Written evidence submitted by the Research Councils UK (GRA0014)

1. Research Councils UK (RCUK) is the strategic partnership of the UK's seven Research Councils. Our collective ambition is to ensure the UK remains the best place in the world to do research, innovate and grow business. The Research Councils are central to delivering research and innovation for economic growth and societal impact. Together, we invest £3 billion in research each year, covering all disciplines and sectors, to meet tomorrow's challenges today. Our investments create new knowledge through funding research excellence; responding to society's challenges; developing skills, leadership and infrastructure; and leading the UK's research direction. We drive innovation through creating environments and brokering partnerships; co-delivering research and innovation with over 2,500 businesses, 1,000 of which are SMEs; and providing intelligence for policy making. Find out more about our work at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK and represents its independent views. It does not include, or necessarily reflect the views of the Knowledge and Innovation Group in the Department for Business, Innovation and Skills (BIS). The submission is made on behalf of the following Councils:

- Engineering and Physical Sciences Research Council (EPSRC)
- Medical Research Council (MRC)

Q1. The research obstacles that have had to be overcome for Graphene, including identifying research priorities and securing research funding, and the lessons from this for other areas of research.

3. Graphene is a single layer of graphite arranged in tightly bound hexagons that is only one atom thick. It is the stiffest known material, optically transparent, can stretch to 20 times its own length and appears to be the most impermeable material discovered. Graphene also has better electrical conductivity that any other material and superb thermal conductivity. Much of the scientific interest in Graphene surrounds this unique combination of properties.

4. Huge potential has been identified for Graphene in applications as diverse as novel composite materials (to enhance strength), electronics (eg flexible displays, devices), conductive inks, energy storage (batteries and capacitors), barrier coatings (eg anti-corrosion and food packaging), lasers & photonic devices, research tools (electron microscopy) and healthcare (exploiting the biocompatibility for dressings or scaffold for tissue replacement).

5. Graphene can be produced in the form of thin films or bulk material (such as powder, platelets or a suspension). Significant challenges remain in scale-up to deliver efficient, reproducible and fully-characterised supplies of graphene. Further challenges exist in order to (a) identify the optimum form of graphene to incorporate into a given system or product, and (b) understand and resolve the challenges associated with the incorporation of a new material into a complex material system or device.

6. The UK is a global leader in research into graphene. EPSRC has been funding fundamental research into graphene for over 15 years and contributed to the research funding that led to the award of the 2010 Nobel Prize for Physics to Prof Andre Geim and Prof Kostya Novoselov at the University of Manchester. The current EPSRC portfolio of grants with relevance to Graphene and Carbon Nanotechnology research includes 46 grants of total value approximately £87M and is an area that EPSRC intends to maintain as a proportion of its total grant portfolio.

7. Following an approach from BIS, EPSRC and TSB (now Innovate UK) developed a business case under guidance from officials in BIS. In October 2011 the UK Government announced a £50M investment to create a Graphene Global Research and Technology Hub. This was intended to build on existing research strengths in many universities and business.

8. EPSRC convened a small group to assess the proposal for a new building to house a Graphene Institute at the University of Manchester, concluding it represented value for money as part of the overall Graphene Hub business case. The business case and value for money assessment for the new institute was submitted to BIS. Following ministerial approval, the single-supplier process for the building was initiated to award £38M of capital funding for the institute via EPSRC. The University of Manchester subsequently submitted a grant proposal to EPSRC to facilitate the award, contributing £7M to the institute.

9. The strategic aim of the National Graphene Institute (NGI) was "to enable the manufacturing of graphene on a large scale through new production methods and techniques, which in turn will open up commercial opportunities in a number of potential application areas." An additional £23M of funding was leveraged from the European Regional Development Fund. The NGI was opened on 20 March 2015.

10. Future government capital investments, focussed on other areas of research, should be part of a Business Case setting out the requirement for parallel investment to support the associated running costs; this should be linked to an appropriate sustainability plan stating how these costs will be met. Where possible such funding should be open to competition.

11. EPSRC launched a call for proposals in early 2012 titled "Graphene Engineering" in order to competitively allocate at least £10M of EPSRC funds, in addition to the remaining £12M of capital investment from the government. The strategic focus for the call was research into manufacturing processes and technologies linked to graphene to accelerate the development of novel devices, applications, technologies or systems.

12. The total EPSRC funding awarded was for 7 research programmes and 5 equipment-only grants, totalling £25.9M (EPSRC actually invested £13.9M). Eight different universities were successful and examples of potential applications included electronics, fibre-composites, packaging, energy storage, membranes and sensors. The successful grants leveraged over £15M of industry support. The awards were announced by George Osborne, as described in a press release in December 2012: https://www.epsrc.ac.uk/newsevents/news/graphene/ (please note that two additional awards were made after this announcement, but values above include all successful grants).

13. The University of Cambridge was awarded three EPSRC grants of total value £12M under the "Graphene Engineering" call which acted as an initiator for the formation of the Cambridge Graphene Centre. This funding is complemented by strong industrial support, worth an additional £13 million from over 20 partners. A further £11M of European Research Council funding supported activities with the NGI in Manchester and Lancaster University.

14. Innovative research exploring potential applications of Graphene is also supported through Research Council Institute programmes. Researchers at the MRC Laboratory of Molecular Biology have developed a method to modify or 'tune' the surface of Graphene using low-energy hydrogen plasmas, which then allows proteins to bind in an even and controlled distribution. This work involved development of specialised specimen supports for cryo-electron microscopy. The first high-resolution structures using modified Graphene supports were published in 2014[1]; patent applications are pending with an intention to license the supports in the near future. This work is one of the first applications of Graphene to address biological research challenges, opening up new techniques for using Graphene to solve protein structures. Such tools will enable the structure to be determined of smaller and more difficult proteins than previously possible.

15. EPSRC is committed to training and for Graphene the importance of providing a pipeline of talented early career researchers was recognised. In November 2013 EPSRC awarded 117

[1] http://www.nature.com/nmeth/journal/v11/n6/full/nmeth.2931.html

Centres for Doctoral Training (CDTs), each training ~50 internationally competitive doctoral students in a cohort-based approach to meet future skills needs in the UK and create the next generation of leaders. Two CDTs were awarded of direct relevance to Graphene. First, "Graphene Technology" at University of Cambridge - total EPSRC award £4.6M and total project partners' contribution of £6.2M. Second, "Science and Applications of Graphene and Related Nanomaterials (Graphene NOWNANO)" at University of Manchester which was awarded £4.5M by EPSRC with a total contribution from project partners of £5.6M.

Q2. The factors which have contributed to the successful development of Graphene and how these might be applied in other areas; including translating research into innovation, managing/ sharing intellectual property, securing development funding, and bringing key stakeholders together

16. The Chancellor announced a further investment in the 2014 Budget for a Graphene Engineering Innovation Centre (GEIC) in Manchester to provide pilot plant facilities for scale-up of Graphene technologies. Innovate UK invested £5M coupled with £15M from HEFCE. A further £14M was awarded for a Graphene Applications Innovation Centre to be based at the Centre for Process Innovation in the North East of England (which is part of the High Value Manufacturing Catapult). This will integrate with other existing facilities, for example printed electronics.

17. Throughout 2013, EPSRC and Innovate UK (IUK) worked together to explore the innovation opportunities for Graphene. Two industry workshops were held in March to explore commercialisation and applications for graphene, and a "Graphene Community Day" was held in October to bring together industry and academia to showcase the breadth of discipline and gather views on specific issues relating to the commercialisation of graphene research.

18. In January 2014, IUK launched the Graphene Special Interest Group (SIG) to provide a focus for academia and industry across the graphene supply chain. The SIG organised four consortium-building workshops to build collaborations for the joint IUK/EPSRC call "Realising the Graphene Revolution" (for short industry-led feasibility studies to accelerate commercial applications). In August 2014, a total of 14 projects were funded of value £2.1M, IUK contributed £1.4M and EPSRC contributed a total of £722k supporting academic collaborators on the projects.

19. In late 2014, the SIG established a national advisory board, the Graphene Innovation Leadership Board (GILB), with ~30 people representing the whole value chain from fundamental science to applications. The first meeting was in September 2014. The purpose of the GILB is to validate and guide the activities of the Graphene SIG in terms of priorities and approach, and act as a forum for consulting the community on graphene related matters. The GILB also provides a channel for the community to influence Government on graphene-related matters.

20. In June 2015, IUK and the SIG hosted another graphene community workshop to start scoping a second feasibility study call "Advancing the commercial applications of Graphene", incorporating advice from the GILB regarding the technical scope. In December 2015 a total of 11 projects were funded of value £1.95M. EPSRC contributed a total of £786k across 9 projects for academic collaboration alongside £1.2M from IUK.

21. In October 2013, after a preparatory period of three years, the Commission launched a €1Bn Graphene Flagship through its Future and Emerging Technologies scheme. This is a long-term, large-scale research initiative aimed at exploiting the potential of graphene. There are currently 17 UK members. Further details are available at

http://graphene-flagship.eu/project/Pages/Consortium.aspx.

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Q3. The benefits and dis-benefits of the way that Graphene's intellectual property and commercialisation has been managed, including through research and innovation collaborations, and the lessons from this for other areas.

22. Responsibility for the management of any intellectual property resulting from RCUK funded research resides with the research organisation that holds the funding award. For grants this may be a university or independent research organisation, and for research council programmes the research council institute. RCUK's guidance for award-holders requires all of those engaged in the research to make every reasonable effort to ensure that the intellectual assets obtained in the course of the research, whether protected by intellectual property rights or not, are used to the benefit of society and the economy. Research outcomes should be disseminated to both research and more widespread audiences - for example to inform potential users and beneficiaries of the research. Unless stated otherwise, the ownership of all intellectual assets, including intellectual property, and responsibility for their application, rests with the organisation that generates them.

23. Where an RCUK grant is associated with more than one research organisation and/or other project partners (usually one or more companies), the basis of collaboration between the organisations, including ownership of intellectual property and rights to exploitation, is expected to be set out in a formal collaboration agreement. It is the responsibility of the Research Organisation to put such an agreement in place before the research begins. Arrangements for collaboration and/or exploitation must not prevent the future progression of research and the dissemination of research results in accordance with academic custom and practice. A temporary delay in publication is acceptable in order to allow commercial and collaborative arrangements to be established.

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