Institute of Physics

Science and innovation: working towards a ten-year investment framework

An Institute of Physics response to a joint HM Treasury, DTI and DfES consultation

A full list of the Institute's responses and submissions to consultations can be found at http://policy.iop.org/Policy/public.html

30 April 2004

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Ten-year investment framework for science and innovation
Science & Industry Team
HM Treasury
1 Horse Guards Road
London
SW1A 2HQ

Institute *of* **Physics**

Dear Sir/Madam

Science and innovation: working towards a ten-year investment framework

The Institute of Physics is a leading international professional body and learned society, with over 37,000 members, which promotes the advancement and dissemination of a knowledge of and education in the science of physics, pure and applied.

The Institute welcomes the opportunity to respond to the consultation document, *Science and innovation: working towards a ten-year investment framework,* and the Government's clear recognition of the importance of science to the nation in the 2004 Budget, and its pledge for increased investment in future years.

The consultation document clearly highlights a number of key issues that the UK collectively will need to address in order to compete and interact more effectively with the US, Japan and the rest of Europe in terms of scientific excellence over the long term. The Institute will use this opportunity to highlight issues of concern pertinent to physics, a discipline whose strength and vitality, from school education through to industry, will be crucial to the Government's vision of making Britain "the best and most attractive location in the world for science and innovation." Physics is at the base of so much of modern society – spanning a broad range of science from blue skies research to many technological applications, such as in medical science, optics and materials – that investment in it is not only important for science, but for society as a whole.

The attached annex highlights the key issues of concern to the Institute which have been linked to the specific questions raised in the consultation document.

If you need any further information on the points raised, please do not hesitate to contact me.

Yours faithfully

Professor Peter Main
Director, Education and Science

Institute *of* **Physics**

Science and innovation: working towards a ten-year investment framework

Summary

Key issues of concern to the Institute relate to three areas in need of support from the Government:

School science teaching, and education in schools

- The Government must address the balance of specialisation of school science teachers. There is an extreme shortage of specialised physics teachers that is being masked by the overall numbers of graduates in other disciplines going into science teaching.
- A major concern has been the steady decline in the number of entrants to physics and mathematics A-level. Unless this is addressed, the number of suitable students in a position to apply for first degrees in physics and engineering will dwindle.
- Practical and experimental work are key to enthusing pupils in science subjects, and large class sizes and a lack of resources make it difficult to give pupils this experience.

Higher education and research

- Over 30% of physics departments have disappeared since 1994. At present, there are fewer than 50 UK universities offering a provision for undergraduate physics.
- The Government should reconsider the proposed allocation of HEFCE teaching funds planned for 2004/05. Physics departments already run at a loss, and the new proposals would mean a 1% cut in funding resource for price band B subjects, which includes physics. If the Government is serious about its commitment to world-class research, more money needs to go into physics departments.
- The proposed introduction of top-up fees may have a bearing on the number of entrants to physics under- and postgraduate courses. At present, no one knows how the market for fees and (more importantly) for bursaries will operate from 2006 onwards.
- It is imperative that an educated student market deciding what degrees to undertake is created. A significant problem facing science, and particularly physics, is that students are making ill-informed decisions about their careers at the age of 15. Teachers, parents, careers advisors should be in a position to highlight the benefits and the wide variety of career options that are available from science.
- The Government has made a fantastic commitment to science, by doubling the science budget. Blue-skies research, particularly in physics, is long term in its nature, and the Institute hopes that new money invested into the science base will continue to support this area of research through responsive mode Research Council funding.

Physics-based industry

- The Institute endorses the recommendation from the Lambert review that, the Government should create a significant new stream of business-relevant research funding, which would be available to support university departments that can show strong support for business. However, this additional support for research exploitation should not be at the expense of Research Council funding for blue-skies research.
- To enable the UK to reap more of the commercial benefits of its physics base, university physics departments and related groups should be encouraged to exploit more of their research in industry. RDAs should have a bigger role in facilitating links, but the Institute along with the Lambert review remain unconvinced that RDAs are the best channel for Government money to help business-university linkages.

Main response

Physics is an integral part of our culture, providing the foundations for many scientific disciplines. The increases in wealth, economic globalisation, living standards and quality of life have been largely based on technological progress, which in turn has relied heavily on innovative research in physics. In addition, physics education develops strong intellectual and practical skills, well matched to the evolving needs of employers, and also provides the foundation for all engineering and many scientific disciplines. However, as reported in *Physics – building a flourishing future*[1], the Institute's report into undergraduate physics in the UK, there are concerns, which are jeopardising the contribution that physics makes to wealth creation, innovation and economic growth. These include:

School science teaching, and education in schools

Physics teachers
[This section relates to question 10 in the consultation document]

There is a crisis in the teaching of physics in schools – a majority of the teachers of physics who teach to the under-16s do not have a physics-based degree. Only those with confidence and competence can teach their subject well, engaging and enthusing pupils and motivating them to pursue careers in science and engineering. Unfortunately, teaching is not seen as an attractive career option for physics graduates, which is an indication of their marketability, as they are in high demand in business and industry. The number entering teaching is low – there were 568 acceptances to PGCE courses in physics in 1993 and 323 in 2002 (GTTR). It is essential that the Government recognises and addresses this problem, and does not hide behind the fact that there have been increases in the number of science teachers, mainly in biology. The UK is desperately short of trained teachers in physics and mathematics.

The Smith report, *Making Mathematics Count*, highlighted issues of concern in the supply of mathematics teachers. A combination of physics and mathematics are pre-requisite for physics undergraduate courses. The Institute would urge the Government to take heed of Adrian Smith's recommendations for mathematics,

[1] http://policy.iop.org/UPI/index.html

particularly those on the supply of mathematics teachers, and extend them to physics, without hesitation. In particular, the Institute fully endorses the recommendation that more must be done to address the issue of pay and other incentives to teachers of mathematics and other shortage subjects including physics. The Government could, for example, investigate differential salaries for shortage subjects, golden hellos, 5-year golden handcuffs, etc.

In addition to good teachers enthusing students, there is a need for good, well-paid teacher trainers to train them. It is proving difficult to attract good physics teachers to become trainers, because school salaries are often higher than those in universities.

The Institute was disappointed by the paucity of data that was contained in the last School Staffing Survey. At present, only the input of physicists into the teaching profession is known and not how many physicists are actually teaching in schools. Unless action is taken to collect better data on the backgrounds of teachers in schools, it will be very difficult to judge the success of recruitment and retention strategies.

The Institute notes that there is not a strong culture of professional development amongst teachers. Recent initiatives such as the KS3 strategy and the forthcoming Science Learning Centres are addressing this to some extent, but a culture change within the teaching profession is needed where all teachers feel obliged to engage in professional development. This will not to happen unless the Government makes more funding available to pay for teachers to participate.

A-level numbers
[This section relates to question 10 in the consultation document]

A major concern has been the steady decline in the number of entrants to physics A-level. Since 1994, there has been a 20% drop (AQA). In the same period, the number of entrants to mathematics A-level has dropped by 15%. Unless there is a reverse in this trend, the number of suitable students in a position to apply for first degrees in physics and engineering will dwindle.

A number of reasons have been suggested for pupils rejecting physics; including:
- a perceived lack of relevance;
- perceived difficulty;
- poor careers advice; and
- mathematical issues.

The Institute hopes that the 14-19 reforms will address the variability in the difficulty of subjects post-16. The 14-19 working group has echoed the concerns of the Roberts review (SET for Success) about the quality of careers advice. In particular, there is considerable anecdotal evidence that young people who might consider a career in science do not receive good careers advice – something which is touched upon in a later section.

The Institute is already working with the DfES to investigate how more girls can be persuaded to take A-level physics. The Institute hopes that there will be a positive Government response to the results of this initiative and a commitment to continue this work.

Curriculum
[This section relates to question 10 in the consultation document]

Although the National Curriculum for science was brought in under the banner of Science for All, it was originally intended for those students planning to continue their study of science. Recent developments such as 21st century Science and Applied Science have addressed this. But the Institute is concerned that the place of physics in these qualifications is much less secure.

One of the distinguishing characteristics of science education in the UK is the amount of practical work that is done. Practical has been in decline in recent years. A plausible explanation for this is the increase in class sizes. This is of a particular concern as the Institute believes that the more able students are those who are most likely to be in larger classes.

Despite welcome investment in school laboratories, there are still significant issues about school laboratories, resources for practical work and technical support. The announcement of a major rebuilding and refurbishment plan for schools is welcome, and it is hoped that within this there will be a priority for improving science laboratories and equipment.

Science communication
[This section relates to question 12 in the consultation document]

One medium that has been underused in communicating science has been public service television. There is a clear lack of science related programmes on the BBC. Exciting, topical science based programmes could provide a means to communicate the benefits and possibilities of careers in science, and help create a society that accepts and is excited by new technology. It is disappointing to hear that the annual Royal Institution Christmas lectures will no longer be shown on Channel 4 – and it is even more of a disappointment to hear that the BBC has not expressed an interest in buying the rights to show the lectures.

The Government should actively promote the representation of scientists amongst their ranks. This would improve the general quality of understanding and debate within Government, as well as improve links between Government and the scientific community, the quality of Government response to scientific issues and the level of public trust in Government on scientific issues.

Higher education and research

Health of physics departments
[This section relates to questions 1 and 6 in the consultation document]

Physics is, by its nature, a resource-intensive subject to teach, in terms of both teaching staff and laboratory provision. In the past 10 years, the university physics student/staff ratio has increased. The increase has been less dramatic than in some other subjects, as there were very few physics departments in the former polytechnics. As industry's demands for graduates with a high degree of technical knowledge and expertise increases, it is incumbent upon universities to have modern facilities and equipment. The cost of providing such equipment has risen at a faster rate than inflation.

The economics of university physics departments has led to the loss of several departments in the past ten years. Over 30% of physics departments have disappeared since 1994. At present, there are fewer than 50 UK universities offering a provision for undergraduate physics.

Larger areas of the population and industry now have no convenient access to a local university physics department offering teaching or research. As the proportion of students living at home increases, and as industry becomes more dependent upon high-technology knowledge, these regions will suffer from a lack of proximity to university physics. The Government rightly, is keen on increasing the number of women, ethnic minorities, lower social classes in science and engineering. For those in this under represented grouping living in the East Anglia region, for example, wishing to study physics, where would they go? There is no undergraduate provision for physics at the University of East Anglia and the University of Cambridge would not be a realistic proposition for many.

The Institute recognises that physics has a problem in recruiting from these under represented groups and is investigating the reasons behind the low-uptake.

The Institute understands that a survey conducted by the THES (23 April 2004) has revealed that more students are staying at home when they enter higher education. The survey found that a quarter of students live at home while studying, a higher proportion than estimated for previous years. If more and more physics departments are forced to close, regional deserts of physics provision are likely to appear all over the UK.

Teaching funding
[This section relates to questions 1, 6 and 7 in the consultation document]

Having continually argued for HEFCE to monitor and review the price groups allocated to the laboratory sciences, in order to maintain the existing high standards in undergraduate physics, the Institute believes that physics, as well as many other science and engineering disciplines, will suffer further under the new weightings, recently announced by HEFCE. As of 2004-05, the weighting of 1.7 for price band B, which includes physics, will lead to a 1% cut in the teaching resource.

HEFCE has argued that measured physics costs are too high due to falling student numbers but this is far from obvious because:

- physics undergraduate numbers have not fallen (acceptances to undergraduate physics and astronomy were 3102 in 1994, and 3103 in 2002 (UCAS));
- departments have closed and large departments have become even larger leading to efficiency of costing, and
- deficit departments have severe limits on spending.

The Institute urges HEFCE (and the other Funding Councils) to look more critically at the actual spend of university departments to determine what the ‘true’ price group weightings should be. At a time when the UK needs a more highly skilled and scientifically capable workforce to respond to today’s technology driven challenges and opportunities, physics departments are facing a crisis. With many departments already operating at a deficit, these further reductions in funding will have serious consequences.

Undergraduate intake
[This section relates to question 10 in the consultation document]

The future strength of the science base is crucially dependent on the flow of quality young people into it. As highlighted in *SET for Success*, the Roberts review:

"…graduates and postgraduates in strong numerical subjects, are in increasing demand in the economy – to work in R&D, but also to work in other sectors (such as financial services or ICT) where there is strong demand for their skills." Physicists fall squarely into this category.

SET for Success, reported that the 'disconnect' between the demand for skilled graduates and the declining number of physical sciences, engineering and mathematics graduates on the other hand, is starting to result in skills shortages. Furthermore, any attempt to address the issues associated with this decline requires action in schools, higher education, industry and the Government.

The proposed introduction of top-up fees may have a bearing on the number of entrants to physics under- and postgraduate courses. At present, no one knows how the market for fees and (more importantly) for bursaries will operate from 2006 onwards. In response, the Institute will introduce bursaries of £1000 per annum for physics undergraduates from less well off families. Whilst income from our reserves will provide the core of this, anecdotal evidence suggests that the potential for the flowering of a new philanthropy to support undergraduates in specific subjects is large and untapped.

It is also imperative that an educated student market deciding what degrees to undertake is created. A significant problem facing science, and particularly physics, is that students are making ill-informed decisions about their careers at the age of 15. Students at this age, irrespective of whether they are girls, from ethnic minorities etc., are not well-educated consumers. Teachers, parents, careers advisors should be in a position to highlight the benefits and the wide variety of career options that are available from science.

Research
[This section relates to questions 1, 2, 3, 6 and 18 in the consultation document]

The International Review of UK Physics and Astronomy[2], conducted in April 2000 by a panel of eminent international physicists on behalf of the OST, reported:

"That at its best, research in physics and astronomy in the UK is at the very highest level worldwide. Beneath the peaks of scientific excellence, however, UK physics research quality noticeably drops, largely due to a lack of adequate resources. For similar reasons, there are deficiencies in the breadth of coverage of some important sub-fields. As a result, the potential for seizing new opportunities and for maintaining the UK's overall excellent standing in international physics and technology research may be impaired. Physics research in the UK continues to suffer from a low level of funding. In fact, the field is currently in a state of slow recovery from a long period of chronic under funding. Substantial increases are now required in order to bring UK physics research up to international levels. Insufficient funding has caused the UK to miss important areas of opportunity. In particular, research infrastructure (both equipment and human resources) has been in decline for many years and may be reaching a critical point." The next international review of physics and astronomy is

[2] http://policy.iop.org/Policy/Intrev.html

expected to take place in 2005, and will be able to assess the progress that has been made.

A recent issue of concern to the physics community has been the low success rates for grant applications for curiosity driven research. The EPSRC, a major funder of physics research, has recently stated that there is a gap developing in the science budget – engineering and the physical sciences are being seriously under funded, and are on the wrong trajectory, in comparison with the biological sciences.

The Institute supports the views expressed in a letter to VCs and Principals, from the EPSRC where it reports that, “The UK’s research capacity in engineering and the physical sciences is heavily dependent on the university sector. But the base of permanent staff is shrinking in these core subjects as is research income and research outputs such as the number of published papers. This partly results from a deliberate shift of resources toward new scientific opportunities in the life sciences. There is a need to sustain the UK’s research capacity in important areas of the physical sciences and engineering by increasing the *quantity* of high *quality* research, and reducing the dependence of that capacity on student numbers.”

In addition, the EPSRC report that, “The reduction in the UK’s research capacity in engineering and the physical sciences has happened over a long period... This contraction will continue and could severely hamper improvements in competitiveness in the UK economy. The restored research capacity has to be in the UK; if it is elsewhere we will begin to lose the ability to understand and use developments elsewhere and will not maintain the research environments necessary to produce trained people. This will require concerted action by a number of bodies.”

The Institute is of the firm belief, that the Government has made a fantastic commitment to science, by doubling the science budget, and of course after such a commitment it would expect an immediate return of investment. Blue-skies research, particularly in physics, is long term in its nature. Productivity won’t be seen for many years, possibly decades. Money has been pumped into managed programmes, following a number of Spending Reviews, but the Government must be patient, and not continue this trend at the expense of blue-skies research. The UK should participate in the development of new knowledge (and, indeed, in its utilisation for wealth creation) by giving physicists the opportunity to follow their scientific instincts in research. Managed programmes should be used by the Research Councils with restraint.

Interdisciplinary research
[This section relates to questions 6, 7 and 18 in the consultation document]

While the conventional departmental structure in universities is fine for undergraduate teaching, it is very poorly adapted to the more interdisciplinary demands and opportunities in research. A much more flexible research structure, cutting across conventional departmental boundaries, is needed. It is a real challenge for universities to put this in place, as increasing transparency of costs makes collegiate strategic decision-making harder.

Furthermore, publications data show that research collaborations between individuals and groups in different universities are encouragingly endemic. It remains the case, however, that funding interdisciplinary research, whether within an institution or across institutions, is a challenge for the Research Councils.

Large facilities
[This section relates to question 8 in the consultation document]

For most large research facilities, at both national and international (European) levels to be competitive, there must be an element of international collaboration, not least because many existing and emerging effective infrastructures are of such a scale that they must now be funded at the supranational level. It would be advantageous to have a supranational body, probably at European level, with the specific remit of evaluating and funding proposals for such supranational large-scale facilities. Such a Research Council could co-ordinate national strategies and investments in facilities whilst also providing a single "letterbox" through which proposals for such facilities could be posted for review and evaluation.

Prioritisation of such facilities has to be carefully balanced between providing those facilities at the cutting edge which ensure the UK has a world lead, and those that provide adequate facilities to enable a large group of UK scientists to remain competitive. It could be argued that the former must take highest priority - but only in those fields in which the UK (either singly or collaboratively) is in a position to capture a world lead: there is little point building, for example, a new synchrotron just to allow more scientists to do more experiments, but there is a need to build a synchrotron that allows UK scientists to do experiments that can be done nowhere else in the world!

Further development of the UK science base
[This section relates to question 2 in the consultation document]

Caution is needed in basing a long-term strategy on existing areas of science. A consistent feature of UK research funding, relative to our main industrial competitors, has been the lack of flexibility in identifying new areas and responding to funding needs. In the physics area, two recent examples have been spintronics and nanoscience. In both cases, the science had been recognised as vital for the 21st century by our competitors before UK funds had been provided.

How funding mechanisms build on existing resources and research assessment reforms to reward excellence and underpin sustainability
[This section relates to question 5 in the consultation document]

The really big risk is that funding will become much less stable than it is now. Although there is a clear need to move to a full accounting procedure for research costs, if universities are dependent on the success of grant applications for the vast majority of their funding, there will be huge fluctuations in income that will make sensible management impossible. The Government needs to grasp the nettle and determine how many, and what type of research centres it wants and then fund them properly, with a balance of discrete and continuous funding to allow proper management and stability. Of particular importance is the stability of manpower and nothing is more likely to disrupt the retention of good people than uncertainties in funding.

Barriers facing business and the science base in effective engagement with EU research programmes
[This section relates to question 20 in the consultation document]

The problems with EU funding have included the massive amount of bureaucracy associated with the funding, the low level of overheads and the need to link the EU funding to other sources. In many physics departments, EU funding is used as a

supplement to national funding but takes a disproportionate amount of administrative effort. In much of physics, there are natural and very strong European collaborations, particularly in areas where large facilities are required, such as astronomy and particle physics. However, there are also strong collaborations in other areas. The essential feature of successful European collaborations is that there should be genuine complementarity between groups. Perhaps the best way forward might be to link EU funding to national funding, to cover the full economic cost of the programme and to ensure that the European dimension genuinely adds value. Reducing the administrative burden would be a distinct advantage.

Physics-based industry

Physics-based industry
[This section relates to questions 9 and 13 in the consultation document]

The Institute's report, *The Importance of Physics in the UK Economy*[3], highlighted that physics underpinned 43% of UK manufacturing by 2000, and the percentage is growing. While "conventional" physics based industries (PBIs) are doing well compared with UK manufacturing as a whole, exciting new areas of industry are emerging based on developments in physics-based research over the past 20 years.

However, there are some worrying trends that threaten to hinder the performance of PBIs over the next decade. In particular:

- investment in PBIs does not match that of other manufacturing sectors and there is limited availability of venture capital for start-ups and small to medium-sized enterprises (SMEs); and
- commercialisation of physics-based research is limited, despite its potential for exploitation.

These issues require immediate attention if the UK is to maintain a healthy PBI base and UK PBIs are to continue to contribute to the growth of the economy. For instance, a modest increase in investment now could have a dramatic impact on the amount of physics-based industrial activity in the UK and the success of its commercialisation. University physics departments are starting to become more active in transferring technology to industry and their attitudes to entrepreneurship are changing. An acceleration of effort has to be encouraged, but it needs to be understood that it is not sensible to expect academics to become entrepreneurs on a large scale.

The Lambert review
[This section relates to question 9 in the consultation document]

The Institute welcomed the publication of the Lambert review of university-business collaboration and fully supports its conclusion that the main challenge for the UK is to raise the overall demand for research by business. A key recommendation from the review to enable this is that the Government should create a significant new stream of business-relevant research funding, which would be available to support university departments that can show strong support for business.

[3] http://industry.iop.org/pbireport/index.html

However, the Institute believes that additional support for research exploitation should not be at the expense of Research Council funding for blue-skies research. A careful balance is vital for the short, medium and long-term success of research in the UK. The Lambert review highlights the difficulty of encouraging such collaboration when resources are concentrated on a small number of "world-class" departments. The Institute strongly supports the conclusion that Government should take steps to fill the funding gap that exists between the research-intensive and the less research-intensive departments, with 'new' money.

The Institute agrees with the Lambert review recommendation that world-class excellence across all types of research should be recognised and rewarded by the RAE and Research Council peer review processes. Excellent research undertaken with industry or other users should be recognised as being of equal value to excellent academic research. An important issue here is the metrics used in the RAE to assess applied research. The issue of the difficulty of assessing multi-disciplinary activity and industry-linked research in a consistent way is a critical one. Appropriate recognition and credit to reward multi-disciplinary work and collaborative research with industry is vital. There is a view in the physics community that the RAE has driven ‘applied physics’ out of physics departments because elements of the RAE process, as applied to physics, favoured ‘pure’ science.

The Institute’s full response to the Lambert review can be viewed at *http://policy.iop.org/Policy/submissions.html#industry*

Regional Development Agencies
[This section relates to question 19 in the consultation document]

One of the challenges identified in the Institute’s report, *The Importance of Physics in the UK Economy*, is that, despite some high-profile spinout activity in the UK, there appears to be a low rate of commercialisation of academic research in physics compared with other disciplines. To enable the UK to reap more of the commercial benefits of its physics base, university physics departments and related groups should be encouraged to exploit more of their research in industry. There is significant potential for exploitation and the RDAs should have a bigger role in facilitating links, but the Institute along with the Lambert review remain unconvinced that RDAs, certainly as currently staffed and operating, are the best channel for Government money to help business-university linkages. Companies want to work with the universities with the most relevant skills and interests to support their business. In many cases these will not be in the same region. There needs to be a balance between innovative regional support for links and national support and co-ordination. DTI support and co-ordination of the major strategic and financial decisions would seem appropriate.

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