable, long-term partnership, underpinned by revenue created through the licensing of intellectual property (IP), the development of products and the advancement of academic understanding.

The TEAM-A PP is on track to deliver its original aims and ambitions, consolidating and utilising the expertise of both industry and academia to the benefit of QinetiQ (QQ), University of Exeter (UoE) and the wider community. At the half-way stage the partnership has obtained further investment and collaboration from diverse industries in sectors such as [food](#) and [medicine](#), with our research leading to scientific publications, patent applications, new studentships and [grants](#). We have built new academic partnerships, undertaken a wide range of outreach activities, and are developing a cohort of entrepreneurial researchers who are gaining valuable skills and perspectives from working with industry. Details of some of our achievements can be seen in our latest annual [report](#) and on our [website](#). The long-term funding provided by the Prosperity Partnership has been critical in providing a stable platform from which to deepen and strengthen the partnership.

In order to support the maturation of our research challenges and protect the development of our Intellectual Property, some minor changes have been made to the project plans/milestones. For instance, formal SME events and industry ideas workshops have been replaced with a more targeted approach to gaining end-user priorities, which we believe is more effective. For example, one-to-one meetings and workshops have taken place with organisations including [William Blythe](#), [The Royal Devon and Exeter Hospital](#), [Numerical Optics Ltd](#), and [PepsiCo](#). We expect such activities to accelerate over the second half of the programme, as we transition some of our research (the majority of which is TRL 1 to 3) onwards into commercial exploitation.

**Research Challenge One:** New materials and structures that control the propagation of microwave and radio frequency radiation

**Leads:** Dr Ian Hooper (UoE) and Prof. Frank Smith (QQ).

**Outputs:** Microwave & RF antennas. Novel RF control elements for electromagnetic control in buildings, and for the physical tracking of assets (parcels & trains).

**Progress:** Collaborations and publications with external university partners, University of Edinburgh re: [Orbital Angular Momentum](#), and University of Warwick re: [treatments for photoconductive silicon](#) (for RF control devices and THz imagery). Research on RF retroreflectors to meet known needs in tracking (e.g. for aerial targets produced by [QTS Ltd](#)). Includes support to Dr Alex Powell (UoE) for winning a Royal Academy of Engineering Research Fellowship on ‘superscatterers’. Building upon two existing joint patents, a new thin and flexible RF absorber that avoids previous scatter problems: paper and patent in preparation. Additional PepsiCo collaboration regarding the RF characterisation of foodstuffs, to aid microwave cooking in industry and domestic environments. Paper in preparation.

**Research Challenge Two:** To exploit the use of optical, infra-red and terahertz radiation for identification, signalling and imaging

**Leads:** Prof. Geoff Nash (UoE) and Prof. Chris Lawrence (QQ).

**Outputs:** Advanced infrared sources suitable for use in terahertz beacons. A hand-held THz scanner. THz taggants for asset ID and optical filters based on metamaterial/ phase-change hybrids, to enable enhanced hyper-spectral imagery.

**Progress:** THz imager has progressed well, with several papers and conference presentations produced. Collaboration with Royal Devon & Exeter Hospital is in place. New links to THz expertise in QinetiQ Malvern have been developed, with the loaning of equipment saving project costs. Graphene-based infrared emitters have been fabricated and tested: a graphene-based thermal beacon has been demonstrated, but preliminary measurements suggest that the output power may be too low for this particular application and the focus of this work will now switch to exploring the potential of these sources for use in non-dispersive gas sensing. Work on chalcogenide materials for applications such as hyperspectral imagery has resulted in a paper being submitted.

**Research Challenge Three:** New materials and structures that control the propagation of acoustic radiation

**Leads:** Prof. Alastair Hibbins (UoE) and Mr Rob Freeman (QQ).

**Outputs:** Technology demonstrators, such as thin acoustic barriers for use on land vehicles.

**Progress:** Via TEAM-A Innovation Funding, Dr Simon Horsley (UoE) has worked with QQ's acoustic materials team to enable direct measurement of 'mid-range' Poisson's ratio materials (extremely difficult). We have a new approach, now to be proven and published. A range of novel acoustic control materials is under study, including metasurfaces, auxetics and novel liquid-filled foams. These include considerations of how such materials can be manufactured (e.g. via novel injection moulding techniques).

**Research Challenge Four:** To develop predictive models of the propagation of electromagnetic and acoustic radiation, supporting the other research challenges

**Leads:** Dr Jacq Christmas (UoE) and Dr Pete Hobson (QQ).

**Outputs:** New algorithms to inform the development of new materials. Materials that can mimic the optical properties of atmospheric propagation. Materials exhibiting previously unattainable levels of scatter and glint control, including RF and acoustic analogues.

**Progress:** Optical models for predicting atmospheric distortion of images have been used to improve a facility that MOD uses to assess risks and prevention of laser dazzle on pilots (also applicable to future camouflage trials – in progress). Our models also account for optical oceanography and the effect of sea surfaces. We are addressing fundamental repeatability and error analysis challenges with bidirectional reflectance distribution function, an apparatus that fully characterises the scatter from surfaces. Error analyses have been used to improve inter-institution comparisons, and better calibration standards are being sought. We are also assessing nanomaterials for William Blythe, modelling their optical behaviour and collaboratively seeking new applications.

**Research Challenge Five:** To explore novel approaches to the manufacturing of advanced materials

**Leads:** Prof. Oana Ghita (UoE) and Mr Chris Spooner (QQ).

**Outputs:** Establish protocols and potential routes for the sustainable, cost-effective and commercially viable manufacture of the advanced materials developed in challenges 1 - 3.

**Progress:** A 'feeder head' for a 3D printer is being developed, allowing the alignment and gradation of particles in polymer as it is printed. This is key to optimising printed structures that can absorb/redirect electromagnetic signals, control heat flow and exhibit other specific effects. A small project has started, looking at whether a specific polymer component can be produced for a QinetiQ-designed hub-drive, for use on electric vehicles. The component is currently produced via injection moulding, but this approach is inflexible and – at present – expensive. The work has just begun, but should result in a highly bespoke polymer 'spring' for use in high-temperature environments.

## Benefits Realisation

As the programme's progress illustrates, the team are actively seeking to maximise the academic and industrial benefits arising from our research and partnership, both locally within the project members and more broadly across industry and academia. We are doing this through diverse means such as regular formal and informal discussions, researching industry business needs, [Popular Science articles](#), attending and presenting at key events, and inviting industry experts to discuss their markets and needs with the TEAM-A members. Amongst others and excluding those aforementioned, we are maximising the benefits that arise from the PP via the following approaches:

### Idea Incubation and Investment

An integral part of our exploitation strategy was the creation of a £400K Innovation Fund. This is managed in a similar way to EPSRC Impact Accelerator Awards, with proposals sought from researchers associated with TEAM-A, often working in partnership with external organisations. So far, seven innovation projects have been [funded](#), ranging in size from £5k to £50k. These innovation projects provide a route to increase the TRL of some of our research (e.g. QQ's materials expertise to make elements of the THz scanner), bring in new partners (e.g. Dr Simon Horsley in RC3; Warwick University in RC1) and - moving forward - will allow some of our postdoctoral researchers (PDRFs) to further develop some of their own ideas. An example of the success of these projects is the development of a wider collaboration with PepsiCo, who are utilising the combined expertise contained within TEAM-A, and are also exploring how some of the techniques and materials developed through the partnership could be applied to food manufacturing.

### Engagement with a broad network of SMEs and External Colleagues

During the second half of the programme, TEAM-A is prioritising more interaction with SMEs to explore advanced engineering links between QQ, UoE and SMEs operating in differing business sectors. So far we have invested in SMEs such as [Theta Technologies](#), using our Innovation fund in order to learn more about their technology's capability and strengthen their links with both UoE and QQ. We will continue to use industry links, one-to-one visits, workshops and event attendance in order to build a broader network of collaborators. The long-term funding provided by the Prosperity Partnership has been critical in providing a stable platform from which to explore future opportunities. For example, our researchers have been able to attend meetings such as [Teranet UK](#), and Innovate UK's [Materials Research Exchange 2020](#), to make contact and gather ideas from other researchers about new applications. A new [Centre for Metamaterial Research and Innovation](#) has recently been established in Exeter, with support from a wide range of academic and industrial partners. Our association with this Centre allows us to tap into a broad spectrum of additional collaborators, and could support our aim of making TEAM-A a sustainable partnership beyond 2022.

**Investment in new generation of entrepreneurial researchers and industry leaders**

The programme's PDRFs and PhD students together benefit from shared training throughout the programme in order to provide them with an understanding of a wide range of industry sectors and insight into a variety of career opportunities. To further support this, movement between UoE and QQ is encouraged and all researchers are integrated with QQ's teams. Expert-led career development meetings take place, such as: UoE-based 'perspectives on academic vs industry careers'; QQ-based 'Industry problem solving workshops'; Royal Society [Media and Communication Skills](#) training; and specialist subject matter courses on topics such as 'electromagnetic theory as applied to radar and defense', Comsol webinars, and radar stealth lecture courses based at QQ. TEAM-A PDRF Dr Alexander May has become a member of The Applied Electromagnetic Society, as well as an article reviewer, also receiving IET career mentorship from Dr Alexander Boyland of [SPI Lasers](#) to guide him through the procedure for chartered engineer status. Our first summer [Internship scheme](#) led to one UoE Undergraduate being offered employment with QinetiQ.

**Management and Government Arrangement**

TEAM-A's success is driven by the team's ability to co-deliver and collaborate in partnership, through both formal and informal mechanisms. The TEAM-A Collaboration and Intellectual Property Agreement, approved and developed by UoE and QQ stakeholders, underpins how both parties interact on a formal level. This agreement commercially and intellectually protects both parties and supports the ease with which tasks such as publications, data sharing and resource management have been administered.

The partnership is managed through a flexible and dynamic [management model](#), involving an Advisory Board -previously known as 'Oversight Board'- that meets annually and is updated as requested -the first advisory update report may be seen [here](#)-. This governance board allows for high-level advice and review to be sought from UoE, QQ, UKRI stakeholders, and an independent Chair (Dr Benny Hallam of The Quartz Corp); this ensures that TEAM-A maintains the best possible quality assurance and gains sector-leading insight. The Advisory Board (AB) is external to the operational delivery of the TEAM-A Programme: it is designed to raise potential opportunities and risks, provide dispute resolution if required, and make written recommendations. The AB is critical to supporting the aim of TEAM-A becoming a sustainable partnership. Recommendations are noted and taken forward by the Leadership Board and actioned accordingly. As we evolve into the latter years of the programme, it is expected that more recommendations for exploitation will come through the AB. The programme's Leadership Board is made up of key parties from both partners, including the academic and business PIs, to ensure that all strategic decisions are made jointly. The board meets

formally on a quarterly basis to address mutually agreed subjects and any risks. Programme Support and Research Challenge Leaders with related teams are also pivotal elements to the programme's governance structure. As a whole, the programme has formally agreed the following approach to risk: All TEAM-A members are required to report any risks or opportunities as soon as possible, either by escalating the issue to their respective challenge lead or supervisor, or to [TeamA@exeter.ac.uk](mailto:TeamA@exeter.ac.uk). In the event that any issues are identified, they are addressed and managed appropriately by the relevant managers, leads and/or the Leadership Board.

Our approach to IP and wider collaboration is defined within the formal collaboration agreement, and is supported by continual and candid communication amongst all involved parties, including individual researchers and the programme's Leadership Board. Within each project, existing intellectual property is agreed at the outset, with regular reviews undertaken to assess new IP and understand progress through the TRLs. Any project that progresses beyond TRL 3 will be taken through the QQ standard product development process to explore initial commercial viability. Through this commercialisation process, routes to market are explored to ensure value to the UK economy, with UoE and QQ commercialisation and innovation teams working together to agree whether ideas will be taken forward by QQ, partners or SMEs as appropriate. Once all initial commercialisation plans are in place, resources from both UoE & QQ will be aligned to undertake business development.

### **Resources (Business Contributions)**

All business contributions are protected and agreed within the programme's collaboration agreement. Matching cash contributions from business partners have been deployed within the programme as agreed; any deviations made are in the best interest of the programme and are discussed and agreed by the Leadership Board. Funds already contributed include, our [Innovation Fund](#) (£400k Ex VAT total), £124k Ex VAT has already been contributed. For the remaining funds purchase orders (POs) have been set up. £200k Ex VAT has been retained by QQ in order to deploy during the programme's latter years of exploitation. Travel and Subsistence [Support Fund](#) (£216k Ex VAT total) £95k Ex VAT has already been contributed. For the remaining funds purchase orders (POs) have been set up.

### **ED&I and RR&I**

TEAM-A aims to support a diverse and inclusive research environment where there is equal access to opportunities. We are guided by and strictly adhere to our institutions' practices and policies, seen here: [UoE](#) & [QQ](#). The Partnership has further enabled TEAM-A to show support for ED&I, and RR&I priorities by enabling our funding of International Women in Engineering Days (2019 & 2020): details concerning the 2019 event may be seen on our [news](#) page and [QQ's website](#), as well as our [Twitter](#) page concerning 2020's event.