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Research and Innovation Organisations in the UK: Innovation Functions and Policy Issues

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Department for Business, Innovation and Skills

1 Victoria Street

London SW1H OET

www.gov.uk/bis

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Author and acknowledgements

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Summary

The ‘knowledge infrastructure’ of the UK includes about 200 ‘Research and Innovation Organisations’ (RIOs). They have many organisational forms, mainly due to historical accident rather than design. Some are independent foundations, some are linked to universities, some are private companies; they have in common a significant degree of public support, either in terms of core or programme funding, or research purchasing. Current UK policy is continuing to develop this system, through new organisations such as the Crick Centre, and the creation of nine ‘Catapult Centres’ based around advanced industrial knowledge bases.

What is the role of RIOs in UK innovation performance, and what governance and financing challenges do they present? The conventional, usually preconceived, view of RIOs is that they perform R&D of various types, and that the primary challenge is to commercialise the results of research. This view is found not only in the UK but throughout the world. The commercialisation imperative has produced long-term policy and governance changes based on privatisation and/or contracting as a major source of funds for RIOs.

The ostensible aim of these shifts has usually been to align RIO performance with the needs of industrial customers. But these changes have rarely rested on a close examination of what RIOs actually do.

By contrast, this paper is a preliminary empirical account of what RIOs do to support innovation, resting on surveys, interviews and site visits. Three broad innovation-relevant activities are identified among RIOs, each with a myriad of sub-activities. These are: (1) *Support to industrial innovation*, involving scientific development of industry knowledge bases, problem solving and advice, and in-house product and process development, (2) *Infrastructure creation and maintenance*, involving provision of specialised or large-scale capital goods, instruments and equipment, and storage of scientific and/or industrial materials and data, and (3) *Public policy development and implementation*, involving contributions to policy development and implementation, contingency planning and monitoring for accidents and natural disasters, and social and health innovation. Very few of these activities involve the commercialisation of research.

The main characteristics of RIO innovation activities are that they are often long-term, indirect, highly uncertain in outcome, intermittently relevant (i.e. they may become important only in some kind of crisis) and infrastructural in

character. The infrastructural aspect of RIOs may raise important challenges for policies directed towards long-term financing and governance, especially where – as in the UK – policymakers seek to rebalance the economy towards a more diversified mix of sectors and industries.

THE REPORT

1 Research and Innovation Organisations (RIOs) in the UK System

Like most advanced economies, the UK has a substantial set of "Research and Innovation Organisations" (hereafter 'RIOs') that use varying forms and levels of public funding to support business innovation. The aim of this paper is to identify the innovation roles of RIOs in the UK in terms of their contributions to UK innovation performance, and to discuss future financing and governance challenges. This is particularly important in the context of growth-oriented industrial policies resting on key sectors and technologies.

In seeking to understand differences in growth rates across the world in recent decades, a dichotomy is often drawn between market economies – such as the US and the UK - and 'developmental states' such as Japan, South Korea, and latterly China. The latter are held to be characterised by extensive government support for knowledge building and industrial investment, while the former rely primarily on market incentives and private decision-making.

This dichotomy is a false one. The UK, like most other market economies, has for centuries had a substantial set of government-owned or government-supported organisations that create, maintain and distribute innovation-relevant knowledge. These organisations have played central roles in creating and sustaining innovation-based growth in the UK. If there is a difference between the UK and 'developmental states' it may lie not in the existence of these organisations but in their funding, governance, coordination, strategic direction and links with business. These are large issues that go beyond the scope of this paper, but an essential starting point in addressing them is the functionality of the RIO system. What is the knowledge creation system in the UK, how does it operate, and what governance and funding challenges does it present?

The 'knowledge infrastructure' of the UK consists principally of two types of organisation. On the one hand there is a university system comprising about 130 universities of different types. This is probably the world's leading university sector in the sense that, weighted by population, the UK has more universities in the world's top echelon than any other country, and performs extremely well on the usual indicators of scientific output (such as high-impact publications).

On the other hand there is a system of what are called here 'Research and Innovation Organisations' (RIOs). RIOs are a complex array of organisations – roughly 200 by a recent BIS count – that perform research, create innovations, gather and distribute scientific information, develop high-level skills, underpin business and public sector operations, and support policymakers (especially in natural crises). Current policy is continuing to develop this system, by supporting major new organisations such as the Crick Centre, and by creating a set of 'Catapult Centres' based around advanced industrial knowledge bases.1

The present array of RIOs is the historical outcome of disparate policies and decisions over many years (in some cases, centuries). This inherited set of organisation functions in diverse and often effective ways, but there has been little in the way of consistent policy towards it, or even a consistent understanding of how it works. Different parts of the RIO system have faced almost continuous governance change, mainly aimed at increasing interactions with business and increasing responsiveness to business problems. The main instrument for this has been changes in funding systems, with higher proportions of funding from competitive processes and private contracting.

2 RIOs in the UK

The present RIO system is highly heterogeneous, with no agreed classification of organisations, and no settled agreement even on terminology. Definitional issues are discussed below, in Appendix D. For the purposes of this discussion, RIOs in the UK are defined as: *non-profit organisations that perform research and innovation support as their main activity, whose existence depends on a significant degree of public funding, and whose work serves some public policy purpose*. Of course some for-profit companies perform policy-oriented R&D and innovation work – although these are very much less significant in terms of numbers and funding.

[1] Important recent studies of this system include Manchester Institute for Innovation Research*, The Public Value of Public Sector Research Establishments. Towards a set of principles and guidelines***,** BIS, 2013, and the seven survey studies *Annual Surveys of Knowledge Transfer Activities in PSREs,* carried out over the past decade by BIS (mostly implemented by Technopolis).

The RIO system in the UK currently has four major components:

- a large set of 'Public Sector Research Establishments' (PSREs) which are research and development institutes sponsored directly by government departments or the seven UK Research Councils (Appendix B presents an overview of these organisations).

- a set of infrastructural 'Public Research Organisations' (PROs), including major standards-setting organisations and research organisations providing – for example - geophysical or metrological information to government and business.2

- a set of Independent Research and Technology Organisations (IRTOs). These are (mainly) private non-profit research performers or commercial research enterprises providing R&D services, both to government and business, and many belong to the Association of Independent Research and Technology Organisations (AIRTO).

- A set of nine actual or projected 'Catapult Centres' which seek to link business, advanced research and engineering around innovation processes with major business implications, and further large-scale collaborative research organisations such as the Crick Centre.3

The reason for our focus on this array of RIOs is that, along with universities, they are the most important publicly-funded research performers in the UK. Universities have been studied in detail in terms of their underlying economics, and in terms of their scientific, innovation and economic outcomes, while RIOs have been relatively neglected. This is despite their large number, and despite very high levels of scientific expertise, research competence and innovation capability within them (one British RIO has won 14 Nobel prizes, the most recent in October 2009, and many are globally important scientific organisations).[4]

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[2] What are called here 'PROs' include the National Physical Laboratory, the National Measurement Office, the Ordnance Survey, the British Geological Survey, and the Design Council.

[3] Thus far there are seven Catapults focused on: cell therapy; the connected digital economy; future cities; high value manufacturing; offshore renewable energy; satellite applications; and transport systems. Two more are in the pipeline, on energy systems and diagnostics for stratified medicine.

[4] The organisation is the MRC Laboratory for Molecular Biology, Cambridge.

3 Towards a Taxonomy of RIOs

The population of UK RIOs is so complex that a taxonomy that reduces it to groups with common characteristics would be very helpful. What is offered here is but a step towards such a taxonomy in the sense of identifying relevant characteristics and sketching what they might look like in one sector.

One obvious characteristic is ownership structure or legal status. This is more important than might appear at first sight: ownership and governance structures may affect innovation performance, and can promote or inhibit strategic coordination.

The present ownership and governance structure of RIOs is the product of long and complex histories, in some cases stretching back centuries. For example, the Ordnance Survey, now a commercial organisation dealing with geographical information and spatial organisation, was founded in 1791. The British Geological Survey was founded in 1832. The National Physical Laboratory, now the central institution in metrology (measurement sciences), was established in 1900. The Medical Research Council was established before the First World War.

An overview of the histories of these establishments suggests that few if any were established on the basis of a perceived market failure related to the economics of innovation. Rather, they emerged for military or strategic reasons related to such issues as naval policy, imperial control of particular regions, or general military needs.

An important section of them were responses to crises of public health. Others were more economic in character, being founded in response to specific scientific opportunities or challenges, such as agricultural problems, fisheries control, or the emergence of atomic weapons and nuclear energy.

Others were created in response to the standardisation and informational needs of an increasingly complex economy – scientific organisations dealing with problems of measurement, for example, are a common feature of advanced economies, as are public institutions for provision of geographic information (essential in urban planning and the construction industry) or geological survey data (a major input to resource-use companies and the insurance industry).

The practical needs that gave rise to the organisations have often persisted over time and – although they have changed in terms of scientific and technological scope – their innovation functions have persisted. But they have often changed dramatically in terms of ownership and governance, especially as a result of decentralisation, deregulation and privatisation. Increasingly 'distributed' ownership means that it can be very difficult to coordinate among these organisations, or to integrate them into a strategically coherent policy.

Taxonomies can be developed around multiple criteria, and can be rather limitless. It is important to shape them, therefore, around the analytical purposes that the taxonomy is meant to serve. In this case, the relevant purpose is the contribution that RIOs might make to strategic growth policy in the UK. This suggests three main classificatory lines:

- Main knowledge fields
- Technological capabilities
- Sectoral and industrial application

We do not have really adequate data to make these classifications. **Table 1** below, and **Appendix A** below, offer a mixture of all three characteristics, and suggest that individual organisations may (and in fact usually do) operate across multiple knowledge fields, multiple technologies and – less usually – multiple industries.

If we isolate (from **Appendix A**) those RIOs that broadly relate to food sector and industries, we can readily see the multidimensional character of functions and knowledge-bases across RIOs:

Table 1: Food Complex: RIOs and Functions

	Agriculture	**Animal Health**	Biological Sciences	Climate Change	Disease Control	Environmental	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Plants	Policy & advice	Sustainability
Fisheries Research Services								■		■				■	
Food & Environment Research Agency (ex CSL)		■			■		■	■							
Health & Safety Laboratory							■	■			■			■	
Macaulay Land Use Research Institute	■								■						
Veterinary Laboratories Agency		■			■			■							
Pirbright		■						■							
Institute of Biological, Environmental and Rural Sciences			■	■					■						
Institute of Food Research					■		■								
John Innes Centre								■	■				■		■
Agriculture & Horticulture Development Board	■												■		
Agri-Food & Biosciences Institute (Northern Ireland)	■		■												
DEFRA Science and Analysis						■									
National Institute for Biological Standards and Control (NIBSC)							■								

Table 1 sets out in a matrix, RIOs and their respective functions

Food security is a central policy challenge at the present time, and will continue to be important. What we have here are twelve organisations related to food innovation, security and safety, operating across multiple knowledge bases and with multiple objectives. It is difficult to build an overall picture of the division of labour and of how they fit together, and this problem is repeated in almost all areas of the RIO population. This is not a problem of the organisations themselves, but of the data and concepts available for building an overview and taxonomy. Given the functions of these organisations – to be discussed below – such a taxonomy is an important future task.

4 Sources and Methods

The analysis in this paper rests in large part on a set of site visits and interviews in RIOs, and separate documentation of their knowledge bases and economic impacts.

We visited an initial sample of 16 organisations, and these form a core set of case studies on which the innovation-oriented sections of this paper rest. Interviews were conducted on the basis of a structured guide, organised into 17 questions in four sections. These covered the following topics:

- R&D strategies and allocation behaviour
- training and mobility
- modes of innovation outcome
- governance issues.

We carried out site visits and held interviews with the following RIOs, chosen to reflect a broad cross-section of the population in terms of ownership arrangements and scientific-industrial focus. They were:

Forest Research Institute
Diamond Light Source (Harwell synchrotron)
MRC Clinical Sciences Centre
MRC Cognition and Brain Sciences Unit
Food Research Institute
John Innes Centre
Babraham Institute
Tate Gallery Research Department
Ordnance Survey
Defence Science and Technology Laboratory (+Ploughshare Innovations)
British Antarctic Survey
Scottish Crop Research Institute (+Mylnefield Research Services)
Centre for Environment, Fisheries and Aquaculture Science
National Physical Laboratory
National Oceanography Centre
British Geological Survey

In recent years some RIOs have set-up wholly owned trading subsidiaries. Two such examples were encountered in the sample of case studies. These

bodies are typically charged with overseeing the institution's trading activities and ensuring the best possible use of its intellectual property and other assets. They generally are or aim to be self-funded and to re-invest profits back into the institution on an annual basis. In theory they also seek to reduce costs, including the not insubstantial opportunity costs of researcher's time if researchers themselves are expected to include maximising commercial revenue amongst their objectives. This paper also draws on a survey of PSRE innovations made by Christine Thompson of Imperial College, London, and a study of RIO capabilities by Neil Campbell of NPL (see **Appendix A**).

5 What do RIOs do in the innovation system?

Our general conceptual approach rejects the idea that RIO innovation consists essentially of the commercialisation of R&D results. It is often the case that impacts of RIOs are seen in terms of commercialisation, as though they produce discrete research results that can be transferred into industrial innovation processes. Such results are usually argued to enter companies via 'technology transfer' of some kind (e.g. licences) or by providing the technological bases of spin-out companies. We suggest that these discrete, separable impacts are certainly identifiable and important, but make up only a part of the activity of RIOs.

A different approach is to identify the wider knowledge bases and capabilities that are supported by RIO activity, and to see RIO functioning in terms of the economic impacts of that support. In this paper we begin the process of identifying the relevant knowledge bases. Our suggestion is that RIOs have important direct and indirect impacts in maintaining and developing business knowledge bases in the UK, and in training skilled people to use them and to innovate with them.

It is becoming commonplace in academic innovation studies to recognise that many key innovations of the modern era originated in public sector organisations, or in companies implementing public programmes.[5] In terms of organisations, the most spectacular example is probably Bell Labs, where modern microelectronics and satellite communications were built, but examples of major RIO innovations can be widely found across countries. In

[5] See Marianna Mazzucato, *The Entreprenurial State. Debunking Public vs Private Sector Myths* (London: Anthem) 2013; F. Block and M. Keller (eds) *State of Innovation. The US Government's Role in Technology Developmen*t (Boulder: Paradigm, 2011.

the UK, such important innovations include fluidised bed combustion, in-vitro fertilisation, and the intra-ocular lens, all of which originated in RIOs. In Germany, the MP3 compression system, the central technology for modern music services, came out of one of the labs of the Fraunhofer system.

These cases can readily be multiplied, but RIO innovation activity is not exhausted by specific innovations, however epoch-making. Rather, it is important to identify and assess the overall balance of RIO functions. Individual RIOs usually came into existence to solve some more or less urgent problem faced by government or industry (and often both).

These problems have ranged from strategic military needs, to public health imperatives, to resource management, to industry organisation. Out of their original objectives, RIOs often expanded into related activities, many of which were not envisaged in the original decisions to establish them. In assessing them it is important therefore to look at the overall range of activities and functions in which they are actually involved, instead of looking at them in terms of historical intention, or some *a priori* function (it is sometimes argued, for example, that universities should do basic research and RIOs applied development work), or to apply individual market failures analysis to what is in reality a complex mix.

The aim here was simply to identify more precisely what RIOs do, in order to permit a better-informed discussion of their rationale, governance and funding. The discussion here is based on BIS analyses resting on more than a decade of survey-based work on PSREs, site visits and detailed interviews on innovation activities with a range of RIOs, and a survey-based study of specific innovation outputs. The BIS work suggests that innovation-related activities and impacts of RIOs fall into three main categories, with a range of sub-activities. These are related to innovation support, infrastructures and public policy. Given the extreme variety among RIOs not all are engaged in all aspects of such work, but most RIOs are engaged in more or less all these activities to differing extents. The core activities are summarised below.

Area 1: *Support to industrial innovation*:

This comprises:

- Scientific support to industry knowledge bases
- Problem solving and advice for commercial firms
- Marketed innovation-relevant knowledge services
- Business-relevant information 'packages'
- Specific product and process development
- Creation of spin-out companies
- User-initiated innovations

Area 2: *Infrastructure creation and maintenance*:

This comprises

- Provision of 'general purpose' technological capabilities
- Physical and knowledge infrastructure provision: specialised or large-scale capital goods, instruments and equipment
- Personnel training, development and mobility
- Storage of scientific and/or industrial materials and data

Area 3: *Public policy development and implementation*:

This comprises

- Contributions to policy development
- Information for policy implementation
- Contingency planning and monitoring for accidents and natural disasters
- Support to issues of public concern in health, mental illness, well-being etc.
- Support to policymakers in crisis management

A key conclusion from this work is that RIOs cannot be seen as organisations with single or limited functions; rather they perform multiple integrated innovation-relevant activities that impact on UK business (and that may have transnational or even global impacts). These activities may be interdependent and to some extent indivisible (at least without serious damage to functioning). It is not possible, in the context of a paper, to give detailed descriptions of all these activities, but here we offer some examples to give a flavour of the scope and character of RIO activities from each of the three areas proposed above.

6 Support to industrial innovation

When firms innovate they often step outside existing areas of competence, because innovation by definition involves doing something new, and because of this they often face problems that they lack the competence to solve. RIOs provide frequent advice, often on an informal basis, that addresses these problems; this is a central collaborative function of RIOs. Every RIO that we interviewed took phone calls on a more or less continuous basis from firms within their 'constituency': this might deal with some relatively small-scale problem that was intractable for the firm but easily solvable with wider expertise.

However such calls could also raise issues that needed site visits and possibly specialised research to solve. These problems, although rather 'everyday', were often generic in character – for example, firms innovating by extending new varieties of trees or timber use might face fungus problems that are quite common and where solutions can be widely adopted. In some cases, the solution of a problem might require significant science inputs and the use of science infrastructures. A major example of this was the use of the Diamond Light Source synchrotron at Harwell to solve problems of materials used across industries.

Support to innovation in practice entails the creation, development, deepening and extension of knowledge related to almost every sector of UK economic activity. RIOs are often sectorally focused, or focused on major areas of social welfare provision (notably health). RIOs often find themselves engaged in research towards product improvement that may be quite generic in character, and might spread extensively across industries.

Often such research outcomes are unmarketable (usually because the activity produces unpatentable and unprotectable outcomes that can be rapidly and

widely adopted). But the economic impacts would precisely for that reason be substantial. One interviewee made the claim – which as far as we could see was justified – that 'every supermarket in Britain sells products based on our research'. The products in question were potatoes, an unglamorous but economically significant item. Even in areas like bio-pharmaceuticals, an RIO like Babraham is operating in upstream areas where research relates to multiple conditions, and where the research is a form of enabling knowledge base for the pharmaceutical industry.

The basis of RIO business support lies in the array of knowledge capabilities supported by the sector. Colleagues at NPL have attempted to overview the specific knowledge fields supported by the PSRE population, by classifying their operations into 21 generic knowledge fields, and by then looking at the distribution of these fields across organisations.

Note that this simply classifies institutions into whether or not they are working in a field: we say nothing here about the scale of commitment to a field. The overall distribution of capabilities can be found in detail in **Appendix A**. This is summarised in **Table 2** below which shows the number of organisations working broadly in each field. This classification does not include cultural organisations (at this stage). All Medical Research Council RIOs have been included as working in one field, namely human health.

This gives the following overview of fields and activities, which are captured in **Table 2** below.

Table 2: ***RIO knowledge capabilities and active organisations***

Knowledge field	**Number of UK RIOs active**
Agriculture	5
Animal health	9
Life sciences	10
Built environment	3
Business	12
Climate change	13
Disease control	5
Environmental	8
Food	3
Human health and well-being	67
Laboratory services	11
Land use	5
Marine environment and aquatic life	12
Mathematical modelling	12
Pharmaceuticals	4
Physical sciences	8
Plants and horticulture	7
Policy advice, development and Monitoring	6
National and individual security	6
Space/Earth observation	6
Sustainability	5

A first point to make about this is that the sector covers a very wide range of knowledge fields: it supports activities that are relevant to almost all industries and activities of the UK economy. The science efforts here are by no means confined to those industries that are usually regarded as science-intensive (such as electronics or pharmaceuticals). Many RIOs contribute to food production via agricultural and horticultural research, to timber products, to construction and transport, and to a wide set of fields that contribute to well-being (such as public health, environment quality, and security).

Commercialisation of R&D is often regarded as a primary task of RIOs. We argue that it is of less importance than other innovation-related functions, but it nevertheless occurs and is frequently very important. An Imperial College survey by Christine Thompson for BIS identified a very wide range of commercialised innovations emerging from RIOs, including:

- Natural antibiotics to fight hospital superbugs
- New silage and forage technologies with major agricultural cost impacts
- High-yielding potato varieties
- Software tools for imaging related to synchrotron use (one of which, related to crystallography, yields approximately £800m p.a. in revenue)
- Medical innovations for rapid lung isolation
- Portable cardiac defibrillators (now used globally)
- A totally-enclosed in-vitro fertilisation process
- Satellite monitoring of harmful algae blooms.

These innovations are merely examples: the list here is the tip of an iceberg. Every interview in this investigation uncovered similar cases; no really comprehensive study of RIO innovation has been performed, but there can be little doubt that the UK's commercial technologies rest in part on RIO developments. Some (such as in-vitro fertilisation) have had profound social as well as economic impacts.

Infrastructure creation and maintenance

RIOs are often involved in the provision and maintenance of large-scale and complex equipment. Some forms of corporate R&D require access to scientific capital goods that go well beyond the capacities of even large

companies to provide. The synchrotron at Harwell is such a facility. But most of the RIOs interviewed provided specialised instrument support (such as advanced microscopes, or testing equipment) for firms. Of course firms are willing to pay for access, and often do, but the scale of investment and its time horizons mean that public agencies usually provide the capital stock itself.

The Babraham Institute, for example, rents out equipment such as electron microscopes and protein purification equipment. This is a key driver for attracting firms to the campus. All the equipment is justified on the basis of BBSRC science, so additional use is purely profitable. It is only sold at a nominal profit however (the rates of return would not be sufficient for much of the private sector) with the justification that developing start-up firms is beneficial to the sector and the economy. Similarly the core facilities on-site at the MRC Cognitive and Brain Sciences Unit are MRI (Magnetic Resonance Imaging) scanners, the MEG (magneto encephalography) laboratory and an EEG (Electroencephalographic) laboratory. The MRC unit have contributed significantly to methodological developments.

Using their instrumentation capabilities, RIOs often provide data and information (such as meteorological or geophysical data). The data developed by the British Geological Survey is extensively used by the construction and insurance industries, for virtually every new construction in the UK. This activity often involves new methods and techniques (such as measurement practices) that provide a basis for research and innovation. Such information is a product of science but not necessarily research, and forms an informational infrastructure. The rationale for support rests on efficiency properties of public or semi-public provision.

A further, often neglected, infrastructural function concerns the storage of scientific materials or data. Processes of knowledge creation often produce materials or data that may be usable at (unpredictable) times in the future. RIOs often undertake the storage of such data or materials; firms do not normally do this because of considerable uncertainty about future value, in the face of continuing storage costs. The public sector role here is that of risk bearer.

For example the British Geological Survey stores, at considerable expense, all drill cores drilled in the UK over the past 80 or so years, plus relevant records and documentation. On-site, the BGS has a warehouse (twice extended) to store core samples. These cores are used consistently, by researchers, inuniversity teaching and by the private sector. The most recent core samples belong to DECC but BGS carries out a storage function. Some private firms are obligated to deliver core samples: petroleum operators must

deliver cores to BGS for example. The cores are being kept for the long term benefit of the nation. These cores are unique, would take billions to recreate and are used consistently by industry.

On-site BGS also has inspection facilities and a complementary paper collection, of which about 1.25million records are available online. The accumulated capital costs are large, and many years of investment are required to underpin the data they produce. These are currently being intensively used by oil and gas firms seeking to develop shale gas production using hydraulic facturing technologies.

This kind of storage function is widely found. The Scottish Crop Research Institute, (now the Macaulay Land Use Research Institute) for example holds a large collection of potato species which provides a large sample for identifying qualities, and the opportunity to cross-breed improved species. The Institute for Food Research holds food databanks involving links with 26 other food databases around the world: IFR has undertaken a major effort to ensure the data was comparable.

This database is widely used by industry. It includes a national collection of yeast cultures, which is a collection of over 3000 yeasts in safe facilities. Finally there is ComBase, a web-based system that contributes to the improvement of microbiological safety, and the optimum design, production, storage and retail of food. This contributes to cost reduction and the microbiological risk assessment of food. This is data deposited freely by researchers (quality checked by IFR, who maintain and upgrade the database). ComBase has had a significant impact on industry - the system is freely available on the web and is used daily by all segments of food industry and academia.

Policy support

Some RIOs exist to provide continuous support to policy makers, and this can be on technical issues or social and economic problems.

Technical expertise for policy can be used either continuously or intermittently. For example British trade policy strongly emphasises the need to reduce barriers to trade, and an important element of this is reduction of technical barriers to trade. Efforts in this area depend heavily on common measurement systems (to quantify the technical characteristics of products), and the national Physical Laboratory has played a central role in this.

Much RIO work is critical to the functioning of government, and includes capabilities and expertise in such areas as:

- Demographics and population dynamics (essential to forecasting budget costs and tax revenues)
- Forensic science
- Fire research
- Flood control
- Animal Welfare
- Economic policy (trade and macroeconomic trends in particular)
- Climate change and its implications
- Health issues, including epidemic disease control and health emergencies

Some RIO activities from time to time become critical for innovation activities or for public policy. During the Falklands conflict, the British Antarctic Survey was a key source of geophysical information for British forces. During the eruption of the Eyjafjallajökull volcano in 2010, the NERC National Centre for Atmospheric Science proved central in the analysis of cloud composition and safety assessment for air transport. The costs of shutting down large parts of European air transport were such that shortening the flight ban by even a few days meant that the economic benefits of this effort were considerable. These needs are of course highly uncertain and unpredictable.

In general, RIOs have a wide range of policy-related activities. For example, the John Innes Centre's engagement with policy-makers includes:

- Food Research Partnership – examines the effect of the EU Directive on pesticide use
- BIS –a relationship with Life Sciences policy on agri-biotech and inputted to the Life Sciences policy last year.
- Defra –issues around GM applications.
- Work on synthetic biology with the Technology Strategy Board
- House of Commons meetings with MPs.

- Input on Calls for Evidence, for example Foresight documents for GO-Science or the EU Innovation Agenda.

In more general areas of policy concern RIOs may relate to key areas of social and health policy. For example the MRC Cognition and Brain Sciences Unit work on emotion in its applications to mental health, and cognition in relation to depression or social disorder. Cognitive methods have shorter delivery and translational time frames than pharmaceutical development, and this is an important area of innovation at the present time. This work has implications for widespread complaints related to depression, post-traumatic stress disorder**,** bipolar disorder and anxiety.

7 The Characteristics of RIO Innovation Functions

Knowledge that is relevant to innovation, production and public administration can be thought of at three broad levels. These are:

- firm-specific knowledge bases, on the basis of which firms specialise and compete;

- industry-level knowledge bases, which are the broad knowledge bases shared by most or all firms in an industry, and

- generic (largely scientific) knowledge bases that are relevant across many industries and public activities.

RIOs support the second and third of these levels: both industry-level knowledge bases and generic scientific knowledge bases. At these levels knowledge creation often has characteristics that differ from those of a firm that may be innovating on the basis of a well understood product and its performance. These characteristics include:

Generic applicability of knowledge across many firms or activities: RIO innovation activities of have a wide spread of application, and are not confined to individual firms. This often implies a lack of appropriability and hence a beneficial externality.

Long-term development trajectories: It is a common feature of more disruptive innovations that they do not work well when first developed, and require long periods of improvement before they are genuinely commercial or widely applicable. Any innovation process other than an incremental change around a well-understood product tend to take many years – often decades, and (in some historical cases) centuries.

Economic or technological uncertainty: tied in with the previous characteristic is radical uncertainty as to the applicability of an innovation or new form of knowledge – this may concern whether or not the technology is actually workable, whether there is a market for it, both of which are affected not only by the technology itself but by the possible development of alternatives.

Intermittent relevance: Where RIOs are developing process technologies then these may be of a scale or type that can be 'mission critical' for activities but only on an intermittent basis. For example, a need for a synchrotron to solve a problem or for analysis of volcano emissions, or for geological data may occur only sporadically.

Infrastructural features: Innovation, like most other economic or social activities, requires infrastructures: multi-user facilities that support multiple activities. Infrastructures tend to be large-scale, persistent over time, and indivisible. These technical characteristics lead to problems of financial commitment, financial scale,

Two other characteristics of RIOs should be mentioned:

Overcoming coordination failures. RIOs often link to business sectors and coordinate among firms as 'gatekeepers' of new knowledge. They act as an interface both with the university system and with the international environment; absence of such coordination can form a more or less serious system failure.

Supply of human capital. Currently we do not know nearly enough about the training and mobility patterns of 'HRST' – Human Resources in Science and Technology. But there is good quantitative evidence from some European countries, and from our interview evidence from the UK, to suggest that RIOs often constitute an important intermediate career stage between high-level post-graduate training and business R&D and management. This may well be a critical function in shaping innovation capabilities of businesses.

Assessing the public sector role towards RIOs requires us to take a view not just of the types of support they offer to innovation processes, but of the characteristics of that support. The key question is, what is it about RIO activity that justifies public support, and how should that support be organised? It is helpful to distinguish between two aspects of innovation support offered by RIOs: firstly, infrastructural support to innovating firms, and secondly, support to the development of specific innovations.

Infrastructural support in effect provides a knowledge background to the operations of the business sector or to other research operations. This covers the important dimensions of RIO activity that cannot be called commercialisation, but nonetheless are central to much innovation activity. Infrastructural activity has multiple dimensions but four capabilities or outputs are particularly important:

1. Geophysical information

2. Measurement concepts and data

3. Problem-solving capabilities

4. Information or materials storage

In the provision of these types of capabilities it can be helpful to distinguish between science and research. An important part of what some RIOs do relies on activity that is scientific, in the sense of using science concepts, methods and instrumentation to collect, manage and present data. This can include marine, geographical, atmospheric, meteorological or geological data, often distributed or sold as packages of data. In some cases this supports businesses that aggregate such data for resale, but it also acts as a constant background to activities that may seem unrelated.

The Antarctic Survey, for example has supplied upper atmospheric data and analysis to the insurance industry for use in satellite launch insurance. These activities are often cross-sectoral in application. Similar points apply to measurement concepts and techniques, to the human resource capabilities that are maintained in RIOs, and to the stocks of data and materials.

These have the principal characteristics of infrastructures, either of the physical or knowledge types. That is, they relate to multiple users, they are persistent over long time periods, they are systemic in character, they are usually indivisible, they have quasi-public good aspects, and they provide generic inputs across sectors. Taken together, these characteristics inhibit private commercial provision, and are one of the central reasons why government is involved in RIO provision and/or regulation.

Apart from general support to the innovation environment, RIOs are from time to time involved in specific innovation projects, sometimes of a radical kind. Some of these are detailed above. *In vitro* fertilisation, software for network applications, medical instrumentation and similar innovations tend to have the following main empirical characteristics:

1. Very long time horizons
2. Very great risk and uncertainty (both technological and financial)
3. Complexity in knowledge bases and use of science
4. Complexity in technological components
5. Major infrastructure requirements
6. Lack of economic signals to innovators and highly uncertain demand patterns

These characteristics also suggest a role for government, since they constitute fundamental barriers to innovation in firms that are necessarily constrained by existing knowledge capabilities, and relatively short time horizons.

8 Governance, Finance and Policy Issues in the RIO System

The argument here is that in considering the long-term financing and governance issues of the RIO system, we need to begin from a better understanding of what this system actually does. What has been offered here is simply a sketch of a complex apparatus, one that needs considerable future development. However a definite conclusion has emerged: that RIOs engage in identifiable multi-dimensional innovation support activities, often of an infrastructural character, that are central to overall innovation performance yet very unlikely to be undertaken by firms.

This conclusion has implications for finance, governance and strategic coordination. If the RIOs discussed here were mainly in the business of delivering discrete research or innovation outcomes that were unambiguously commercialisable, then finance and governance issues would be relatively simple: with enough scale and portfolio diversity, RIOs could feasibly operate on the basis of privatisation and/or mutualisation, seeking commercial returns on investment.

But this is far from the reality of the RIO system. RIOs are a very diverse group of organisations, but taken together they are operating in a complex economic and technological space that is not readily amenable to ‘normal’ methods of economic calculation and investment appraisal. They clearly perform a very wide array of functions that relate to the complex problems thrown up by innovation in a diversified economy. Given the historical

achievements of the system, it may be that a case exists for a more long-term and indirect approach to outcomes and this would of course have implications for finance and governance.

Moreover it may be that their strategic impact of the RIO system could be improved. Most UK RIOs develop strategic plans that are coordinated with Research Councils or Government Departments. But at the present time we lack an integrated view of the system as a whole in terms of its research priorities, industry orientations and technological trajectories. This inhibits the ability of policymakers to use the system in a genuinely strategic way. Developing such an overview, and thereby improving the strategic coherence of the RIO system, could be an important contribution to improving its effectiveness.

Appendix A

RIO population: Knowledge Fields

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
DEPARTMENTAL RESEARCH BODIES																							
Animal Health and Veterinary Laboratories Agency		■					■				■							■				DEFRA	Executive Agency
AWE																			■			MoD	GoCo
Cefas			■					■			■		■					■			■	DEFRA	Exec Agency
Defence Science & Technology Laboratory																						MoD	Trading Fund
The Environment Agency																		■				DEFRA	Exec Agency
Fire and Resilience (Research & Statistics)				■										■								DCLG	NDPB
Fisheries Research Services											■		■					■				SGMD	Exec Agency
Food & Environment Research Agency (ex CSL)		■					■		■	■	■							■				DEFRA	Exec Agency
Forest Research						■						■					■					DEFRA	Exec Agency
Health & Safety Laboratory					■					■	■			■				■				DWP	Agency

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
DEPARTMENTAL RESEARCH BODIES																							
James Hutton Institute					■					■	■			■				■				Scottish Govt	
Met Office						■								■		■			■	■		MoD	Trading Fund
Moredun Research Institute		■	■												■							N/A	Charity
National Nuclear Laboratory								■			■			■		■					■	DECC	GoCo
National Measurement Office					■													■				BIS	Exec Agency
National Physical Laboratory					■											■		■		■		BIS	GoCo
Ordnance Survey														■								DCLG	Trading Fund
Rowett Institute of Nutrition and Health		■	■								■											Scottish Govt	Independent
Biomathematics & Statistics Scotland	■	■	■						■	■				■								Scottish Govt	Subsidiary
Trinity House																			■			N/A	Charity
UKAEA								■								■		■			■	BIS	Trading Fund

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
RESEARCH COUNCIL HQs and INSTITUTES																							
Biotechnology and Biological Sciences Research Council Institutes																							
Babraham Institute			■				■			■												Cambs.	Charity
Pirbright		■									■											3 sites	Academia
Institute of Biological, Environmental and Rural Sciences			■			■						■										Aberystwyth	Academia
Institute of Food Research							■		■	■												Norwich	Independent
John Innes Centre											■	■					■				■	Norwich	Independent
Plant Bioscience Limited			■						■		■											Norwich	Subsidiary
Roslin Institute		■								■												Edinburgh	Charity
Rothamsted Research	■					■								■								Herts	Independent
Medical Research Council										■													
Over 50 Institutes, Centres and Units support the MRC – see Appendix B										■												DoH	Academia
Natural Environment Research Council Institutes																							
British Antarctic Survey			■			■		■								■				■		BIS	Academia
British Geological Survey					■	■		■										■				BIS	Academia
Centre for Ecology and Hydrology						■		■				■										BIS	Academia
Centre for Population Biology										■				■								Imperial	Academia
National Centre for Atmospheric Science						■							■	■						■		Many	Academia

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
RESEARCH COUNCIL HQs and INSTITUTES																							
National Centre for Earth Observation						■		■					■	■						■		NERC	Academia
Plymouth Marine Laboratory						■		■					■									Plymouth	Academia
Scottish Association for Marine Science		■	■																			Oban	Charity
Sea Mammal Research Unit		■											■									St Andrews	Academia
Tyndall Centre for Climate Change Research						■								■								Many	Academia
The United Kingdom Hydrographic Office													■	■								MoD	Trading Fund
Science and Technologies Facilities Council																						RCUK	
Isaac Newton Group of Telescopes																■				■		Spain	Academia
Joint Astronomy Centre, Hawaii																■				■		Hawaii	Academia
UK Astronomy Technology Centre																■				■		Edinburgh	Academia
Chilbolton Observatory						■										■						Hampshire	Academia
Daresbury Laboratory																■						Warrington	Academia
Rutherford Appleton Laboratory					■											■						Harwell	Academia
National Oceanography Centre			■			■		■					■			■		■				NERC	Academia

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
Academic Institutes and University Departments																							
Centre for Observation & Modelling of Earthquakes and Tectonics														■						■		NERC	Part of NCEO
Centre for Polar Observation and Monitoring														■						■		NERC	Part of NCEO
Centre for Terrestrial Carbon Dynamics														■						■		NERC	
Centre for the Study of Democracy										■													
Centre of Observation of Air-Sea Interactions and Fluxes								■						■						■		NERC	
Data Assimilation Research Centre														■									
Environmental Systems Science Centre								■														NERC	
Centre for Process Systems Engineering														■									
Institute for Environmental Health								■		■									■				
Institute for Development Studies										■												DFID, ESRC	IRO
International Trade Policy Unit										■													
Jenner Institute										■												MRC, DoH, DEFRA,	
Centre for Defence Studies										■													
Nursing Research Unit										■													
Strangeways Research Laboratory										■													

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
CULTURAL INSTITUTIONS																							
Over 20 cultural institutions are regarded as PSREs – See Appendix C																							
Other Relevant Bodies																							
Agriculture & Horticulture Development Board	■																■					DEFRA	NDPB
Agri-Food & Biosciences Institute (Northern Ireland)	■		■																			DARD	NDPB
Armagh Observatory																				■		STFC	IRO
British Potato Council	■								■													AHDB	Levy funded
Building Research Establishment				■																			RIO
Centre for Business and Public Sector Ethics					■					■													Charity
Dartington Social Research Unit										■													Charity
DEFRA Science and Analysis								■														DEFRA	Part of DEFRA
Dept for Agriculture and Rural Development Northern Ireland	■	■						■	■									■				DEFRA	
Diamond Light Source											■											STFC	
Foreign Policy Centre										■													
Forest Service (N Ireland)																	■					ARD	Exec Agency
Public Health England										■												DoH	Independent

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
Other Relevant Bodies																							
Home Office Science and Research group																			■			HO	Part of HO
Home Office Police Scientific Development Branch																			■			HO	Part of HO
Institute for Conflict Research										■													
Institute of Occupational Medicine										■													IRO
LGC (NMS only)										■												BIS	Independent
Medipex Ltd							■			■												NHS	
National Horizon Scanning Centre										■												NHS	Subsidiary
National Institute of Economic and Social Research										■												ESRC	IRO
NEL (Part of TUV; NMS only)					■																	BIS	Independent
New Economics Foundation										■													Charity
NHS Innovations North							■			■												NHS	
NHS Innovations South							■			■												NHS	
Overseas Development Institute										■												ESRC	Charity, IRO
Royal Botanical Gardens Edinburgh								■									■						
Scottish Agricultural College	■	■						■	■			■										Scottish Govt	

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
Other Relevant Bodies																							
Scottish Agricultural Science Agency	■	■	■					■	■			■						■				Scottish Govt	
Scottish Health Innovations Ltd							■			■												NHS	
Sir Alister Hardy Foundation for Ocean Science													■										Charity, IRO
Tavistock Institute of Medical Psychology										■												ESRC	IRO
The Genome Analysis Centre							■			■												BBSRC	
Transport Research Laboratory					■																	DfT	Independent
Trustech							■			■												NHS	
UK Energy Research Centre								■														RCUK	
UK Space Agency																				■		BIS	Executive Agency
Wildfowl and Wetlands Trust		■						■									■						Charity

Research and Innovation Organisations																							
AEA Technology							■	■	■														PLC
Aircraft Research Association								■		■	■						■			■			Non-profit research organisation
BHR Group Ltd						■		■		■	■									■			Private company
BIBRA International Ltd	■		■						■	■	■												Private company
BMT Group Ltd						■														■			Company limited by guarantee
BRE Group				■							■												Charitable trust
BSRIA Ltd				■							■												Non-profit distributing company
CABI Bioscience UK Centre	■							■	■	■													Intergovernmental not for profit organisation
Campden BRI									■	■	■												Member based organisation
CIRIA				■																			Not for profit organisation
Centre for Process Innovation				■		■		■			■						■			■			
C-Tech Innovation	■					■		■	■		■						■						Ltd company
Castings Technology International																	■						Company limited by guarantee
East Malling Research	■								■	■	■												Company limited by guarantee
FIRA International										■													Not for profit member organisation

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
Research and Innovation Organisations																							
Fraunhofer UK											■					■							Private company
HR Wallingford Group Ltd								■			■		■										Non-profit distributing company limited by guarantee
Institute of Spring Technology										■													Private company
Leatherhead Food Research									■	■	■												Ltd company
LGC			■				■			■	■											BIS as sponsor of NMIs	Private company
Lucideon				■							■					■				■			Private company
Manufacturing Technology Centre											■					■							
Mineral Industry Research Organisation								■															Private company
MIRA Ltd						■		■			■					■							Private company
Motor Insurance Repair Research Centre (Thatcham)								■								■							Private company
National Renewable Energy Centre						■		■															
National Metals Technology Centre (NAMTEC)						■		■			■									■		Part of Advanced Manufacturing Research Centre	
National Institute of Agricultural Botany	■		■						■		■						■						Company limited by guarantee
Pera Group								■		■	■												Private company

	Agriculture	Animal Health	Biological Sciences	Built Environment	Business	Climate Change	Disease Control	Environmental	Food	Human Health & Well Being	Laboratory Services	Land Use	Marine Environment & Aquatic Life	Mathematical Modelling	Pharmaceuticals	Physical Sciences	Plants	Policy & advice	National and Individual Security	Space/ Earth Observation/ Aerospace	Sustainability	Sponsoring Department/ Main Funder or Location	Organisation Status
Research and Innovation Organisations																							
Paint Research Association				■							■												Corporate membership organisation
Qinetiq Group Plc										■									■	■			Plc
Quotec Limited							■			■						■							
Steel Construction Institute				■																			Company limited by guarantee
Smithers Rapra Technology Limited				■						■	■												Private company
Scotch Whisky Research Institute									■														Member based organisation
Smith Institute														■									Private company
SATRA Technology Centre										■													
Transport Research Laboratory					■			■		■													Non-profit distributing private company
TWI Ltd											■					■				■			Part of the TWI Group
TUV NEL																■						BIS as sponsor of NMIs	Private company
Water Research Centre	■		■					■	■				■										Mutual

Department Acronyms				Organisation Status
ARD - Agriculture & Rural Development (Northern Ireland)				Academia - based at, or subsidiary of, Universities
BIS - Department for Business, Innovation & Skills				Charity - an organisation funded in part by charitable donations, or income from
DCLG - Department for Communities & Local Government				a trust fund
DCMS - Department for Culture, Media and Sport				Exec Agency - part of a Department that is treated as managerially and
DECC - Department for Energy and Climate Change				budgetarily separate, but answerable to a Minister
DEFRA - Department for Environment, Food and Rural Affairs				GoCo - Government owned, Contractor operated
DoH - Department for Health				GovCo - a wholly owned Government Company
DfT - Department for Transport				Independent - an organisation which may operate independently of Government,
DWP - Department for Work & Pensions				even though it may receive Government funding
HO - Home Office				NDPB - Non Departmental Public Body, answerable to Parliament
RERAD - Rural and Environment Research and Analysis Directorate (Scotland)				Trading Fund - a part of a Government Department that is allowed to use its
SEED - Scottish Executive Environment Directorate				receipts to meet its outgoings (not returned to the Treasury)
SGMD - Scottish Government Marine Directorate				Independent Research Organisation – Status granted by RCUK to organisations who meet set criteria, and are therefore eligible to apply for research funding
				CLG – Company limited by guarantee

Appendix A is a matrix showing individual RIO organisations by the following categories: Departmental Research Bodies; Research Council HQs and Institutes; Academic Institutes and University Departments; Cultural Institutions; Other Relevant Bodies; Research and Innovation Organisations, and plots them against the respective Knowledge Field(s) in which they operate

Appendix B: Medical Research Council Institutes

- Anatomical Neuropharmacology Unit
- Biostatistics Unit
- Cancer Cell Unit
- Cancer Research UK/ BHF Clinical Trial Service Unit
- Cell Biology Unit
- Centre for Protein Engineering
- Clinical Sciences Centre
- Clinical Trials Unit
- Cognition and Brain Sciences Unit
- Collaborative Centre for Human Nutrition Research
- Epidemiology Resource Centre
- Epidemiology Unit
- Functional Genomics Unit
- Health Services Research Collaboration
- Human Genetics Unit

- Human Immunology Unit
- Human Reproductive Sciences Unit
- Immunochemistry Unit
- Institute of Hearing Research
- Laboratories The Gambia
- Laboratory of Molecular Biology
- Mammalian Genetics Unit
- Mitochondrial Biology Unit
- MRC Technology
- National Institute of Medical Research
- Prion Unit
- Protein Phosphorylation Unit
- Social and Public Health Sciences
- Toxicology Unit
- Virology Unit
- UVRI Uganda Research Unit on AIDS

- Weatherall Institute of Molecular Medicine

Appendix C: Cultural Institutions

	Sponsoring Department/ Devolved Authority	**Status**
Arts Council of England	DCMS	NDPB
British Library	DCMS	NDPB
British Museum	DCMS	NDPB
English Heritage	DCMS	NDPB
Imperial War Museum	DCMS	NDPB
Museum of London	City of London and Greater London Assembly	Charity
Museums and Galleries of Northern Ireland		
National Galleries of Scotland	Scottish Government	
National Gallery	DCMS	NDPB
National Maritime Museum	DCMS	NDPB
National Media Museum		Charity

	Sponsoring Department/ Devolved Authority	**Status**
National Museum Wales		
National Museums Liverpool	DCMS	NDPB
National Museums Scotland	Scottish Government	
National Portrait Gallery	DCMS	NDPB
Royal Air Force Museum		Charity
Royal Armouries	DCMS	NDPB
Scottish Natural Heritage	Scottish Government	
Tate Gallery	DCMS	NDPB
Ulster Museum		
Victoria and Albert Museum	DCMS	NDPB

Appendix D: Various

D.1 List of Public Sector Research Establishments / Research Council Institutes currently owned by Government at January 2014 including notes on plans for review

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
Department for Business Innovation and Skills	The Met Office	Trading Fund	Shex undertaking review of Met Office business model.	The Met Office was formally transferred from MoD to BIS on 9 November 2011, under a Machinery of Government change, as part of the establishment of the Public Data Group
	National Physical Laboratory	Government Owned Contractor Operated (GoCo)	BIS is currently working towards a change in operating model. Current contract ends on 31 March 2014.	
	UK Atomic Energy Authority	Executive NDPB	Triennial Review planned to take place in 14/15	
Department for Culture, Media and Sport	Natural History Museum	NDPB	Cabinet Office to schedule for next round of Reviews – to be decided January 2014	
	Science Museum Group (formerly	NDPB	Cabinet Office to schedule for next	

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
	known as the National Museum of Science and Industry)		round of Reviews – to be decided January 2014	
Department for Energy and Climate Change	National Nuclear Laboratory	GovCo	Next review due in 3-5 years.	In the process of identifying long term strategic partners. Shex now taking a shareholder representative seat on the NNL Board.
Department for Environment, Food and Rural Affairs	Animal Health and Veterinary Laboratories Agency (AHVLA) [1]	Executive Agency	No current plans for review	Created from the merger of the Veterinary Laboratories Agency with Animal Health in 2011[2]
	Centre for Environment, Fisheries and Aquaculture (Cefas)	Executive Agency	No current plans for review	Last review reaffirmed that the current business model is the most appropriate. A private company has been established to exploit commercialisation.
	Food and Environment Research Agency (Fera)	Executive Agency	Sponsoring Department is currently working towards a change in operating model	A market soundings exercise was launched last month and DEFRA are seeking a commercial partner for an equity based joint venture
	Royal Botanic Gardens Kew	NDPB with Charitable Status. Also runs a Limited Company	No current plans for review	

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
	Veterinary Medicines Directorate (VMD)	Executive Agency	No current plans for review	
Department of Health	Public Health England (PHE)	Executive Agency of the Department of Health	None. Established on 1 April 2013	Public Health England was established on 1 April 2013 to bring together public health specialists from more than 70 organisations into a single public health service.
Forestry Commission	Forest Research	Executive Agency	tbc	An independent review of science at Forest Research was conducted in 2011-12. No recommendations were made for changing the status of Forest Research.
Health and Safety Executive	Health and Safety Laboratory (HSL)	Executive Agency	HSL to address issues arising from HSE triennial review which was finalised in September 2013 with reference to the PSRE guidance and Manchester principles.	Reviewed 2011. It has been deemed unfeasible for the private sector to provide some of the services HSL provides, though there is a potentially large market which is yet to be exploited
Ministry of Defence	Atomic Weapons Establishment	Government Owned Company	No plans for review – a 5 year contracting period commenced in April 2013 – see notes.	AWE is contracted to the Ministry of Defence (MOD) through a government-owned / contractor operated (GOCO) arrangement. AWE ML is a consortium comprising three equal partners: Serco Group plc, the Lockheed Martin Corporation and

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
				Jacobs Engineering Group. Following competition, a contract was awarded to AWE ML covering an initial period of 10 years from April 2000. In 2003, the contract was extended to a 25-year term following a detailed evaluation of AWE ML's long-term partnering proposals. The contract is priced in five-yearly periods. The current contract period took effect from 3 April 2013.
Ministry of Defence	Defence Science and Technology Laboratory (DSTL)	Trading Fund	No current plans for review	Last reviewed 2011. Provides services which cannot be procured from the private sector. Separate company has been set up for the exploitation of technology for civilian uses.
Ministry of Defence	Hydrographics Office	Trading Fund	No current plans for review	Last reviewed in 2010 with decision that UKHO should remain a trading fund.
BBSRC	Pirbright Institute (formerly Institute for Animal Health)	Registered Charity and Company Limited by Guarantee	Pirbright Institute is presently as a PSRE, but subject to ONS approval BBSRC expect Pirbright to be transferred to the private sector in the near future with BBSRC retaining an appropriate level of interest in the safe running of its operations.	The rationale for the proposed transfer would be to bring governance arrangements, budget management, research programme direction and responsibility for staff into line with the responsibilities and role of the Institute's governing bodies.

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
MRC	National Institute for Medical Research (NIMR)	Presently Research Centre wholly owned by MRC	Due to merge into Crick Institute in 2015. [3]	
MRC	Clinical Sciences Centre (CSC)	MRC wholly owned Research Centre	Tbc	
MRC	Laboratory of Molecular Biology (LMB)	MRC wholly owned Research Centre	Tbc	
NERC	British Antarctic Survey (BAS)	NERC wholly owned Research Centre	NERC currently reviewing future ownership of its research centres. Second gateway decision due in July 2014. See notes.	Announced on 9 December 2013: NERC Council has agreed to proceed to the next stage of its review of the ownership and governance of research centres. NERC is considering the benefits and potential risks of giving independent status to three of its wholly-owned centres, the British Geological Survey (BGS), National Oceanography Centre (NOC) and Centre for Ecology & Hydrology (CEH), and of giving the National Centre for Atmospheric Science (NCAS) a similar independent identity.
NERC	British Geological	NERC wholly owned		

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
	Survey (BGS)	Research Centre		
NERC	Centre for Ecology and Hydrology (CEH)	NERC wholly owned Research Centre		
NERC	National Oceanography Centre (NOC)	NERC wholly owned Research Centre		
STFC	Rutherford Appleton Laboratory (includes Chilbolton) (RAL)	National Laboratory	Retains status as a National Laboratory but now underpins Harwell Oxford Science and Innovation Campus.	Development of National Science and Innovation Campuses to increase collaboration between the research base and industry and maximise economic impact.
STFC	Daresbury Laboratory (DL)	National Laboratory	In 2009, a prioritisation of the STFC science programme recommended the closure of this site in 2015.	
STFC	The Isaac Newton Group of Telescopes (ING)	An island telescope site of STFC, located on La Palma in the Canary Islands primarily encompassing the		STFC's predecessor, PPARC, agreed in 2001 to wind down operations of the island telescopes as part of UK accession to the European Southern Observatory (ESO) organisation. Membership of the ESO gives UK

Owner	Name of PSRE/RCI	Status	Plans for review	Notes
		William Herschel Telescope (WHT)		astronomers access to world-class telescopes in Chile.
STFC	The Joint Astronomy Centre (JAC)	An island telescope site of STFC, located in Hawaii, encompassing the United Kingdom Infra-Red Telescope (UKIRT), James Clerk Maxwell Telescope (JCMT), and the associated Joint Astronomy Centre (JAC)	In 2009, a prioritisation of the STFC science programme recommended the closure of this site. JCMT will operate to the end September 2014. STFC has supported the operation of UKIRT until the end September 2013.	
STFC	Diamond Light Source Ltd	A joint venture company funded by STFC (86%) and the Wellcome Trust (14%) located in STFC's Rutherford Appleton Laboratory		

[1] Now called the Animal and Plant Health Agency [2] In February 2015 Defra announced a joint venture with Capita and Newcastle University to help run Fera.

[3] Merged with the Crick Institute on 1 April 2015

Appendix D.1 tabulates data for Public Sector Research Establishments / the Research Council Institutes in five columns covering: owner (Departmental; Research Council, etc); individual PSRE/RCI; legal status of the PSRE/RCI; Plans for review; Notes.

D.2 Defining RIOs

There is no generally used definition of RIOs. They are variously labelled as Public Research Institutions in the OECD, or PSREs in the UK, or PROs (as such organisations are generally known in Europe). Definitional problems turn mainly on what the word 'public' means. The OECD's R&D guidelines defines government firstly as 'the legislature, the executive, departments, establishments and other bodies of government' and the guidelines include within the government sector all R&D performed by such bodies (which can be very substantial). But the guidelines also include 'Non-Profit Institutions (NPIs) controlled and mainly financed by government, but not administered by the higher education sector'. What makes these NPIs public is said to be government control, defined as 'the ability to determine the NPIs general policy or programme by having the right to appoint the NPI's management.' Unfortunately the guidelines immediately undercut this definition by noting that 'NPIs mainly financed by government should be included in the government sector even if the government control is not clear.'6 This immediately blurs the distinction between public sector organisations and the private non-profit sector.

A more recent definition, also from OECD, widens things by treating PRIs as:

> 'National entities, irrespective of their legal status (organised under public or private law): whose primary goals are to conduct fundamental research, industrial research, experimental development, training, consulting and service provision, and to disseminate their results by way of training, publication and technology transfer; and whose profits (if any) are reinvested in these activities, the dissemination of the results, or training; and which are either totally or to a substantial share publicly owned, and/or are funded primarily from public sources via base funding (block grants) or through contract-based research, and/or are regulated, so as to achieve primarily public missions.'[7]

This broad definition is broadened further by the remark that 'The entity could come from any statistically-defined sector (government, higher education, business or private non-profit)'. The main problems with this definition are that it does not distinguish between higher education and non-higher education institutions, and it does not allow for organisations with relatively small public sector financing.

In this study, we define RIOs in the UK as: *non-profit and non-higher education organisations that perform research and development as their main activity, whose existence depends on some degree of public funding, and whose work serves some public policy purpose*. A main ambiguity in this is that some for-profit companies perform policy-oriented R&D; these will be discussed separately. PSREs are the subset of RIOs that are directly governed either by Government Departments or Research Councils.

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[6] OECD, *Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development* (OECD: Paris), 2002: 63

[7] OECD, *Analysing the transformation of public research institutions*, (OECD: Paris), DSTI/STP/RIHR(2009)5, April 2009: 29

D.3: Summary of Innovation Case Studies

(By Christine Thompson, Imperial College)

John Innes Centre and Hospital Superbugs

- around 5,000 people a year in England and Wales die from 'hospital acquired infections' - MRSA and C. difficile.
- estimated cost to the NHS is over £1Bn a year plus 8.7m recovery days.
- Novacta Biosytems, the first JIC spin out company, was set up to develop natural antibiotic solutions based on their Streptomyces discoveries to fight C. difficile and MRSA.
- Novacta was established by JIC's innovation company, PBL, around a portfolio of JIC intellectual property.
- Novacta has grown from six staff in 2002 to nearly 30 now.
- In 2009, Novacta received £13.1 million of investment from Celtic Pharma Holdings and existing investors.

IBERS Grasslands Research

- Grass and clover breeding programmes have attracted £0.5M annual investment from the private sector to fund near market costs of variety development
- Seeds of 'Aber' varieties marketed under licence by Germinal Holdings Ltd take 28% of the UK market with an annual retail value of £5.5M
- IBERS silage technologies, including bacterial inoculants have improved the nutritional quality of preserved grass
- Research at IBERS has increased the dietary quality of forage, reducing the need for supplementary feeds by 30% with an annual cost saving to UK agriculture of £400M.

IBERS: Institute of Biological, Environmental and Rural Sciences

SCRI and Lady Balfour Potatoes

- Lady Balfour is a high yielding potato developed by the Scottish Crop Research Institute (SCRI).
- Has a 2% share of the total UK potato market, equal to a 30% share of the UK organic market.
- Marketed by supermarkets as a distinct brand rather than a generic organic variety.
- Mylnefield Research Services Ltd (the commercial arm of SCRI) licensed Lady Balfour exclusively to Greenvale AP making them the largest single supplier of organic potatoes in the UK with a 40% market share.
- Sales of Lady Balfour potatoes support an estimated 136 jobs throughout the country every year.

Overall Economic Impact*

Public funding for programme: £1m

Projected value: £9m per annum.

Estimated net economic impact: £85.2m over 10 years

*All figures based on data from 2007.

STFC and the Diamond Light Source

- The potential of Macromolecular Crystallography – a sophisticated imaging technique - was a key driver behind the Wellcome Trust's initial investment of £50M in the Diamond Light Source in Oxfordshire
- One software tool, CCP4, developed at the Synchrotron Radiation Source generates £800k annual revenue for STFC
- One user, Astex Therapeutics, has raised over £50M investment and $1Bn in external collaborations
- The Foot and Mouth Disease Virus research represented a collaboration between PoRIOn Down, Oxford University and Wellcome Biotech, to determine the 3D structure of the foot and mouth disease virus

NHS Innovations: ALERT Training course

- 1 day multi-professional training course allows early detection and treatment of acutely ill patients
- Up to 20% unscheduled ICU admissions avoided
- Newer versions of ALERT including flexible e-learning modules for clinical staff launched in 2009
- Over 160,000 UK healthcare staff received training
- Franchised overseas: Ireland, Sweden, Denmark, Norway, Australia, New Zealand, Italy
- £400k turnover per year
- NHS Innovations South East assisted with business infrastructure, IP advice, branding, commercial negotiations overseas
- Potential impact assuming 10% impact on ICU/CCU admissions:
- Life-threatening events avoided: 351
- ICU/CCU admissions avoided: 1,634
- Savings to NHS: £26.9M

Health Enterprise East (HEE): the Papworth BiVent Endotracheal (ET) Tube

Health Enterprise East (HEE) supports development of the Papworth BiVent Endotracheal (ET)Tube which facilitates rapid lung isolation

- Approximately 500,000 surgical procedures requiring lung isolation are carried out world-wide each year.
- The lower price of the BiVent tube means that it can save the NHS and other healthcare providers £70 per procedure.
- PSRE funding enabled patent protection, prototype development, clinical testing and commercialisation of the BiVent tube.
- As well as general thoracic surgery, the BiVent tube also has benefits in areas where rapid lung isolation is required (the Accident and Emergency or armed forces settings), where there is no satisfactory device that can be used for quick lung isolation.

NHS – Cardiac Defribillators

- In the United Kingdom 270,000 people suffer a heart attack each year and a third of them die before reaching hospital.
- Professor Frank Pantridge, a Cardiologist at the Royal Victoria Hospital in Belfast, developed a portable defibrillator to deliver a controlled electric shock to the heart as a treatment for heart attacks – developed through start-ups
- Portable defibrillators save the lives of 40% of people aged under 65 on whom they are used.
- Used worldwide this innovation has saved thousands of lives.

[The first portable defibrillator required car batteries and weighed 70 kg. Thanks to advances in capacitor technology, devices weighing less than 3 kg are now widely available in public places throughout the world.

“The global market for Cardiac Defibrillators is forecast to exceed $16 billion by 2015" – from a report titled C*ardiac Defibrillators: A Global Strategic Business Repor,* published by Global Industry Analysts, Inc.]

NHS Innovations North - Vitro Safe Systems Ltd

- The technology comprises a series of enclosed isolators linked together with integrated incubators to provide the first totally enclosed IVF process from oocyte retrieval to embryo transfer.
- The stable environmental conditions achieved using the Vitro Safe System reduces cellular stress and increases the viability of embryos.
- Vitro Safe Systems has recently received its first order totaling over half a million pounds worth of IVF equipment from a private laboratory based in Europe.
- NHS Innovations North continues to actively market the product in conjunction with Vitro Safe Systems and has recently exhibited at the European Society of Human Reproduction and Embryology conference in June 2009.

NPL and reduction of technical barriers to trade

- UK economy depends on trade - a common international measurement system reduces technical barriers to trade
- NPL provides national measurement standards recognised internationally
- UK businesses use these standards to trade UK goods internationally

- The common international measurement system, which NPL is a part of, increases international trade by more than $4 billion pa

The UK annual trade in natural gas is worth £20 billion

75% of this is expected to be imported by 2015. NPL provides UK industry with gas concentration standards – instilling confidence in the trade of natural gas internationally

HSL Safety Climate Tool

Helping to improve the safety culture in Britain's workplaces.

- The Health and Safety Laboratory's Safety Climate Tool enables organisations to evaluate their culture with respect to safety in the workplace and allow staff members to feedback their thoughts on management attitudes towards safety.
- This in turn promotes a good safety culture and leads to reduced accident and illness rates.
- The Safety Climate Tool has been developed by HSL scientists, with a mixture of public sector funding, and piloted across several industry sectors with the help of industry collaborations.
- HSL have now signed a commercial agreement with a specialist software company to launch the Tool as a software product in autumn 2009.
- The benefits of evaluating and improving safety culture across Britain's workplaces are obvious, for both the UK economy and the workforce and population.

This publication available from www.gov.uk/bis

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Department for Business, Innovation and Skills
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000
Email: enquiries@bis.gsi.gov.uk

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