HEA

Higher Education Authority
An tÚdarás um Ard-Oideachas

> RESEARCH INFRASTRUCTURE IN IRELAND - BUILDING FOR TOMORROW 2007

Forfás

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Foreword

In early summer 2006, the Higher Education Authority (HEA) and Forfás agreed to conduct a review of the research infrastructure in Ireland. The purpose of the review was to internationally benchmark the research infrastructure in the higher-education sector in particular and to identify gaps in the national platform of research infrastructure, which could be addressed in the short to medium term. The review was conducted mindful of the goals, objectives and enhanced investment proposed in the Government's Strategy for Science, Technology and Innovation, 2006–2013 (SSTI) published in June, and of the new National Development Plan 2007–2013 (NDP).

Review Process

A key feature of the process was the appointment of an independent international Steering Committee, which had oversight of the comprehensive process review of research infrastructures in ten broad disciplinary areas covering the spectrum of research activity in Ireland. The review included the preparation of a database of the existing infrastructure in the higher education sector, which built upon earlier work of the Capital Review and Prioritisation Group ('Kelly Review'—September 2004). A consultation questionnaire was prepared and submissions were sought from a range of stakeholders. An advertisement was also placed in the national press welcoming submissions from all those who wished to engage with the review.

Through this process inputs were received across the spectrum of national research activity and across a wide range of stakeholders (see Appendix 3). The HEA and Forfás are grateful for the many submissions received from stakeholders, a significant effort having been made by researchers, higher-education institutions, funders, policy bodies, government agencies and departments to provide detailed submissions in support of this exercise in a short time-frame.

In addition, thirty-four international experts conducted visits across a sample of research infrastructures in the higher education sector. In the region of 50 per cent of all research infrastructure was visited. These visits provided the independent international benchmark for our research infrastructure and were invaluable to the process. We sincerely thank those international experts who gave of their time and expertise to assist us with this important national exercise.

A special workshop was organised to obtain inputs from the business and enterprise sector with knowledge of the existing research infrastructure base. There was a high level of congruence between the views of the enterprise sector on key gaps and needs, and that of the international reviewers.

The outcomes from the site visits and the emerging findings from the process were presented and discussed at a specially convened Forum at Croke Park in late October. This event provided an opportunity for the international Steering Committee to get feedback and engage with the Irish research community in advance of the conclusion of the process.

Findings and Conclusions

In short, the Steering Group's key finding is that notwithstanding the significant investment of funds in research infrastructure since 1998, and the remarkable transformation of the Irish research landscape since that time, weaknesses exist and gaps remain in the higher-education and national research infrastructure. This finding, in the context of the lack of investment prior to 1998, means in effect that we are still in 'catch up' mode whilst at the same time trying to compete with our international competitors. The gaps and weaknesses identified in the review require to be addressed in the context of the enhanced investment in R&D announced by the Government in June 2006 under the SSTI if Ireland is to achieve its potential.

MICHAEL KELLY CHAIRMAN, HEA

MARTIN CRONIN CHIEF EXECUTIVE OFFICER, FORFAS

Encouragingly the Steering Group's report has demonstrated that there is sufficient strength in many areas to be used as a foundation on which to build critical mass but importantly raises concerns in a number of instances where there has been a lack of investment in spite of the strategic importance of the area nationally. The biosciences area has received significant investment in recent years, but is still in need of investment in basic infrastructure requirements. This is also the case in the relation to chemistry. There are significant renewal requirements in the areas of physical sciences and mathematics, earth sciences and engineering. In the creative arts, humanities and social sciences, space provision and data management and archiving facilities need to be developed in way that promotes collaboration in research and excellence in scholarship. Similarly, there is urgent need for expansion and upgrade of the HEANet research support infrastructure to continue to support the ever more complex needs of researchers.

There are of course also areas where the need was not as clear from the range of stakeholders and where further work will be required to validate needs. HEA and Forfás are committed to facilitating further examinations of gaps and needs at the micro level, and further stakeholder consultation will be necessary. This review is the start of an on-going process and subsequent revisions will be vital to better define priorities for sectors or cross-cutting themes identified for further investigation. Decisions will be made early in 2007 on a number of areas due for further examination.

This broad review of Ireland's research infrastructure needs, and any future review, will also have to be cognisant of developments and opportunities at the European level, whilst also building a strong national infrastructure which will attract and retain quality researchers.

Finally on behalf of the HEA and Forfás, we would like to express our gratitude to the members of the Steering Committee, Professor Ken Pounds, Professor Roger Jowell, Dr. Anneli Pauli and Ms Eeva Ikonen, and in particular to the Chairman of the Group, Dr. Hans Chang. They have completed a difficult task in a limited period of time. Thanks also to Dr. Tom Higgins, who was the Secretary to the Committee, and to Dr. Eucharia Meehan (HEA) and Mr. Declan Hughes (Forfás), and their respective teams, who supported the process.

In conclusion this report will now become a key guiding document for forthcoming cycles of the PRTLI and will be presented to Government through the implementation structures for the SSTI. We look forward to working with all stakeholders in moving forward to establish a strong research infrastructure for Ireland.

Michael Kelly / Martin Cronin

BIOGRAPHIES OF THE INTERNATIONAL STEERING COMMITTEE

DR. HANS CHANG CHAIRMAN

Dr. Hans Chang is Director of the Foundation for Fundamental Research on Matter (FOM). FOM is the national coordinating research organization in the field of physics, mainly financed by the Dutch national research council, NWO. The organisation runs four national laboratories and also acts as a funding agency for physics projects executed in the science departments of Dutch universities. Hans Chang holds a Ph.D. in physics (condensed matter, 1972) from the University of Amsterdam. Subsequent to the completion of this he published a number of studies dealing with scientific issues. Thereafter he moved into affairs of national science policy at the Dutch Ministry of Education and Science. Since 1985 he has occupied the position of Director of FOM. In this capacity he is also Director of the Physics Division of NWO. He publishes regularly on science policy matters.

He was the inaugural Chairman of the European Union of Physics Research Organisations (EURPRO)—a union of the physics divisions of European national research councils; the first Chairman of the COST technical committee on physics, a Vice-Chairman of the OECD Global Science Forum, and the inaugural Chairman of the European Strategy Forum on Research Infrastructures (ESFRI). Within these bodies he continues to serve as the Dutch delegate. He has been a member of international panels evaluating research agencies and he is the Dutch delegate in several other international scientific bodies.

PROFESSOR KENNETH POUNDS, CBE

Professor Kenneth Alwyne Pounds, CBE, FRS is Emeritus Professor of Physics at the University of Leicester.

He was born in Bradford, Yorkshire, and gained his B.Sc. and Ph.D. from University College London. He then moved to the University of Leicester as an Assistant Lecturer in 1960. He became Deputy Director of Space Research in 1967, and was one of the pioneers of using rockets and satellites for research in the U.K.. He subsequently became the inaugural Director of the X-ray Astronomy group in 1974. His research is in the area of active galaxies, and one of his many discoveries is that black holes are common in the universe.

Ken Pounds became Professor of Space Physics at the University of Leicester in 1973. He was appointed Head of the Department of Physics in 1986, and the following year he took the decision to merge the Physics and the Astronomy Departments to create the present Department of Physics and Astronomy.

He has been a member of the Science and Engineering Research Council, 1980–1984, and President of the Royal Astronomical Society, 1990–2002, and he was seconded as the first Chief Executive of the newly-formed Particle Physics and Astronomy Research Council, 1994–1998, following the restructuring of the Research Councils. He then returned to the University of Leicester as Head of Department until his retirement in 2002. He remains active in the Department as a Research Fellow.

Ken Pounds was elected a Fellow of the Royal Society in 1981, and received a CBE in 1984. He holds five honorary doctorates, including the rare distinction of an honorary degree from his own institution, the University of Leicester (2005).

PROFESSOR ROGER JOWELL, CBE

Professor Roger Jowell is a British academic social scientist. He is a Research Professor at City University London from where he heads the Centre for Comparative Social Surveys. The Centre houses the 30-nation European Social Survey, a multi-funded European time series, which he initiated and still coordinates. Prior to joining City University he was the founder-Director of the National Centre for Social Research, now Britain's largest non-profit research institute which he headed for over 30 years.

An elected member of the International Statistical Institute and a founding Academician of the U.K. Academy of Social Sciences, he was awarded a CBE in 2001 for services to social science. He is also a recent Vice-President of the U.K.'s Royal Statistical Society and a Descartes Prize Laureate in 2005 "for excellence in collaborative scientific research".

His primary research interests are in social and political attitudes and survey methodology. His writing has focused primarily on Britain's and Europe's changing social condition, and his publications include a text-book on survey methods, eighteen edited books on changes in British social attitudes, and four co-authored books on British electoral behaviour.

DR. ANNELI PAULI

Since 2001, Dr. Anneli Pauli has been Vice-President of the Academy of Finland, responsible for matters concerning science policy and funding as well as for international cooperation. Before that she worked as Secretary General of the Research Council for Environment and Natural Resources, and also had responsibility for the implementation and development of the Finnish Centre of Excellence Programmes. Dr. Pauli completed her doctoral thesis in 1994 at the University of Helsinki. Her field of research is aquatic microbiological ecology.

Dr. Pauli has been a member of several Nordic and European committees. She is Vice-Chair of the Nordic Research Board, Finnish ESFRI delegate, Chair of the Network Steering Committee of ERA-NET project BONUS for the Baltic Sea Science Network of Funding Agencies, and member of the OECD Global Science Forum and its Steering Committee on Science Education. Within the EU 4th and 5th Framework Programmes, she has been a member of the management committee of the programmes on environmental research. For many years, Dr. Pauli was also active in the Joint Committee of the Nordic Natural Science Research Councils. In addition, Dr. Pauli works in numerous national committees dealing with science and technology policy.

MS. EEVA IKONEN
ASSOCIATE STEERING COMMITTEE MEMBER

Ms. Eeva Ikonen is a Senior Science Adviser at the Academy of Finland and a Member of the ESFRI Executive Board since 2005. She has lengthy and wide experience in Finnish research and higher-education policy, both at the ministerial level and in the funding agency (Academy of Finland) for basic research, as well as in university administration. Her expertise in management and administration has been put to good use in the Research Council for Environment, the Research Council for Natural Sciences and Engineering, and in the International Relations Unit of the Academy of Finland. She had an active role when Finland joined EMBL, ESRF, CERN and ESA. When Japan joined the EISCAT Scientific Association, and when the new EISCAT Svalbard radar was planned and constructed, she acted as Chair of the Finance Committee of the Association.

Eeva Ikonen has also been a member of the Board of Directors, Nordic Academy for Advanced Study, (1994–2001); a Finnish Delegate on the Science Policy Council of the European Space Agency, 1995–1998; and the Representative of the Ministry of Education on the Advisory Board for Space Research in Finland, 1992–1995. Ms. Ikonen has also been a member of the EU Framework Programme committees, and of expert groups for the training and mobility of researchers and for infrastructures.

PART 1
REPORT OF THE INTERNATIONAL STEERING COMMITTEE

Executive Summary

Our task has been to review the status of research infrastructure in the higher-education sector in Ireland and make recommendations for future support. We have received reports from site visits and had oral and written evidence from across the sector.

We have found a research system in impressive transition as a result of the major injection in funds over the past few years. This investment is beginning to transform the research base in Ireland, supporting a growing influence and recognition in the now-global research enterprise.

However given the historical deficits in infrastructure funding, Ireland is still some way behind other developed nations competing and collaborating in international research programmes. Recent investments have had a strong positive impact, but these investments must be properly supported and maintained. It is also important to recognize that the research base remains narrow at the highest international level.

Building on the progress to date will require the Irish authorities to balance several competing and critical demands on new investment funds. These cover:

- Consolidation of the investments recently made so as to ensure their full and effective exploitation
- Broadening the base of research in the Irish higher-education sector
- Investing for rapid development in specific, high-priority areas

Accordingly we recommend for consideration by the relevant authorities:

- A restructured PRTLI that will accommodate support for new proposals and for existing investments, as well as for pre-determined infrastructures, disciplines or areas, on an open competitive basis
- Re-instatement of the mechanism formerly operated by the HEA for replacement, updating and renewal of research equipment
- Discussion within research groups, and with the HEA and Forfás, of both the general and specific issues (identified in Section 3 below) pertaining to the development of proposals for future rounds of infrastructure investment
- Establishment of a systematic and periodic process for infrastructure reviews in the future

Main Report

1. INTRODUCTION

We were invited by the Higher Education Authority (the higher-education policy and funding body) and Forfás (the science and technology policy body) of Ireland to assist in a review of research infrastructures in the Irish higher-education sector. Our review is based on findings from site visits, carried out by international experts, to a cross-section of higher-education institutions; on survey results, and on inputs from funders, policy bodies and other stakeholders in the research domain in Ireland.

We particularly appreciate the reports of the site visit teams and the contributions from representatives of a wide range of research and research-related bodies in attendance at a specially-organised Consultation Forum at Croke Park on Monday 23rd October 2006.

Our task was to provide an overview of the quality of facilities currently available to third-level researchers and to identify gaps in the existing infrastructures that are most in need of attention in forthcoming rounds of national infrastructure funding under the SSTI (Strategy for Science, Technology and Innovation).[1]

The process adopted by the Committee for this purpose is outlined in Appendix 1.

We are pleased to acknowledge the assistance provided by the joint HEA/Forfás project team in facilitating our work and the highly professional manner in which this assistance was provided.

The Committee comprised:

Dr. Hans Chang, Director of the Dutch physics research organisation, FOM, and first Chairman of the European Strategy Forum on Research Infrastructures (ESFRI).

Professor Ken Pounds, Emeritus Professor of Physics, University of Leicester and former Chief Executive of the U.K. Particle Physics and Astronomy Research Council.

Professor Roger Jowell, Head of the Centre for Comparative Social Surveys, City University, London.

Dr. Anneli Pauli, Vice President (Research), Academy of Finland, Finnish ESFRI delegate.

Ms. Eeva Ikonen (Associate member), Senior Science Advisor, Academy of Finland, ESFRI Board member and Finnish delegate.

In order to meet the schedule established by the Irish authorities, our examination had to be undertaken within an unusually constrained time frame. Thus while we have been able to address our set agenda and make specific recommendations, we feel that there are other issues that would benefit from consultation within the various research groups and stakeholder communities in Ireland. These are identified in our report and we commend them for further discussion and analysis.

We have adopted the broadly based ESFRI definition of infrastructure.[2] This covers both physical facilities and equipment, including the associated human resources, as well as the soft infrastructure (collections, databases, archives, networks, processes etc) and includes the support personnel and services required for exploitation of infrastructure.

We have been apprised of government ambitions for Irish research, as expressed in recent public policy documents, and we applaud these. The challenges are formidable, but not beyond achievement. We hope that the outcome of this initial and broadly-based review will be of help. However we believe that a more detailed examination and evaluation of requirements will be necessary, sector by sector, to ensure that the essential further investments are soundly based. We recommend the establishment of systematic and periodic review processes for research infrastructure in the future.

Finally we wish to express our strongly-held view that, in any discussion about infrastructure metrics and deficits, it is critical that the focus is on quality rather than quantity. Academic research is now a highly competitive global enterprise and requires high-quality performance. Only the best research is good enough and, of course, the best research and education require a first-rate research infrastructure.

[1] *Strategy for Science, Technology and Innovation 2006–2013* (Government of Ireland, 2006)

[2] European Strategy Forum on Research Infrastructures, *European Roadmap for Research Infrastructures Report 2006* (Luxembourg: Office for Official Publications of the European Communities, 2006).

2. THE STORY SO FAR

The Committee is aware that it is examining a work in progress.

In recent years the Irish authorities have made a major commitment to strengthening the research base in the higher-education sector and a substantial capacity building process is now underway. The commitment was first given expression with the launch of the Programme for Research in Third-Level Institutions (PRTLI) in 1998, which was a landmark event. Subsequent funding through this mechanism alone has provided in excess of €600 million, largely for support of new research infrastructure. We find evidence that this injection, together with new funding following the establishment of Science Foundation Ireland (SFI) and the two new Research Councils, is dramatically changing the research landscape in Ireland.

Higher-education research infrastructure in Ireland in 1998 and prior to the PRTLI, was characterised by chronic public under-investment and a consequent heavy reliance on support from the rest of Europe. We were told that researchers had to chase funding wherever they could find it, usually outside the country, and fiercely compete with one another for the meagre domestic funding that was available. It was apparently not unknown for researchers to have to shift fields and specialties more than once in order to qualify for funding. As a result, the direction of research in Ireland in this period was inchoate and set more by international agendas than by domestic priorities. Of necessity, Irish academic research was opportunistic rather than strategic in its direction. In effect, much depended on the 'lone scholar' model of research. There was inadequate opportunity for planning or priority setting or for strategy formulation and little necessity for a planned approach anyway, given the paucity of national funding available. As their counterpart institutions in Europe and beyond moved progressively towards a more professional and strategic basis for research investment, the Irish institutions were falling well behind. The institutions themselves had too little influence on the content or overall direction of the research undertaken within them.[3]

In the *PRTLI Impact Assessment* (2004) Banda and his team reported significant improvements in both the volume and quality of research output, in institutional capacity, and in international competitiveness.[4] Based on international comparators, PRTLI-funded researchers were found to be producing excellent work of a higher standard than that of non-PRTLI-funded researchers. Banda detected a cultural shift in research planning and management at the institutions. He found that institutions were taking a more strategic approach and adopting a stronger corporate perspective on the research

function, especially in the way they planned and managed their research. Thus whilst, pre-1998, only one institution had a published research strategy, twelve such strategies were found by Banda in 2004. Similarly whilst, pre-1998, only two institutions had a senior designated Vice-President or Dean for Research, seven such posts had been established by 2004. We have the impression now that virtually all third-level institutions provide strategic plans for research and have a high-level dedicated research administrator. Banda noted evidence of stronger interdisciplinary and inter-institutional collaboration, concluding that the PRTLI was transforming the higher-education research landscape in Ireland.

Based on the findings presented to us, we are persuaded that the improvements noted by Banda and his team in 2004 are continuing and becoming embedded in Ireland's research system. Today, as a result of the infrastructure injection beginning in 1998, the situation has been substantially transformed. Research institutions in Ireland are now able to set their research agendas and prioritise their strengths, while individual researchers and institutions can collaborate on shared programmes for the benefit of scholarship across Ireland. A collaborative culture is establishing itself. As a result, institutions and researchers have significantly more discretion in the choice of research topics, and are thereby more able to compete internationally in many fields. In addition Irish research groups are more attractive international partners and are more pro-active in putting together teams for international competition.

In summary, progress over a relatively short period has been extraordinary. It is however vital that the present momentum is maintained as there is still much to do.

[3]*Comparative International Assessment of the Organisation, Management and Funding of University Research in Ireland and Europe* (The Higher Education Authority, 1996).

[4]*PRTLI Impact Assessment: Report by the International Assessment Committee, 2 vols.* (The Higher Education Authority, 2004).

3. WHERE IS IRELAND NOW–A REALITY CHECK

Based on the information received during our Review, we have formulated a number of general and specific conclusions as to the current state of research infrastructure in Ireland. In developing these conclusions we have had access to the views and concerns of a wide cross-section of senior researchers at the institutions. We have been provided with the judgments of the institutions themselves on their existing infrastructures. Our calibration of these views and opinions has been greatly assisted by the reports from the international site visitors. We also had available many written inputs from a wide range of stakeholders and the outcome of a debate at the specially convened Enterprise Forum. Finally, we had the benefit of a day of dialogue with senior representatives of the research system at the aforementioned meeting at Croke Park.

Reports on the site visits by international experts are provided in Part 2.

Based largely, but not exclusively, on these inputs, we have formed the following **general conclusions:**

Facilities and Space

- There remains a patchy landscape of research facilities, with new state-of-the-art facilities co-existing in some locations with buildings/facilities which are in poor condition and not fit-for-purpose. Site layout and usage of both new and old buildings needs to be addressed in many discipline areas.
- Space limitations, even in some of the newer facilities, mean that many are already at their maximum capacity. Overcrowding was particularly identified in the physical sciences and engineering, and is seen as a barrier to the attraction of international researchers, even at a number of high-profile, successful centres. The space problem is also causing the fragmentation of existing research groups.
- The current space allocation model is believed by many researchers to be out-dated and should be reviewed.
- More efficient space utilisation and space management in some newer facilities would also be desirable.

Foundation Infrastructure

- IT systems, computing services, and e-infrastructure, and the maintenance thereof, are generally deficient. The lack of common IT networks and platforms and of wireless access were high-lighted. High-end computing capability is generally weak, affecting many research areas, especially in the medical sciences, humanities, physical sciences and mathematics. Site visitors frequently commented that computation and data-analysis facilities were not adequate for first-class research.

- Deficiencies in data-management infrastructure were noted in the life sciences, medical sciences, physical sciences, engineering, earth, atmospheric and ocean sciences, and in the social sciences.

- Data archives and repositories remain at an early developmental stage—data access (to existing national and international sources) and data acquisition (storage and updating across the spectrum of disciplines/areas) is weak. These issues emerged strongly in the medical and social sciences areas.

- The absence of adequate library provision in general was identified, but in particular in the arts and humanities.

- On the positive side, HEANet, Ireland's National Education and Research Network, was cited consistently as a strength of the national research infrastructure. It provides a high-speed national network with direct connectivity for its community (the educational research sectors) to other networks world-wide.

Support infrastructure

- The technical and administrative support systems needed to underpin effective research performance were found to be inadequate in a majority of the sites visited.

- High-end technical support, frequently at Ph.D. level, for servicing, maintenance and operation of complex facilities and operations is needed. The case for permanent technical staff for this purpose was made during many site visits, especially in the areas of the physical sciences, earth, atmospheric and ocean sciences, and biological sciences.

- It is a natural consequence of the investment in improved research facilities that management and management systems have also to be improved. There is need for better administrative support, especially for space management and strategic planning.

Equipment

- Whilst there is an expanding equipment portfolio in the higher-education institutions, much remains in urgent need of replacement. This issue was high-lighted particularly in the areas of earth, atmospheric and ocean sciences and in chemistry, but is an issue across many areas.

- While very large equipment can be obtained under the PRTLI, and some small equipment from other funders, there has been no dedicated equipment fund for new acquisitions and updating—especially of small and middle-sized items—since the closure of the earlier HEA fund (the Large Equipment Grant). As most national funding agencies nowadays have such a fund, the Committee suggests new arrangements to cover these needs on an on-going basis.

- The flow of funds for the maintenance of research equipment was also found to be a major issue in many discipline areas. It was particularly critical in biological and medical sciences and in physical sciences.

We also wish to draw the attention of local management to the fact that in some of the site visit reports occupational health and safety issues were raised which will need to be addressed urgently.

In addition to these general findings, we wish to draw attention to a number of issues that are associated with specific disciplines, and have formulated the following **discipline-specific conclusions:**[5]

Arts, Humanities and Social Sciences

- Although data archives and repositories need attention, existing national research collections and data repositories in the humanities were identified as a strong base upon which to be built. There are, for example, unique collections, such as the TCD Library, which in addition to its status as a legal deposit library for Ireland, has also had U.K. legal deposit privilege since 1801.
- Instances where humanities' researchers are engaged in innovative collaborative links with physical scientists in the use of technology were noted by visiting experts. However it was also found that interaction between researchers in the arts and humanities, education, and creative arts and media, and other disciplines is held back by the lack of designated, high-quality, fit-for-purpose research space.
- Notwithstanding severe under-investment in research infrastructure and research capabilities, recent successes by institutions specialising in media and creative arts were noted. It was considered, however, that there remains a compelling need for an underpinning infrastructure to enable researchers to compete in this area. Space and obsolete equipment were problems across these disciplines.
- Key strengths in social sciences identified during the site visits were some new interdisciplinary research centres. The Irish Social Science Data Archive (managed by one Dublin-based institution) has, in the view of the expert visitors, the potential to be a key infrastructure resource, despite being under-resourced. Access to specific data was identified as a serious problem, with deficits in access to both national and international data sets. The absence of data storage and archive facilities and their ability to be updated with fresh datasets is a serious and continuing impediment to high-quality social science research in Ireland.

[5]The disciplinary areas were: Arts and Humanities; Biological and Agricultural Sciences; Computer Sciences; Creative Arts and Media; Earth, Atmospheric and Ocean Sciences; Engineering Sciences; Medical Sciences; Physical Sciences and Mathematics; and Social Sciences and Psychology. The visiting expert reports for each of these broad disciplinary areas can be found in Part 2 of this report. Conclusions are presented here in discipline clusters.

Biological and Medical Sciences

- The strength and future potential of Irish hospitals as part of the national research infrastructure, and the recent award by the Wellcome Trust and the HRB for a new Clinical Research Facility, were noted. However it was the view of the experts that there remains a significant gap in the interaction between the academic community and the medical community.

Physical Sciences, Mathematics and Environmental Sciences

- The strength of the existing network of facilities in the West of Ireland in marine and environmental sciences was noted by visiting experts. However investment in equipment and technical support is a barrier to progress in this area.

- In the environmental sciences, researchers have access to the Mace Head Atmospheric Research Station in Connemara. It is an internationally recognised coastal site and part of the global air chemistry monitoring network. However experts noted the lack of adequate investment in atmospheric science facilities to exploit this potential. Fragmentation of effort was also highlighted.

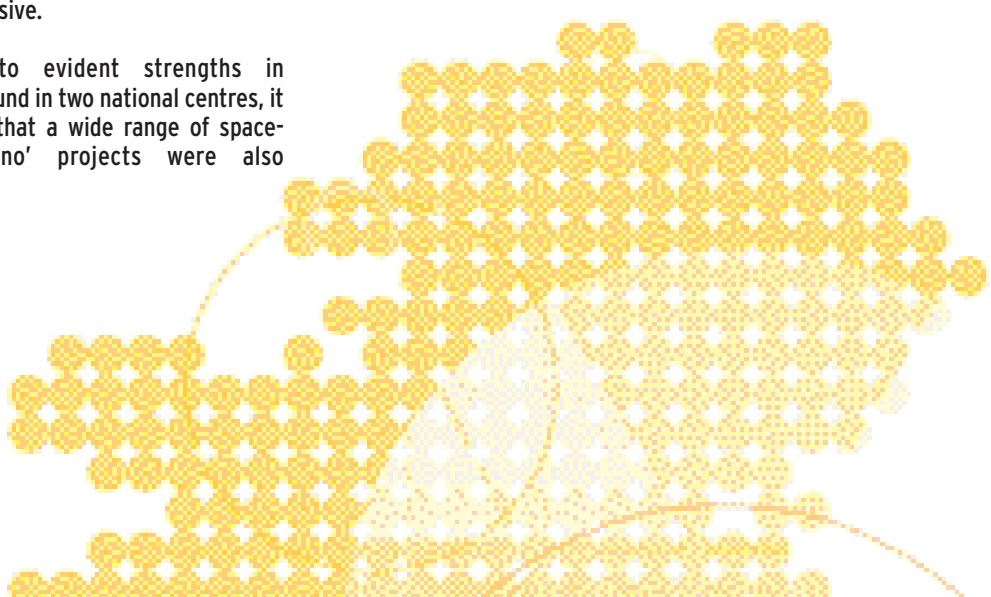
- Geology was identified as an area in which there are very severe short-comings both in buildings and equipment.

- The success of one institution in integrating materials and engineering research within one location was noted by the visiting experts. The level of interdisciplinarity observed in the physical sciences, in particular in two Dublin institutions, was also deemed impressive.

- In addition to evident strengths in nanoscience found in two national centres, it was observed that a wide range of space-intensive 'Nano' projects were also underway at a number of other institutions. Overall these projects are rather small-scale and the achievement of the critical mass required for their success may be a significant challenge. It was felt that Ireland will need to consider the value of this work and avoid duplication across the sector, perhaps through the encouragement of a collaborative approach.

We recommend further discussion of all these issues, general and specific, within the relevant research groups, and with the HEA and Forfás, in the development of proposals for future rounds of infrastructure funding.

The Committee also noted that Ireland is not participating in a number of the large European research organisations. The Committee realises that here choices have to be made. As an example we draw attention to the fact that with a community of 150 academic researchers in the fields of astronomy/ astrophysics, the possibility of membership of the European Southern Observatory (ESO) is an issue to be discussed at governmental level. However it should be noted that such a membership requires a simultaneous commitment from the government/funding bodies of Ireland to proper research funding in this field. Otherwise the expensive membership cannot be utilized to its full potential.



4. SUGGESTIONS FOR THE FUTURE

The landmark event of the commencement of the PRTLI dramatically changed the research landscape in Ireland. However momentum has to be maintained as there is still much to do. Whilst formulating research policies, the authorities should address 'balance questions' dealing with:

- Consolidation of the investments recently made, so as to ensure full exploitation of those investments.
- Further broadening of the base of academic research in Ireland.
- Investing for rapid development in specific priority areas.

The Committee realizes that the question of how much extra funding is needed is a matter of political debate. Since 1998 Ireland has been closing the gap with OECD/EU but is still short of their average investment levels. In 2004 the Irish HERD (Higher-Education Expenditure on R&D) was 0.40% of GNP compared with an average OECD/EU figure of 0.43%, ranking Ireland in 14th position out of 30 countries.[6] At the upper end, Sweden, with a higher-education system somewhat comparable to that in Ireland, allocates 0.83% of GDP, more than twice the Irish level. Other relevant comparators are Finland 0.67%, Denmark 0.60% and Austria 0.57%. We suggest these, rather than the EU average figures, provide the appropriate targets for Ireland.

Clearly the investment gap is still too large. Higher levels of funding will be required if Ireland is to achieve the stated government policy objective of matching the top institutions in the OECD. Indeed the HEA's own stated strategy is to match the top decile of OECD countries, an achievement which would represent a substantial shift from Ireland's current position.[7] Given the historical deficits in infrastructure funding that accumulated over many years, we find a research system in transition, still at a relatively immature stage, and lacking the scale and critical mass of its realistic international competitors. There is no deficit of intellectual capacity in the Irish research system, only a deficit of opportunities. We consider the case for increased and sustained investment is very strong.

An appropriate mix of top-down and bottom-up funding decisions could address the issues of balance mentioned above. Thus a top-down decision might be made to selectively add broad areas or disciplines in which important deficiencies exist. Perhaps a ring-fenced sum might be set aside for supporting or enhancing existing investments. Within both these pools, however, institutions and researchers should presumably still have to compete for funds. Previous recipients of funds ought not, in our view, to be privileged, but equally they should not be penalized. Thus previous recipients of funding might be subject to a performance appraisal, based on the use they have made of that funding.

In sum, we suggest that the mechanism for funding infrastructures on the next occasion might have two elements:

- An open element, which would call for proposals for both new and existing infrastructures, including upgrades of existing facilities, and would be allocated on a competitive basis.
- A selective element, which would be reserved for certain HEA/Forfás-nominated infrastructures or disciplines, such as access to and replenishment of databases, IT systems, computing, etc also to be allocated on a competitive basis. The consolidated reports at the Forum, questionnaire results and the site visit findings would provide valuable evidence for the selection of appropriate subject areas.

Overall we believe that this will provide a mechanism that will help to broaden the Irish research base. Its open and competitive basis allows all researchers to apply for support, under the open element, and be selected on the basis of excellence. Its selective element allows the authorities to specify important aspects of the base that need support and invite suitable competitive proposals from all interested researchers and institutions. This funding structure will, we believe, help the Irish authorities to address the balance issues that we described above.

[6]OECD, Main Science and Technology Indicators, 2004.

Both elements of the model should, in our view, favour collaborative proposals, as the PRTLI currently does, and proposals which demonstrate the fullest exploitation of existing and proposed new facilities. This includes considerations about access. New facilities should offer access for all interested and competent researchers, irrespective of their institutional location, and not just for the benefit of particular institutions.

Irish researchers have a long tradition of international (particularly EU) collaboration.[8] We understand that it was precisely these links that sustained the research system during earlier decades of under-investment. Such international collaboration will continue to be extremely important for Ireland in an age of increasing globalisation. So the existence of international links should also be a factor in awarding new infrastructures. Whereas Irish researchers have in the past looked abroad for opportunities, a scaled-up and higher quality research infrastructure at home will provide new opportunities for attracting researchers from abroad who seek access to state-of-the-art facilities for high-calibre research. Irish researchers will also be able to play an increasingly prominent role in EU research frameworks.

In this context, it is opportune that after two years of intensive work, ESFRI has recently presented the first European 'road-map' for new, large-scale research infrastructures, based on international peer-review. The road-map includes a short description of each of the projects together with an estimate for construction costs. Some are evolving projects while others need firm financial commitments very soon. Also, Irish ministers responsible for research have been invited by ESFRI to embark on national discussions about which projects Ireland could join. Discussions and decisions at a national level will therefore also be critical in influencing the focus of future European research infrastructures. We anticipate that these discussions might also encourage the development of national road-maps and the ear-marking of dedicated national budgets for the construction of research infrastructures with a European/international dimension.

There are important opportunities here for Ireland. Research communities that are currently less well structured than those appearing in the first ESFRI road-map will be stimulated to participate more effectively in the process from now on. National representatives will be able to participate in discussions about the realisation of these Europe-wide infrastructures. These opportunities will enable Irish policy-makers and researchers not only to engage with nominated ESFRI projects, but also to begin formulating projects of Irish origin in which prominent Irish researchers could play the lead role in future infrastructures.

Selected investments in research infrastructures should be viewed as investments for capacity building in strategic areas of research and career development of young people. International collaboration and researchers' mobility between institutions and participation in international research infrastructure projects provide wider opportunities for researcher training and career development of Irish researchers. High-quality research infrastructures are a necessary prerequisite in attracting foreign researchers and

[7]Don Thornhill, Chairman, Higher Education Authority, 8th September 2004 in *Review and Prioritisation of Capital Projects in the Higher Education Sector: Report of the Review Group (The Higher Education Authority, 2004).*

[8]A recent example of the universities' commitment to international collaboration is their proposal for a new digital repository of publications that would facilitate easy discovery, increase citation rates and make Irish research output easily available internationally. This would follow similar initiatives in the Netherlands, and the U.K..

good collaborations in Ireland. Quality infrastructure is also essential in retaining the best Irish research talent in Irish institutions.

Investments in infrastructures must be viewed in a national, as well as an institutional context. Thus, issues of access, sharing and transparency, nationally and internationally, will have to be more formally addressed than in the past, including access to existing national databases.

Although particular institutions or groups of institutions are given the privilege of hosting particular infrastructures and national databases, they should not be given exclusive or proprietary rights to the infrastructures themselves or to their products. Indeed proposals for infrastructures should be judged on the basis of their quality, their inclusiveness and their envisaged utilization.

In addition to national-level investments in research infrastructures, research institutions need to have funding mechanisms available that will help to secure long-term investments in research facilities and equipment.

PART 2
REPORTS OF THE INTERNATIONAL SITE VISITORS

1. INTRODUCTION

A key component of the Review was the infrastructure site visits. A total of 34 international experts were invited to visit a sample of sites in Irish higher-education institutions (see Appendix 2). Owing to time constraints of this Review, not all facilities could be visited. As a result, a selection was made on the basis of the relative amount of research space in a given discipline area. In addition, facilities in both good and poor condition were selected to represent the national picture in a particular research field, this selection being informed by information submitted by individual institutions on the condition of facilities. It is anticipated that future national reviews will focus in more detail on individual research areas. A total of 14 different institutions were visited, with just under half of the research space in Irish higher-education institutions captured by the visits. During the Review, in the region of 95 facilities were visited. In addition, two visits to national libraries were carried out as part of the arts and humanities' site visits. Visits took approximately one half-day per institution per discipline area. A breakdown of the scope of the site visits is given in Table 1 below.

Individual reports from different discipline areas were submitted to the Steering Committee for the Review and summaries of these reports are published here. The reports have been grouped as follows:

- Arts & Humanities, Education, and Creative Arts & Media.
- Psychology and Social Sciences
- Biological and Medical Science (including Agricultural Sciences and Chemistry*)
  Clinical Research Facilities
- Computer Sciences
- Earth, Atmospheric, and Ocean Sciences
- Engineering
- Physical Sciences and Mathematics

* Chemistry facilities were also visited under the category of 'Physical Sciences'

Table 1. Breakdown of the scope of the site visits conducted as part of the Research Infrastructure Review.

Discipline Clusters International	Sub-disciplines	Number of Institutions Visited	Number of Facilities Visited	% Total Research Visited (approximate)	Number of Site Visitors
Biological and Medical Sciences	Biological Sciences (including Agricultural Sciences and Chemistry), Preclinical *in vivo* facilities, Clinical Research Facilities	5	16 Bio/Agri 15 Preclin/Clin	43%	10
Arts, Humanities & Social Sciences	Humanities, Social Sciences & Psychology, Education, Creative Media & Arts	7	19	30%	10
Physical Sciences	Physical Sciences & Mathematics, Engineering	6	11 Phys Sci/Maths 12 Engineering	48%	8
Earth, Atmospheric, and Ocean Sciences	Earth, Atmospheric, and Ocean Sciences	3	9	42%	4
Computer Sciences	Computer Sciences	4	13	54%	4*

**Two of these site visitors also carried out a site visit in the thematic area of physical sciences and mathematics*

2. ARTS & HUMANITIES, EDUCATION, AND CREATIVE ARTS & MEDIA

Overall Observations

- The space allocation model used is out-dated; it may be time to reassess needs across institutions. Good quality, fit-for-purpose research space is needed. The lack of space provision is problematic in that it precludes a sense of belonging or ownership which is important when trying to encourage commitment and contribution from Ph.D. candidates. Supervisory arrangements are also challenging, as it can often be difficult to locate candidates who are mostly situated off-campus as a result of lack of provision. It is suspected this also has a detrimental effect on completion rates.
- Research centres appear to work in isolation. Physical grouping of centres in cognate areas could facilitate a different arrangement of space more conducive to the sharing and stimulation of ideas, exploration of solutions to common problems, and the creation of an integrated support network (of people not systems. Bringing together of centres would also allow a more integrated provision of administrative support—particularly in the case of secretarial assistance—and also provide a more co-ordinated approach to IT.
- In the field of education in particular, the lack of postgraduate seminar rooms was noted and, in the rare cases where these facilities do exist, there was an absence of AVC equipment. Generally the infrastructure for research in the areas of education and adult/continuing education is non-existent. Neither site visited in this area, because of space restrictions, facilitates the interaction of researchers. In general researchers in the areas of creative arts & media, arts & humanities, and education were not located in proximity to each other
- There is a clear lack of any acknowledgement of the creative arts and design fields as an important element of the national strategy for research and innovation. Facilities are totally unfit for purpose, dangerous and certainly unsuitable for use as a premier creative arts postgraduate research facility. The equipment provided in film and video studios is woefully out of date. Digitisation is urgently required if those researches produced in this field are to serve a purpose in industry. Those institutes successful under the National Digital Research Centre (NDRC) programme have highlighted the need to progress this project. Opportunity for the provision of a springboard for the creative arts is being wasted by long delays in NDRC start-up. In addition, The National College of Art and Design is limited by the outdated provisions of the 1971 legislation under which it functions.
- In addition to its status as a legal deposit library for Ireland, the Library of Trinity College Dublin was given U.K. legal deposit privilege in 1801. It continues to receive copies of all material published in the British Isles. The storage space for early printed books/manuscripts is full and extensive use is already being made of off-campus storage. A strategic decision, at national level, is required to decide on the future expansion of this major national research resource.
- The lack of major data repositories and national depository for qualitative data and repository for research papers is a significant gap.
- Absence of an adequate library provision needs to be addressed. Where this resource exists, there is a need for dedicated research space. Library provision as a whole is as an undergraduate resource and is generally unsuitable for postgraduate use.
- The increasing availability of electronic books and journals means the IReL electronic library initiative should be rapidly extended to the humanities and indeed the Institute of Technology sector.
- Enhanced administrative support and funding from the research offices is needed.
- The intellectual capacity is certainly here but the physical support required to achieve the step-change necessary is not present. Once again genuine willingness was demonstrated but not the physical resources required.

Summary of Findings

Building Condition and Space

The institutions visited presented something of a dichotomy. In some cases the quality of space was generally good and fit-for-purpose, but insufficient in quantity and not of world-class calibre. In other cases it was very poor, bordering on the dangerous, and certainly no longer adequate.
There is a clear need for good quality, fit-for-purpose, dynamic and community-enhancing space to serve the needs of a vibrant and successful research community. Ireland is uniquely positioned to engage in this type of research at world-class level if the facilities were available.
In many cases research space currently needs to be carved out of the undergraduate provision, as the specific funding models do not support provision of research space.

Equipment

Equipment where available was adequate and reasonably up-to-date, in other places it was non-existent and centres had to strive to keep up-to-date with very limited budgets. In the context of the humanities capital intensive equipment is not a necessity in most areas. However in other areas the data access issue identified earlier is clearly of major concern.

Foundation Infrastructure

Foundation Infrastructure deficits include lack of access to high-end computing facilities to handle the large data-sets of information from surveys, focus groups and interviews. However this access to high-performance computing is a constraint across the research landscape in Ireland.
Access to specific data was identified as a serious problem. Large data sets are collected by such government agencies as Forfás and the Central Statistics Office (CSO), and by independent entities such as ESFRI, and could be of tremendous use to researches in this field. The data collated is very current and could be invaluable even at macro level. Lack of 'in progress' access to this data has been cited as restrictive as availability is common in other EU states. Restricted access precludes Irish academics from participation in international research programmes. Specific access problems appear to be a result of lack of support staff in these agencies or specific rules and policies.
Provision for the storage and dissemination of research data (in particular from funded programmes such as the PRTLI) has not been made. As many projects will run for a specific term and have significant outputs provision for data hosting, mining, updating and access should be made at a national level.

Technical Support

Information technology support was an issue. There appears to be little IT support and the specialised staff in place are 'overwhelmed' and primarily employed to support teaching. While support is available, this is mostly located in centralised system support offices and geographic distance can result in slow response rates. The support system is extended to postgraduates more through personal support of the tasks being carried out rather than as a specific support role. Software provision and support was also problematic in certain areas.

Management

Little formal administrative support on the scale necessary to support the activity required. Most existing efforts are dependent on the time and efforts of the individual. In other cases support is 'borrowed' through good will and is taken from the undergraduate provision. A dedicated resource (secretarial and administrative support) at local level to facilitate research is absent.
There appeared to be a lack of overall direction from the management in terms of teaching, learning, and research in respect of the utilisation of resources. As mentioned above, the teams raised the question of how space and equipment were distributed throughout institutions and across disciplines cognate to the arts and humanities in particular.

Access to large scale or multi-user facilities

A library lending exchange provision is required across all higher-education institution libraries.

Site layout and accessibility

The dispersion of academic staff and researchers over a number of buildings is not conducive to good interaction. Of the sites visited, those designed and built with grant monies and a specific mission are good. However other re-allocated spaces, which are generally located in undergraduate and teaching and resource centres, are less suitable to the provision of a positive atmosphere.

There appeared to be a fragmentation of communication across sites and no means of exchanging information. As mentioned above, building layout does not facilitate collegiality. In spite of this general observation, reviewers commended the innovative collaborative links that have been established between physical scientists and humanities' researchers.

Space is required for visiting researchers, including in libraries. Some 'hot desks' are available in certain institutions but on a first-come first-served basis. In certain cases there is no central administrative support in relation to the provision of library and computer access. Each centre has to address its own requirements.

3. PSYCHOLOGY AND SOCIAL SCIENCES

Overall Observations

- There are striking contrasts between facilities for psychology and other social sciences. Whilst research in psychology and sociology is being conducted in buildings that are simply not suitable for modern research methods, research in other social sciences is being conducted in new buildings.
- The absence of an adequate national data archive is a serious impediment to social science research in Ireland, as well as to research undertaken in other countries that is inclusive of data pertaining to Ireland. UCD has established the basis for developing a national archive but lacks the resources to proceed.
- Absence of adequate library provision needs to be addressed.
- All of the sites visited are planning to expand their research activity, aiming to double Ph.D. output by 2013 in line with the national research strategy. Space constraints alone make this aim unrealistic. Each university should identify its research priorities and focus on those.
- A key issue is the continuity of funding for top-class facilities. A particular problem is how to deal with major research groups established, usually on a five-year contractual basis, and the uncertainty about future funding is a major problem when trying to retain researchers in Ireland.

Summary of Findings

Building Condition and Space

The condition of buildings varies from excellent to adequate or no longer fit-for-purpose. Even newer facilities are now approaching capacity as the ambitious increases in postgraduate students envisaged in the new National S&T strategy were not anticipated when the buildings were designed. Most psychology research facilities were not fit-for-purpose. Such research necessitates access to specialised research laboratories which are not currently available and which, it seems, cannot be accommodated in existing buildings.

Equipment

No particular equipment problems were noted. However the absence of a clear mechanism for equipment maintenance and renewal is a concern.

Foundation Infrastructure

The major issue here is the availability of data archives for social science research. There is, on the one hand, the need to establish a national archive, exemplified by the fact that the ESRI has a mine of useful data, both current and from the pre-electronic age, that is not covered by the UCD archive. On the other hand, there is the need (now lacking) to access international data archives such as the ICPSR in Ann Arbour, the Data Documentation Initiative (DDI), the Luxembourg Income Survey (LIS) and the Cross National Equivalent File (CNEF at Cornell University).

The Social Science Data Archive in UCD should be a key infrastructural resource for the Irish social sciences community as well as for international researchers. Only if data pertaining to Ireland is available through a data archive can researchers from other countries include Ireland in their studies. Archives in general need much greater resources and better research capacity (in order to know what researchers really want), which must result in wider promotion and ease of access to the academic community in all fields of social and behavioural sciences.

On some sites, the inadequacies of the library provision, particularly for research, were observed. Access is a problem, in addition to the fact that the range of books available for scholarship and research is narrow and out-of-date—issues which the reviewers did not address in detail on these visits.

Technical Support

With the exception of research in psychology, there are no serious issues with technical support for research. However this probably reflects the absence of an adequate data archive; should this lack be rectified then technical support will need to be expanded also.

Management

Management of space is critical. Space shortages are evident in a number of areas. There could be potential for more effective management of space across the campuses but this issue was not really fully addressed. Likewise there is neither room nor resources for expansion across all disciplines, and research prioritisation is necessary.

Site layout and accessibility

The newer buildings and social science research centres are designed to encourage interaction between researchers and good interdisciplinary work was observed at most sites. However the older buildings are completely unsuited for this; some buildings house a multitude of departments and activities, making access by visiting scholars difficult.

Other Comments

It was considered that the social sciences' research observed is close to or at world-class. There are some infrastructural issues to be addressed (e.g. national data archive), but the major barriers to further progress are elsewhere. In the other areas visited—psychology and sociology—the infrastructural issues verge on the insurmountable in terms of the amount and quality of space available in the existing buildings.

4. BIOLOGICAL AND MEDICAL SCIENCES

Overall Observations

- The reviewers considered that world-class research is being conducted in particular areas. It appears that this has been achieved through the development of a clear institutional strategy to attain international standards of excellence. However there remains a great need to invest in people. Without the provision of more long-term contracts, high-quality staff will not be attracted. Critically important is the absence of both administrative and technical support for researchers in the biosciences.
- The demand for monitoring and reporting from research funding agencies has been passed directly to the research performers, diverting them from research into routine administration. Technical officers, usually at Ph.D. level, are needed to operate and maintain complex and expensive equipment.
- Good equipment quickly becomes obsolete and the absence of resources for on-going maintenance, upgrades and renewal exacerbates the situation and prevents laboratories remaining at the cutting-edge of experimental science. The absence of a mechanism for replacing equipment on a regular basis is a barrier to progress.
- There are serious health and safety issues in a significant number of the laboratories visited.
- The biosciences, in general, need to be closely aligned with the medical arena to exploit the synergies from closely related areas of fundamental science

Summary of Findings

Building Condition and Space

There is a huge variation in the quality of buildings in the life sciences. New buildings are in excellent condition, and would have no difficulty attracting international students and researchers. Although staff are making valiant efforts in the very old facilities, these are, in the main, not fit-for-purpose. In general, it is preferable to re-build rather than refurbish existing buildings.

In some cases there appeared to be a gross imbalance between the usage of space in the various parts of the buildings, some areas of which are facing serious over-crowding. Even some new buildings failed to anticipate the increased demand for space for both staff and students which has resulted from dramatic rises in research income and performance.

Basic requirements such as temperature control, air conditioning, suitable ceilings and benches are needed in some facilities.

The food processing hall visited is unique, most similar facilities having been dismantled but its potential is not exploited. For example, with greater collaboration between the various parties some of the research equipment could also be used for training in food process engineering.

The GMP facility visited was considered as an ambitious undertaking but small and under-resourced in comparison with similar facilities elsewhere. Its activities will be subjected to international quality control as it aims to generate materials for use in clinical trials. Although other GMP facilities were not visited as part of this review it was stated by reviewers that GMP facilities would be required to support growing needs in translational research. This need would need to be investigated further.

Equipment

The majority of equipment in newer facilities was considered as adequate. Within that there was a range from good to excellent. In older facilities there was a lot of antiquated equipment, which needs to be replaced.

Some specific requirements include high resolution TEM, rheometers, calorimeters, solid state NMR (Nuclear Magnetic Resonance) or low resolution NMR.
Priority must be given to generating a policy for upgrading equipment.

In chemistry, there appears to be a great need for some basic analytical equipment and even relevant modern equipment is not being properly maintained because of the absence of an adequate maintenance contract budget and the lack of suitable technicians.
It would appear that the discontinuation of the HEA's Large Equipment Fund removed a mechanism which was found very useful for replacing obsolete equipment. The reviewers felt that this or a similar mechanism for funding needs to be reinstated.

Foundation Infrastructure

Generally the foundation infrastructure was considered adequate even in the most inadequate of buildings. Access to electronic journals has improved enormously in recent years; however many journals are still unavailable and this is an issue for some researchers.

There is a lack of access to high-performance computing capacity for such areas as bioinformatics.

Technical Support

The absence of a suitable career structure for highly qualified research technicians and for research administrators is a serous weakness in the Irish biosciences system.
There is an insufficient number of highly qualified technicians. As a result, many sophisticated and expensive pieces of equipment are under-utilised or not operating at maximum efficiency and this impacts on the quality and efficiency of the research effort. There is a need for sustainable long-term funding to support technical expertise.

Management

There is a critical need for administrative support. Administrative tasks, both reporting on research inputs and outputs as well as preparing new research proposals, is a very arduous task in a research environment. The absence of administrative support staff is a severe hindrance to the development of a research environment which is both attractive to leading researchers and conducive to the efficient and effective performance of the research itself.

There are serious health and safety issues in a significant number of the laboratories visited and these need to be addressed and rectified at a local level.

Access to large scale or multi-user facilities

Research groups should have access to European facilities as required. Establishing lines of collaboration with centres of excellence around the world would allow for instant access to facilities that are currently wanting within the higher-education system. Programmes for exchange of students, postdoctoral fellows and faculty could enhance the research potential.
Ireland needs a generic national transgenic facility for the research community. Furthermore, access to large animal facilities is needed. Improved imaging facilities were also identified as being a specific need.

Site layout and accessibility

The newer facilities have been set up to be interdisciplinary and they seem to be working well in this regard. To encourage inter-institutional work the use of two-way video conferencing facilities might be of benefit. Linking with other institutions and hospitals would certainly facilitate such interactions. An initiative such as this would be welcomed by many researchers.

The layout of older buildings does not facilitate and encourage interaction of researchers.

Other Comments

The classification of food science as part of agriculture reflects the old view of the subject as being producer-led, whereas the modern view, such as that proposed in EU funding, is towards consumer-led work; it may be that this change needs to be reflected within the structure of Irish science. Nevertheless the food groups could benefit from better links with agriculture.

5. PRECLINICAL *IN VIVO* FACILITIES

Overall Observations

- There is a great need to establish either a high-capacity national central preclinical facility or some regional medium-capacity facilities.
- There is a great need to increase the number and capacity of small animal facilities and of GLP surgical space in dedicated institutes.
- More specialised capabilities are needed, in particular robust transgenic production at a local and/or national level, including schooling Irish junior staff for future central and regional facilities.
- Absolute need to move toward the closure of substandard facilities.
- Absolute need for transparency regarding aims and perspectives of the on-going and planned experimental research, in order to avoid anti-lobbyism.

Summary of Findings

Building Condition and Space

The condition of preclinical *in vivo* facilities in the sample of sites visited was mixed. Recently commissioned facilities were in very good condition, up-to-date and adequate for the research being conducted. A total of eleven units were visited. Seven of these were in good condition, one needed some remediation, and three were inadequate and were not considered fit-for-purpose. For the latter the reviewers considered that while refurbishment might be possible, this was unlikely to be a cost-effective approach and that replacement facilities were required.

Overall where facilities were of a high standard, lack of sufficient capacity and room for growth was highlighted as a key issue. Specifically, some specialised facilities (SPF or clean conventional) were being compromised to house animals that did not require these conditions. In addition, more non-holding space was required, in particular for advanced surgical procedures that were being conducted to a high standard but in modified animal housing rooms, owing to an overall lack of space.

Furthermore researchers were either currently being impeded by the lack of sufficient housing space or had identified that, if the situation did not change considerably, in 2–5 years there would be a significant negative effect on the advancement of research using these technologies. In certain cases the units were dispersed but were working well and the reviewers did not consider this a disadvantage. The reviewers agreed that, from a hygienic point of view, dispersed units offer safer conditions

against epidemic contaminations with specific pathogens than a single central high-capacity animal facility within a university.

Moreover it was highlighted that there is a need for holding space for experimental purposes within committed institutions in addition to central medium- to high-capacity facilities shared by all institutions. The key recommendation on building condition and space was that there needs to be a move toward the closure of substandard facilities and a significant increase in the capacity of small animal units.

All of the institutions visited were aware of the space issues and have individually explored the needs of researchers for the future and appeared to be at an advanced stage of thinking with regard to the design of proposed new facilities.

Equipment

Equipment in the main was considered to be adequate. Apart from the need for microinjector equipment, it was felt that specialised clinical research equipment for large animal studies including imaging equipment needed some investment. Where specialised facilities do exist, it is imperative that appropriate structures are put in place to facilitate effective access to other researchers nationally. Reviewers suggested that some form of access funding might assist this facilitation.

Technical Support

Technical support services and availability of service personnel was not adequate in all cases. In general the team felt that skills and expertise were present but that in some cases this expertise was not being invested in core institutional staff but rather in transient contract researchers. As more specialised facilities are developed in the future it is imperative that these are run and maintained by core technical staff to ensure continuity of in house expertise. Hiring of suitably trained staff from abroad may be required as necessary expansion takes place. This approach had been taken in some cases and has been effectively demonstrated. Long-term aim, however, was felt to be that schooling by technical staff should help ensuring availability of suitable trained Irish junior staff in the future.

Research Capabilities

The issue of specialised capabilities within the animal facilities was also addressed at each site. Overall there is a strong need for increased transgenic production capabilities. Limited capability does exist and there are plans for the introduction of more on other sites, and this will go part of the way to addressing this need. On a national scale, the reviewers considered that this expertise should be widely available at a local level to supply the needs of researchers. This technology is essential for many Irish researchers to compete internationally and to attract researchers here. In addition it was felt that the costs for microinjection set-up were not prohibitive.

Access to large scale or multi-user facilities

The reviewers considered that a major hurdle to the research activities in this area was the issue of animal importation. With the current set up all small animals are sourced from abroad. This is expensive and has serious timing issues, forcing researchers to house animals ahead of time in holding areas that could be more effectively employed. As a result researchers are paying more than their European counterparts. The reviewers recommended that this issue be explored further, potentially with the involvement of a commercial partner. As Irish researchers increase the demand, a centralised national source would perhaps be a viable approach. Whilst it was stressed that certain specialised experiments be conducted at a local level, it was felt that certain services could be effectively run centrally. This might for example include routine breeding, backcrossing, cryopreservation (as an effective means to retaining genetically modified lines) and long-term housing.

Other Comments

Clinical Research

An issue highlighted by reviewers and researchers was the future trend in the advancement of translational research in Ireland. As the move toward clinical trials and clinical testing is encouraged and advanced, so too will the need for high-standard GLP animal facilities as the step prior to clinical research. This is in keeping with the move toward the commercialisation of research and the ability of researchers in Ireland to effectively translate research.

Regulatory Issues

Although somewhat removed from the remit of this visit, the reviewers noted that the regulatory system in Ireland needs to be addressed. Project and personal licences were reported to take up to twelve months in cases and this was considered excessive. It was admitted that this process was also now adapting to changes in the research system.

6. CLINICAL RESEARCH FACILITIES

Overall Observations

- Different clinical research facilities across Ireland need to adopt standard operating procedures and have similar effective management structures in order to maximise the co-ordination of research activities. Although steps have been taken towards the development of significant clinical research infrastructure, the reviewers felt that these steps had not yet been co-ordinated to a consistently high standard. The reviewers could not overstate the need for oversight in the development of this infrastructure in order to avoid the creation of under-used and over-specified facilities. A co-ordinated strategic approach with national equity is vital. Surveillance procedures should be put in place to ensure close adherence to this recommendation.
- Technical support does not currently meet requirements. There is a great need to increase core personnel to run the clinical research facilities (CRFs). Fostering of "institutional memory" is critical to success. Key functions include core management, research nursing, statistical and study design support.
- The establishment of a network of nurse managers will play an important part in the setting-up of new clinical research facilities. They should develop and sustain close links with the nurse manager network already established in the U.K..
- There is a need for dedicated resources for data acquisition, visualisation and analysis. National data archives (paper, electronic and biological) need to be stored in safe and secure environments.
- Appropriate national networks and core facilities need to establish a common information technology platform capable of providing comparable data sets across all facilities (which will also enable multi-centre trials), common regulatory and trial support, and a common GMP facility to support clinical research activities.
- The reviewers proposed that a balance at individual centres between disease specific approaches and methodological specialisation be struck. Certain core facilities should be centralised to reinforce the high quality of projects put forward. Requirements would depend upon research

approaches but examples of core facilities could include genotyping, GMP production, mass spectrometry, image analysis (different types could be located at prime sites) and physiological laboratories.

- New facilities need to be informed and educated by existing facilities to avoid any unnecessary duplication of efforts or resources. There should be a co-ordinated development of new facilities.
- The reviewers recommend that, unless already undertaken, a programme of formal visits to facilities in the U.K. (or elsewhere) be conducted by a dedicated team, representing clinical research facilities in Ireland, in order to learn from the experiences of others in establishing autonomous facilities that adhere to common procedures.

Summary of Findings

Building Condition and Space

Within the Dublin area, there are currently three CRFs, at various stages of development: fully operational, recently commissioned, and yet to be commissioned. In addition the reviewers were told of plans for an additional larger facility within Dublin, to be funded jointly by the Wellcome Trust and the Health Research Board (HRB). Outside of the greater Dublin area, there are currently no purpose-built CRFs although there are plans for the development of at least two additional facilities. The reviewers agreed that, if between four and six state-of-the-art facilities were to be run successfully in Ireland, then these should be run in parallel so as to guard against over-provision.

With respect to facilities in existence, it was concluded that building conditions were generally very good but that there were examples where space was not being used for the purpose originally intended. The layout of rooms should be optimal for the flow of operations and the tracking of a linear data trail. There was insufficient storage space and as a result data were being stored inappropriately; for example lead-lined laboratories (built for specialist applications) were, on one site, used to archive paper records.

Underpinning these observations was the reviewers' perception that the design of existing Irish CRFs had not been informed by a careful prior analysis of the structural and functional relationships within the proposed CRF.

There is a need to plan carefully in advance how research data gathered in the CRF is to be handled, checked and open to verification, perhaps for many years. In general, the reviewers concluded that data storage was insufficient at all sites. This is a critical constraint on the conduct of clinical trials (probably relevant to many other domains) for which there are strict regulatory requirements for data validation, storage and independent audit for up to fifteen years following acquisition. The reviewers advised that hard and soft copies of data should be stored in fire-proof, limited-access areas.
In addition the secure storage of biological materials must also be established with systems in place that provide clear records of who has obtained access to these, their subsequent actions, and of when specific samples are removed from storage (ideally employing bar code readers). It was acknowledged that, in certain cases, there were plans to introduce these systems.

The reviewers emphasised the importance of retaining patient/human subject written records of consent and records of the precise nature of use to which archived materials might be put. They also stressed that these records should be open to future inspection by ethics or research committees. Failure to facilitate this might, in later unspecified circumstances, preclude the full exploitation of archived materials.

In order to scale-up significant research activities at existing sites, a radical rethink of layout and room usage needs to be implemented. The reviewers did recognise the strength in maximising intellectual synergies by locating academic research adjacent to clinical research. However should space be a limiting factor, then priority should be assigned to activities that can *only* take place adjacent to the hospital, with lower priority given to activities that might, in optimum circumstances, be near to clinical facilities. Currently, the reviewers suggested that researchers were not yet in a position to exploit fully the fact that they were located close to a hospital, as the role of clinicians was often minimal. The CRF should provide an environment in which health professionals can be trained and

exposed to research.

On several sites the laboratories conducting basic research in hospitals were not fit for purpose and were in great need of redevelopment, in line with the development of a new CRF. Overall, laboratories based in the main body of hospitals visited were sub-optimal and in need of significant development. These researchers were, in the main, conducting research on samples obtained from in-patient studies.

Equipment

The availability of appropriate research equipment did not feature high on the wish-list of researchers. In general, where a CRF was operational, the appropriate equipment was available. Wet laboratories that were up and running and conducting basic research appeared to be well equipped (a detailed appraisal of each piece of equipment was not made by the reviewers). The lack of sufficient equipment funding for new facilities was raised.

The positioning of a research MRI scanner on a university campus as opposed to adjacent to a hospital was noted. The reviewers felt that for such a major investment, location was suboptimal and may compromise research applications, owing to the lack of nearby clinical capabilities. Whilst not necessarily a current issue, this factor would need to be considered as research progresses in specific clinical areas. It was acknowledged that plans were in place for an additional research scanner on hospital grounds.

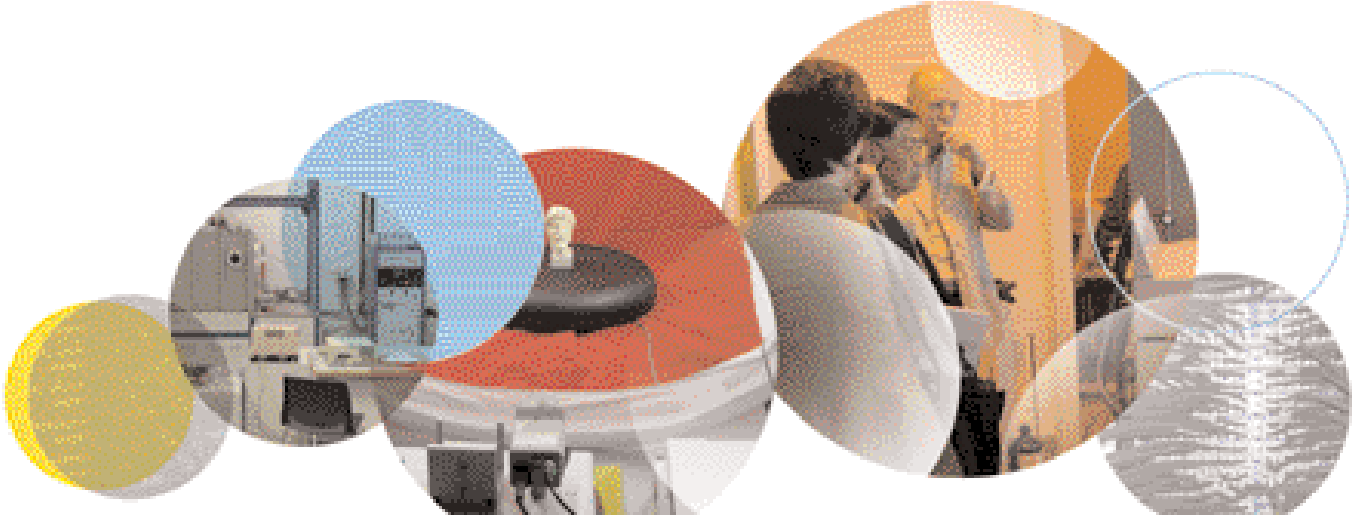
Where specialised equipment (e.g. the aforementioned experimental MRI) has the potential for national use it was anticipated by the reviewers that such equipment carried a significant risk of running at a loss. It would be important (and perhaps critical to research planning) that costing needed to be carefully reviewed going forward. Where activities are distant from the local CRF, there should be strong links with the CRF with adherence to standard operating procedures that are open to audit (research governance). In addition, compatible set-up and software should be employed at all sites if the full potential of the research equipment is to be realised.

Foundation Infrastructure: Data Management

Data management is an enormous, recurring issue discussed on all sites. It is imperative that a source of funding for this type of infrastructure is continued and developed further.

Data acquisition and storage requires robust IT systems that are universal across the country. Data storage for hard-copy and electronic documents needs to be safe and secure. Data storage for biological materials also needs to be properly resourced and aligned with standard operating procedures that are the same in every CRF. A common approach would enhance collaboration and facilitate data sharing in a efficient and productive manner. This is critical if Ireland is to compete internationally. The possibility of having a core facility to fully integrate the IT requirements of each CRF was proposed. It should be possible to have shared data acquisition from local sites with a common facility for data mining and data analysis. This would be very attractive to potential research partners in translational research who see this level of organisation on a national scale as a strong indicator of the potential for rapid results from an efficient and productive research collaboration.

Centralised off-site archive facilities for both clinical research paperwork and the storage of biological samples should also be considered. Storage was identified as an unsolved problem at all sites visited.



Basic IT systems currently in place within the hospital (clinical) infrastructure were recognised to be a barrier to progress in linking clinical (especially outcome) data to research laboratory findings. Links with academic institutions were cumbersome and in need of updating. Scope was identified from knowledge of data mining strategies under development elsewhere for Ireland to contribute to and learn from these innovations in complex data analysis. The existence of productive international collaborations of this type would be a huge potential long-term asset.

Technical Support and other personnel

An investment in core staff in existing and future facilities is critical. Personnel required include clinical facility directors, research nurses, statisticians and clinical trial support staff. The role of nurses in the day-to-day running of the CRF was felt by the reviewers to be a critical and integral prerequisite of success. Investment in their selection, training and retention would be paramount. Core staff are essential for the maintenance of the "institutional memory" that ensures continuity of services. Reviewers were informed of training provided by the RCSI for the training of research nurses and this approach should, in their view, be encouraged and enhanced. The reviewers were informed that the lack of a career path for research nurses in clinical research meant that they were difficult to retain in hospital-based research.

Support staff are needed to assist researchers in the design and implementation of clinical tests and clinical trials. Currently this expertise lies with individual researchers and may not be an efficient process. The lack of such core support staff may prevent clinical researchers from partaking in research. Given the limited time that physicians can currently give to research, it was recommended that investment be made in support systems designed to facilitate the smooth running of the CRF with clear, comprehensible and universal operating procedures.

Clinical Scientists

The reviewers agreed that there was no shortage of "brain power" to run CRFs in Ireland and to conduct world-class research. Whilst the focus of this exercise was to review the facilities and tools available to perform "cutting-edge" research, the reviewers also felt strongly the need to comment on broader policy issues that may be barriers to advancement in this area. These issues will, therefore, also be summarised.

On all sites the reviewers lamented the universal lack of protected research time for clinical scientists; they strongly recommended that (1) this is a major barrier to the advancement of clinical research and to the forging of links between academia and clinical practice and (2) that it is not an option for the present lack of research time to continue if Irish aspirations to become "internationally competitive" are to be realised. The introduction of funding for clinical scientists by the Health Research Board was seen as a move in the right direction, but so far insufficient to meet the national need. Translational medicine is patient-led with clinician and hospital involvement vital for success.

The reviewers felt that current Irish medical employment practices make success unlikely in

the face of intense competing, clinical pressures. Health services will not volunteer to do research unless incentives are available. The introduction of an incentive scheme was suggested. Such incentives currently exist elsewhere, where there is slight extra ("ring-fenced /seed corn") funding for a hospital conducting research with much greater rewards for peer-reviewed publications and external research funds awarded through competitive processes to hospitals. Eventually, if financial rewards were sufficient, hospitals might regard such funding schemes as highly prestigious, enhancing the standing of their senior medical personnel both in the local and wider community. In turn, they might then be encouraged to make specific appointments designed to improve both their clinical effectiveness and research performance, analogous to the set up in Irish university-based research.

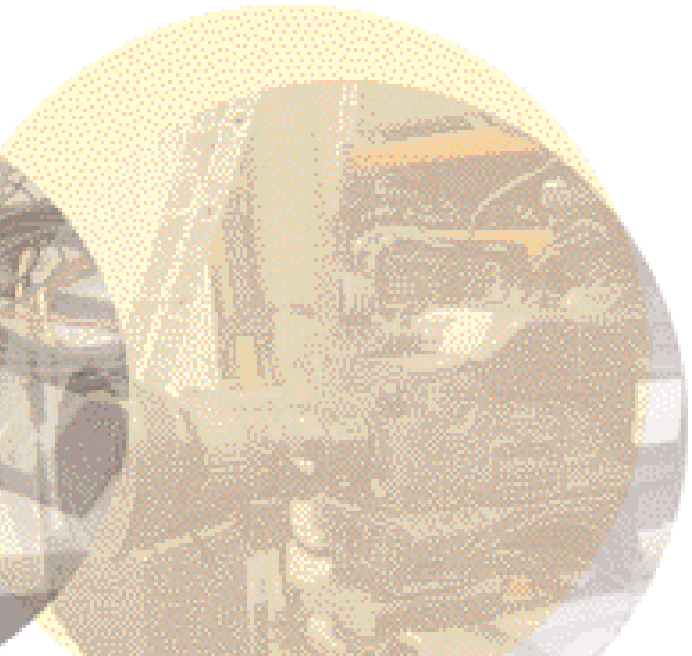
Other Comments

Strategic national approach

The reviewers felt strongly that in a country the size of Ireland, it is of paramount importance that an organised and co-ordinated approach is taken to the running of each CRF. The reviewers were informed during the visit of the recently formed ICRIN (Irish Clinical Research Infrastructure Network) and of the role of the Dublin Molecular Medicine Centre in both the acquisition of the new Dublin facility and the co-ordination of other Dublin facilities. The expansion of this clinical research network to include other partners, namely UCC and NUIG was mentioned, as was the future membership in the European counterpart (ECRIN). However the reviewers felt that a co-ordinated approach had not been taken to date and, from speaking with researchers at individual sites, that a national strategy and approach was not yet evident, although it is acknowledged that progress is being made in this regard.

Funding

The researchers found that the funding stream for clinical research was not clearly defined and open to public scrutiny, apart from the HRB, and that this did not assist researchers to plan for future activities. Much of the recurrent funds were from an array of charities and infrastructure funding was also from several sources. Whilst this is not considerably different from other discipline areas, it was felt by the reviewers that to compete successfully in this area that (1) complete transparency of all sources of funds available was essential and (2) translational research needs to be funded in its own right.



7. COMPUTER SCIENCES

Overall Observations

- The space allocation model used is out-dated; it may be time to reassess needs across institutions. The challenge seems to be the provision of quality, fit-for-purpose, dynamic and community-enhancing space. Overall, specific staff (or a staff member) to manage resources and space at faculty level would be beneficial as the high-level model currently in use does not seem to work in some institutions visited.
- Current support infrastructure is inadequate to sustain first-class research in a newly developing system. Technical, and to a greater extent, administrative support is urgently required. Lack of support leads to senior researchers having to carry out administrative or technical support activities. This deflects researchers away from their core work, an obvious waste of a valuable resource.
- Clear and strategic choices need to be made. A wide range of space-intensive 'Nano' projects seem to be underway at a number of institutions. Ireland will need to consider the value of this work and avoid duplication across the sector through the encouragement of a collaborative approach.
- Research activity in the Institute of Technology sector has been limited in the past due to the sector's remit in undergraduate training and the lack of funding ear-marked specifically for research activity.
- Research resources in the form of physical library provision and the extension of the IReL electronic journal resource are necessary, the latter being a particular requirement of the Institute of Technology sector. A national approach to the development of an electronic depository for theses was also cited as a useful infrastructural project.
- Provision of software was well regarded. HEAnet service provision was also positively reviewed. However upgraded or more reliable video-conferencing facilities were required as was further development of the fibre network.
- An approach to the provision of national and indeed international access through the development of innovative middle-ware systems for user authentication on a national platform would significantly improve researcher mobility.
- Any new investment for major infrastructure or research programmes should be provided through a competitive process. Large-scale investment cannot commence in advance of the innovative ideas that need to emerge.
- High-Performance Computing and Grid Computing are in development. Some fears were expressed that this Grid Computing technology was being promoted as a local resource in a number of locations while the research projects requiring its use were not yet clearly articulated by the computer science communities driving it. Consideration should be given to offering external access to promote practical application of the technology. HPC should also be shared, usage levels did not seem optimal and a review to ascertain strategic application could be required. However additional resources to support this national provision of facilities may be required.
- Dublin institutions had suitable physical infrastructure for postgraduate research and the opportunity to engage in world-class work. Researchers in the Institute of Technology sector on the other hand were constrained by the sector's roots in the postgraduate training model with a primary focus on its teaching mission. World-class research was not a realistic possibility without the investment to drive it. The PRTLI seemed to offer a model for this type of support as large-scale investment cannot commence in advance of the innovative ideas that need to emerge.
- A national debate on standards is required in order to encourage a collaborative approach to research projects.

Summary of Findings

Building Condition and Space

The institutions visited offered something of a range of quality both within and across institutions. In some locations the space and physical setup was good and encouraged multi-user application but management issues stiffed true collaboration. Overall better cognisance should be taken of stakeholder needs in the planning and designing phases. Facilities need to be viewed as a 'facilitators of research' not just as physical objects.

In one case the quality of space was generally very good and fit-for-purpose but insufficient in quantity. In other cases the space was very poor, bordering on the dangerous, certainly no longer adequate. A clear (if obvious) correlation was displayed between prior investments (under the PRTLI for example) and the quality of space provision.

Specific buildings visited had good space provision but as they were originally intended for undergraduate or multi-purpose use they were therefore unsuitable for use in the creation of an atmosphere for multi-disciplinary research and the exchange of ideas. This was also reflected in the lack of meeting and demonstration space and widely distributed nature of facilities for researchers.

A wide range of space intensive 'Nano' projects seem to be underway at a number of institutions. Overall these projects are rather small-scale and the achievement of the critical mass required for their success may be a significant challenge. Ireland will need to consider the value of this work and avoid duplication across the sector through the encouragement of a collaborative approach.

Equipment

Maintenance at a significant level is required to keep equipment up-to-date. Good equipment today may not meet the needs of tomorrow and the block grant and core funding model may not be sufficient. This investment is incremental but necessary.

Equipment viewed was generally adequate to good, but it is difficult to appraise across the board. The physical environment was poor in places with a need for basics such as air-conditioning and a better approach to management of the space and physical environment. In other locations there were good examples of laboratories but these were configured for teaching and undergraduate use rather than as a research environment.

Overall, specific staff (or a staff member) to manage resources and space at faculty level would be beneficial as the high-level model currently in use does not work.

Foundation Infrastructure

The foundation infrastructure is considered to be inadequate. One of the main strengths in the university sector is the e-journal access and this should be extended to the IoTs but there are many weaknesses such as:

- Poor high-powered computing capability
- Poor maintenance of existing computing capability
- No wireless internet access
- Broadband is only at 10mg locally

Technical Support

Technical support was patchy to non-existent in some places while in others only just appropriate. Staff training levels were also an issue as projects depended on particular levels of support service. In many cases postgraduate or postdoctoral researchers serviced their own equipment; overall this was deemed inappropriate as it distracted researchers from the research work.
Current support infrastructure is therefore inadequate to sustain first-class research in a newly developing system. Technical, and to a greater extent, administrative support is urgently required. Lack of support also leads to senior researchers having to carry out administrative or technical support activities. This deflects researchers away from their core work, an obvious waste of a valuable resource.
Technical support provision was also largely driven by the demands of teaching—perhaps a review of the balance between teaching and research is needed.

Management

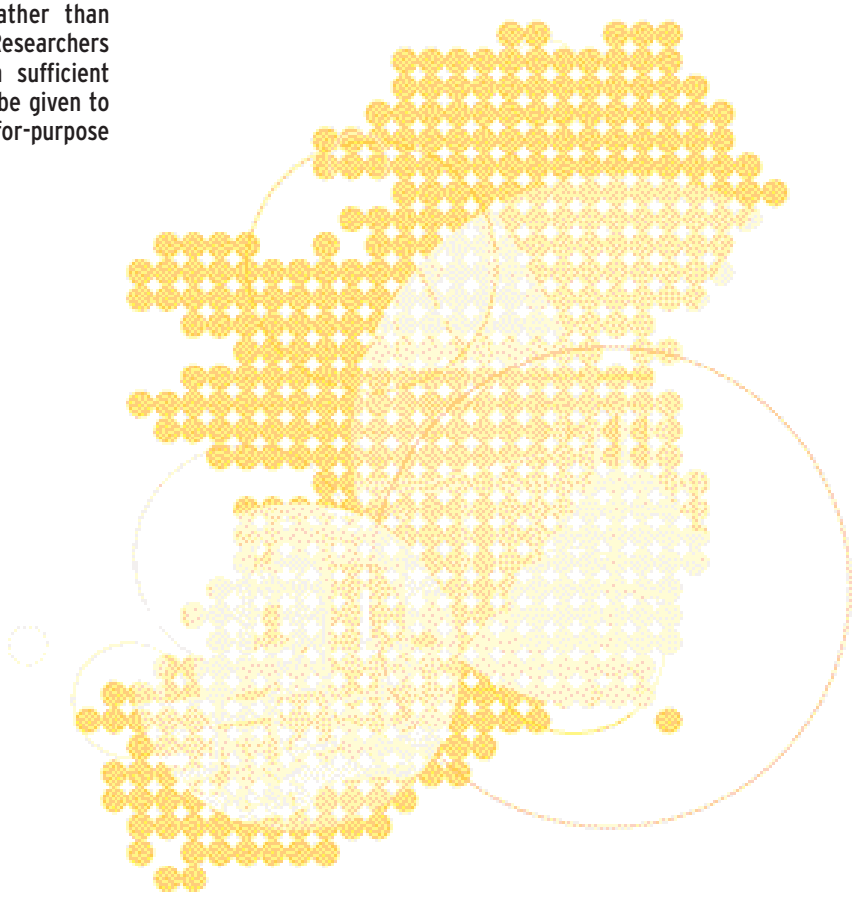
It seemed clear that in places the physical facilities were better than the management structure. Management structure rather than investment was therefore required. Researchers and desks alone will not provide a sufficient catalyst. Consideration also needs to be given to materials and design to encourage fit-for-purpose environments.

Access to large scale or multi-user facilities

In some cases there were particular infrastructural facilities that should be made nationally available through broader access policies. It may require a change of mind-set to realise that the facility is unique and can also be recognised as a service that can be provided to others in the form of a national facility. However additional resources to support this national provision of facilities may be required.

Site layout and accessibility

In general sites were not capable of supporting world-class research because the buildings are disjointed and existing across multiple sites. More importantly there does not appear to be buy-in from all the participants in many faculties, departments and centres.



8. EARTH, ATMOSPHERIC, AND OCEAN SCIENCES

Overall Observations

- The condition of basic facilities varies from very poor to very good (in the case of a small number of relatively new buildings).
- Equipment is for the most part obsolete. Even recently acquired items (usually 3 to 4 years' old) are often in jeopardy because of (i) lack of regular maintenance, (ii) lack of technical support to operate and maintain the equipment and to train users, (iii) absence of an equipment replacement budget to upgrade equipment on a regular basis
- There is a need to introduce a mechanism to provide research groups with highly qualified Technical Officers to operate and maintain specialised equipment and to train students in their use.
- Geology research (and teaching) is particularly badly served in relation to buildings and equipment. As a foundation science, it should have much better facilities.
- A mixture of old and some new buildings means that departments and activities are fragmented between locations, making research difficult.

The potential for developing Galway and the western seaboard as a leading centre in the area of marine and environmental sciences was emphasised.

Summary of Findings

Building Condition and Space

It is a very mixed picture, ranging from totally unsuitable (geology) to over-crowded to modern and good quality. There is a serious space utilisation issue in relation to one unoccupied facility and with under-utilisation evident in other areas.

Equipment

The main problem with equipment is not the lack of any specific instruments but the overall impression of seriously dated or obsolete equipment due to the absence of funds for renewal and replacement. Geology lacks even the most basic equipment. Otherwise the equipment seen is at best adequate, with very little that would be classed as cutting-edge.
One item of equipment lacking is an Aerosol Mass Spectrometer, which most international environmental groups would have, but of which there is none in Ireland.
The absence of funding for maintenance contracts not only shortens the life of equipment but can lead to extended downtimes when a fault occurs.

Foundation Infrastructure

No serious issues identified. This could be because other infrastructural problems (buildings, equipment, technical support) are the major concerns at this stage.

Technical Support

The absence of suitably qualified (often at Ph.D. level) technical support is one of the most important issues identified. Modern scientific equipment is highly specialised and sophisticated; it can take considerable time to learn to operate it efficiently and safely. Not only can such technicians ensure that equipment is operated and used properly, helping to train students on how to use it, but they also help to prolong the life of the equipment by ensuring proper maintenance. Such technicians are needed on a full-time basis for this work.

Management

There is not sufficient management support available to researchers, both at local level and centrally. Issues such as strategic planning, space utilisation and coordination of resources and effort are areas which could be improved. The overall impression is of good and enthusiastic people whose performance is limited by inadequate equipment, space problems and proper planning.

Access to large scale or multi-user facilities

No major issues. Researchers have access to two excellent and modern research vessels.

Site layout and accessibility

Some of the facilities are capable of supporting interdisciplinary work. But fragmentation of people and equipment is a problem in other areas. In general, not much evidence of such interaction was found. Not all of this is the fault of the site design and layout.

Other Comments

At the moment this field of research is not operating in Ireland at leading international levels. The reasons for this are infrastructure, management and personnel related, and are interlinked. Major infrastructural problems inhibit the ability to do research, and are a disincentive to hiring and keeping good researchers. Stronger management planning and guidance will be needed to identify and exploit the right research opportunities.

The already existing network of facilities in the Galway and Connemara areas in marine and environmental sciences offers a good opportunity for building world-class expertise in marine science, climate change and biodiversity.
Ireland is too small to have multiple well-resourced centres in these sciences. The national authorities need to take hard decisions on priorities and locations for funding, and to follow through with continuing support thereafter. Building on existing strengths and potential should be the priority.

9. ENGINEERING

Overall Observations

- Overcrowding of facilities is evident and is forcing research activities to become fragmented and disparate.
- There should be a rolling programme of investment in research active space with good facilities management.
- There should be funding sources for facility and equipment maintenance
- Dedicated permanently-funded research technicians are required across the engineering sector
- There are many health and safety issues which need to be addressed as a priority.

Summary of Findings

Building Condition and Space

Of the buildings visited the majority were of an adequate standard but overall were no longer fit-for-purpose, principally because of insufficient space to properly house research activities. In many cases, there is no room for expansion and research sites have become fragmented. In some cases, in an effort to meet needs, relocation of research activities has resulted in poor and inappropriate usage of the space with certain research groups located on three or four floors or in separate buildings. There were examples where meeting rooms had been taken over for research work space and often there was no social space. Integration into a single custom-built facility would contribute significantly to the research potential.

Overall, there is a need for a review of space usage and allocation at a local level in order to keep currently disparate research groups in one location. Additional space is needed for postgraduates and administration and other services should also be located close by.

Additional investment is needed in basic services, including air conditioning, gases and power through either block or overhead grants. The 30% overhead rate quoted to reviewers was considered to be inconsistent with international norms. In the U.K. the 46% rate has been increased to virtually 100% through full-economic costing and in industry it is often over 100%.

Equipment

While equipment varied from state-of-the-art to obsolete, overall it was considered to be adequate for current use but insufficient for future requirements and unlikely to enable competitive research on an international level. A greater issue was the housing of expensive equipment in inappropriate space.

The reviewers considered it important for researchers to build the cost of maintenance of their equipment into their project proposals. If this was not possible in the current funding system, the funding bodies must consider changing the system.

The reviewers recommended a strategic review of national capability in a number of disciplines such as electron optics / microscopy to increase synergies and reduce duplication of expensive resources. Funding for access to specialised facilities should be considered.

Foundation Infrastructure

In the majority of facilities the foundation infrastructure was considered adequate although there were some cases where high-performance capabilities were required.

Technical Support

Technical support was considered to be poor. There is a real need for dedicated research technicians across the engineering sector as opposed to secondment of teaching technicians. There should be investment in technical support for equipment operation, maintenance, safety and training. A small amount of equipment requires technical support from people at Ph.D. level. Currently equipment is (at best) operated and maintained by postgraduate students with their knowledge and expertise lost as they complete their studies and leave. At worst there is no control over the use of equipment leading to questionable research outputs, poor use of infrastructure and safety concerns.

Management

At a local level, the management support for research was variable and individuals were dealing well with the limitations of their site. In other areas the local management is under-resourced and needs to be underpinned by clear institutional strategy.

Access to large scale or multi-user facilities

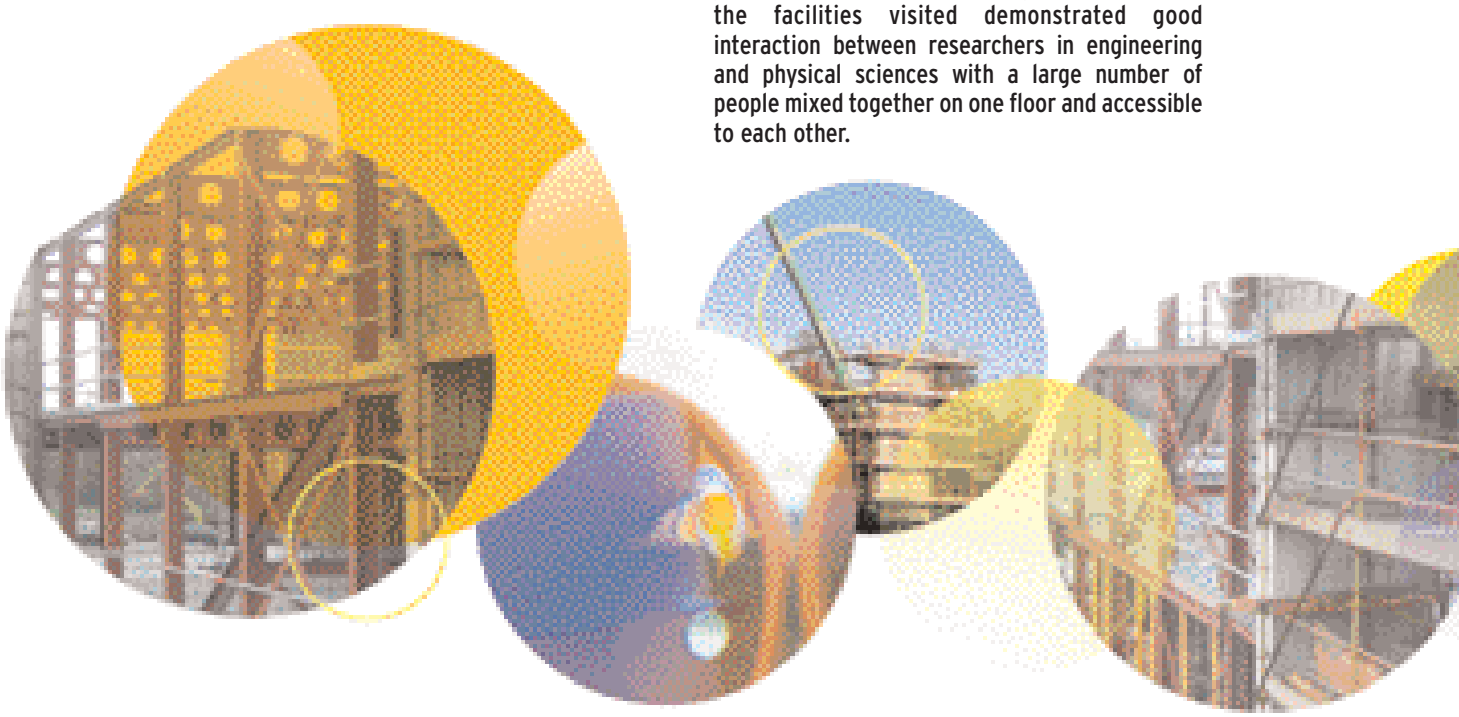
Access to international facilities should be available through a funded access programme at national level to complement that available via the EU's large scale facilities programme.

Nationally, consideration should be given to building a dedicated Irish beam line on one or more key facilities (e.g. DIAMOND). Such lines are also of industrial relevance and could be built with industrial, as well as state, support. This is the approach taken by other smaller countries such as New Zealand, Australia and The Netherlands where provision of national facilities is not feasible.

Consideration should be given to the purchase of a FEG-TEM, FEG–SEM and ESEM provided money is also available for technical support, maintenance and additional supporting facilities. These facilities should be shared with other institutions through a well-managed national access programme which would serve to link Irish scientists to international researchers.

Site layout and accessibility

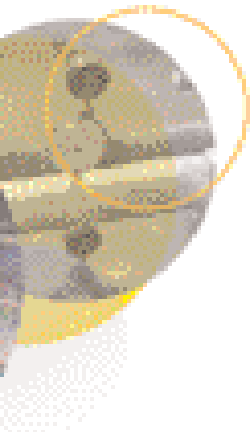
Some groups do undertake multi-disciplinary work but this appears more the exception than the norm. There is scope to use equipment to greater effect by extending collaborations between groups and institutions and access routes with appropriate charging mechanisms might need to be developed. In many of the groups in engineering there is insufficient critical mass for a wide range of researcher interactions to take place. There are however exceptions and one of the facilities visited demonstrated good interaction between researchers in engineering and physical sciences with a large number of people mixed together on one floor and accessible to each other.



Other Comments

Health and Safety

Investment is needed to ensure the safety of researchers and students. Electronic systems should be installed with swipe in for access to buildings on a safe and recorded 24-hour basis with CCTV. Where they are working at night, two people should be present. Overall, there appears to be a complete lack of an appropriate safety culture. Risk assessments are needed and must be posted in the labs (which are often cluttered therefore posing potential for hazard). Personal protective equipment should be available and routinely used with special consideration given to biological hazards and the facilities needed in such areas. Visitors should be briefed on safety as a matter of routine. Overall, training and structural issues related to safety matters must be embedded in the research culture and form an integral part of facilities management and development.



10. PHYSICAL SCIENCES AND MATHEMATICS

Overall Observations

- The state of buildings is quite variable, from very new and state-of-the-art to adequate and some completely unfit for purpose.
- Space shortages and overcrowding, in new buildings as well as old, call into question the feasibility of doubling Ph.D. output within 7 years. Overcrowding is evident equally in leading research centres and this is a barrier to the attraction of international researchers.
- A lot of the equipment seen is old or on the point of obsolescence. Reviewers recommended the introduction of a mechanism for providing continuous access to funds to renew and replace equipment.
- The lack of adequate numbers of highly qualified technicians to operate and maintain sophisticated equipment and research laboratories, and to train students in their use, is a major impediment to good research and training. Reviewers recommended the creation of new positions of technicians, with advanced qualifications often to Ph.D. level. These positions need to be permanent so that continuity and know-how is created and maintained.
- Enhancement of administrative support for researchers is required.
- It should be ensured that future investment builds on the excellent research groups and facilities now in place so as to maximise existing infrastructure.

Summary of Findings

Building Condition and Space

Accommodation conditions vary from poor to very good, with many buildings operating at the limit of their capacity or beyond. There is little room for expansion in any buildings seen. Many activities are spread between buildings and fragmentation of research groups is again occurring, even in some of the excellent new buildings.

Equipment

Much of the equipment seen is adequate but a lot is becoming dated and some is obsolete. For example, the chemistry department on one site visited has only one mass spectrometer which is six years old. There appears to be a problem with maintenance budgets, and many pieces of equipment do not have service contracts. The absence of funding for maintenance contracts not only shortens the life of equipment but can lead to extended downtimes when a fault occurs. Research groups and departments need access to a regular source of funds for equipment renewal and replacement.

Foundation Infrastructure

The situation in Ireland for access to high performance computing is not considered satisfactory to support this discipline area.

Technical Support

The shortage, or complete absence in some cases, of highly qualified technical support to operate and maintain sophisticated equipment and research laboratories is a major weakness in the system. In their absence this function is usually assumed on a part-time basis by a Ph.D. student. This is unsatisfactory and inefficient, and means that equipment and laboratories are used less effectively than they should be and that expensive equipment is not always properly maintained.

Management

Most sites visited did not appear to have administrative support for developing research proposals or for writing regular reports on the progress of on-going projects. In some cases adequate strategic planning and intellectual drive for the research activities was missing.

Site layout and accessibility

Many research groups are aware of the advantages of interdisciplinary research and of the role of physical proximity in encouraging it. This was particularly observed in the two institutions visited. However the overcrowding in many sites is an obstacle to achieving this.

Other Comments

In some sites the infrastructural barriers to top-class research were outweighed by other issues (e.g. gaps in funding, five-year programmes, ability to retain staff). But most sites, with the infrastructural problems already identified, will find it difficult to conduct leading research and to attract top researchers. On the other hand, if these problems are remedied, there is the potential to generate first-class research in a number of areas.
Future investment should concentrate on building on those research facilities and teams which are now in place, addressing the infrastructural issues identified, to move Ireland up to the next level in research.

> CONTRIBUTION FROM THE BUSINESS SECTOR

1. INTRODUCTION

As part of the process of canvassing the views of key stakeholders about investment in research infrastructure, Forfás commissioned the CIRCA Group Europe to undertake a survey of industry. The survey took place during September and October 2006. Although the scope of the survey was limited by the overall time pressures of the review, the findings appear to present a coherent and consistent view which it is unlikely would be radically different from those of a more comprehensive study.

The survey consisted of:

- Telephone interviews with eighteen senior executives in major multinational corporations with bases in Ireland and in selected indigenous small and medium enterprises
- Discussions with over fifty industrialists attending a half-day forum on 13 October 2006, held to review and extend the findings from the interviews.

This section presents a summary of the findings from the CIRCA study. The full report is available on the Forfás website.

2. OVERVIEW OF FINDINGS

There was general consensus that industry welcomes the opportunity to engage with the HEA directly, to contribute to the development of their strategy and to build upon the strong sense of collaboration most sectors feel with the higher-education institutions.

In the time available companies found it difficult to provide detailed responses under the various research infrastructure headings. Industry would welcome on-going consultation in future, in order to build up a fully reasoned and articulate analysis of requirements. However it should be noted that many companies are entirely unaware of the facilities which exist within the HE system and that there is a need for a major rethink of policies and programmes to develop HE/industry cooperation.

As national research policy has increasingly focused on the higher-education sector as the major driver of public-sector research, rather than other state or independent locations, there is an increasing need to develop a higher-education research infrastructure which is open to industrial collaboration and is, to some extent at least, aligned with industrial development needs. Industry has very few other options to turn to, within Ireland, for assistance with technological problems.

There was also agreement that Ireland is facing major challenges as its cost base rises and other lower cost, high-quality locations develop—China and Eastern Europe for manufacturing, and East-Asia and Eastern Europe for software. Recognition is now universal that we need to move to higher added-value activities, R&D in particular, if industry is to survive and develop here. Achieving this goal will only be possible if the major players in the Irish R&D system—the higher-education institutions and industry—are encouraged and enabled to work much more closely together.

The views from industry were wide-ranging and covered a number of issues relating to research besides infrastructure. In particular, it is the overall research capability in the HE sector which is of critical importance to industry. In section 3 below the views expressed on research infrastructure are summarised, while section 4 deals briefly with some of the wider issues raised.

3. INFRASTRUCTURE REQUIREMENTS

General Comments

- Investing in research infrastructure is not only investing in overall research priorities, it is also investing in ways in which funded buildings or equipment will be used: who will use them, under what conditions and for what purposes. If we are to develop a coherent research infrastructure which will contribute both to world-class academic research and to industrial development, it is essential that from the very beginning, we set up research infrastructure under the most appropriate governance model. This model must seek to avoid the traditional difficulties of higher-education / industry cooperation.

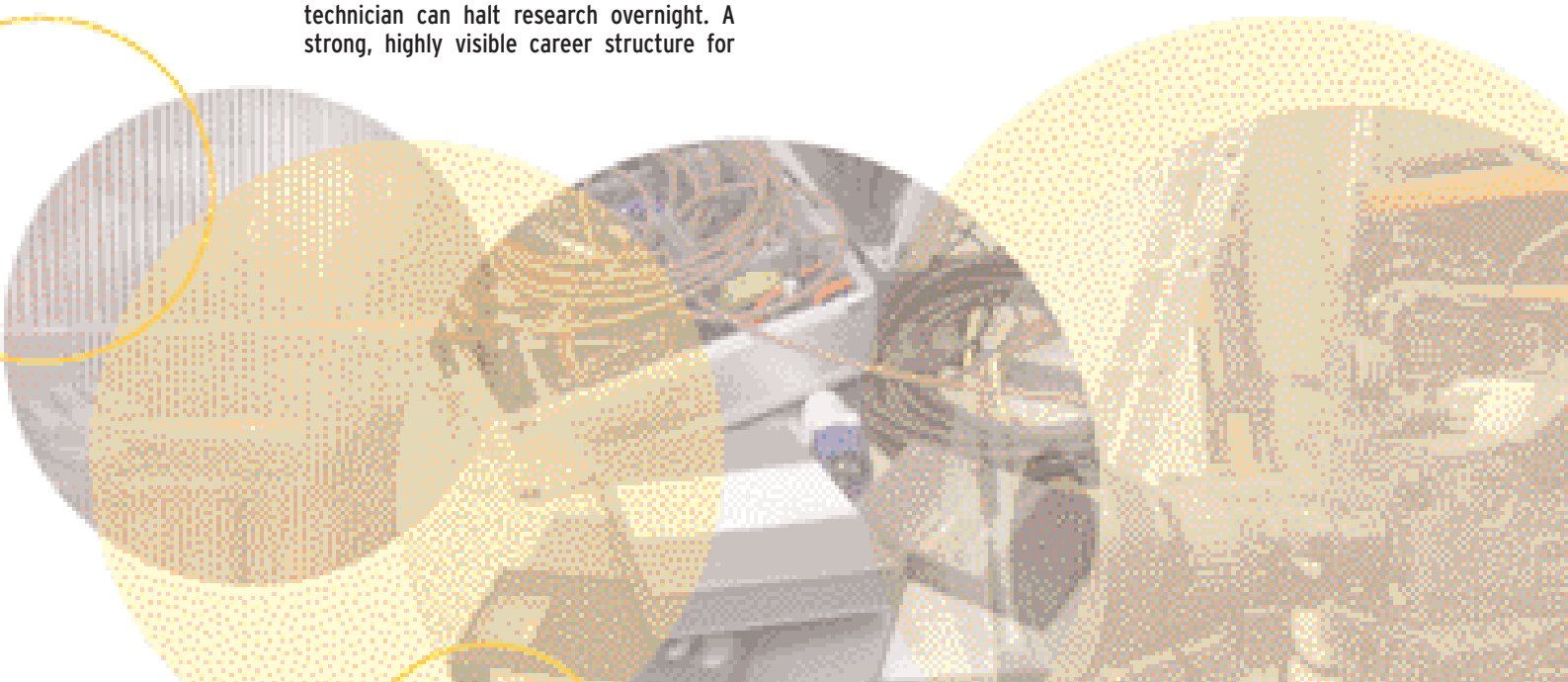
- Government, higher-education institutions and industry should jointly develop a number of new approaches to the accommodation requirements of research infrastructure. For example, there should be increased co-location of university and industry research activities; developing new joint industry-academic research locations, preferably close to relevant industrial clusters. The accommodation and space shortages on some campuses could be an incentive to develop new campuses with industry involvement.

- There is currently no career structure for operatives of vital equipment in many HE facilities and consequently there is a high turnover of these staff. Especially in universities, the loss of an experienced technician can halt research overnight. A strong, highly visible career structure for research technicians is seen as an important element in overcoming such difficulties.

- Any piece of capital equipment must come with a running cost budget. Without such a budget the chances of it being used efficiently will be low.

- Research into medical devices and products (a major industry sector in Ireland) is hampered by the low involvement of medical doctors and hospitals in research, in contrast with other developed economies. Hospitals must be developed as an explicit part of the research infrastructure.

- Access to large-scale international research facilities—most obviously in areas such as engineering test-beds and the use of synchrotron beam-time—can be problematic for some companies. A joint industry-university approach to joining and utilising such facilities was proposed.



Specific Requirements

The table below presents a synopsis of the specific research infrastructure requirements of each of the major research-performing industrial sectors.

Sector	Industry Requirements
ICT–Software	• Major Test-Bed facilities for both testing software and for allied research. • Training facilities for high-skilled programmers in multi-core, parallel and GRIDS environments. • Duplication of Cork's National Software Centre in other cities
ICT–Hardware	• Advanced facility for manufacture at "nano" level • Advanced facility for manufacture at "micro" level
Pharmaceuticals	• Greater focus on post-discovery phase research infrastructure: formulation, manufacturability, etc. (including chemistry). • Better GLP/GMP facilities • Develop critical mass • Need multi-disciplinary input
Instruments & medical devices	• Clinical Research Centre / Hospital Infrastructure for device trials. • Pre-Clinical Animal Testing Facilities / Cadaver Facilities • Bioinformatics • Gene Bank / BioBanks • Biomaterials • Technology platforms • Research collaboration with other sectors such as wireless and ICT
Food and drink	• Food packaging / new materials research centre • Food flavours / organic chemistry research centre • Food processing engineering facilities • Seafood research centre • World class Centres of excellence
Machinery and equipment	• An advanced facility for engineering manufacture. • High Temperature coating facilities • A facility for electrochromic technology
Energy, Environment & Transport	This is an area which has not been covered but deserves formal recognition in the consultation process and in considering industry's research requirements. Much of the benefits of energy, environment and transport research will accrue to companies in other sectors which implement the findings of the R&D. As such there is need for a broad based industry consultation process, including firms from this sector, but with a much stronger user representation. A recent CIRCA survey of VC companies in one of these sectors shows relatively little or no new-company activity.
Services / Financial Services	• Development of an International Centre for Research in Financial Services • A strong demarcating and strengthening of the opportunities for research support for financial services within the existing system.

4. OTHER INDUSTRY COMMENTS

Facilitating Industry–HE Co-operation

- The time period required for companies to realise a net return on their time, money and effort in university cooperation is long. The 3-year research project is seen by some as a poor basis for working with universities (and retaining good researchers). Examination of a 5 or 7-year 'research programme' model should be undertaken.

- Further, the traditional, incremental step-by-step approach to cooperation with universities is coming to be seen, by some, as inadequate in the current global R&D environment. There was a need to develop R&D mechanisms that will support major companies entering quickly into long term, intense, cooperative relationships with specialist university groups. This quantum jump in the potential duration and size of cooperative partnerships needs to be recognised by government and supported.

- There is a major need for government R&D programmes which support the integration of university and industry research. The programmes of the National Institutes of Health and the Small Business Innovation Research (SBIR) programme in the U.S. are good examples of what can be achieved.

- Current 'Industrial Parks' should be designated 'Science & Technology Parks' and upgraded. The regional development dimension of industrial parks should be reinforced in the new science parks. In an approach somewhat in line with the Credit Unions, local government, industry and communities should contribute to and be given a stake in the Science Parks. The overall vision is that "research is carried out to create value for all the stakeholders"—not just for the academic community. The business plans of those seeking research investment should reflect this joint community approach.

This said, it was recognised that the Science Parks must be become specialised. They must avoid the current criticism of universities in which there is a failure to prioritise research areas—and a tendency that everyone tries to do everything.

Prioritising Investment

Given that there will be far greater demand for investment than the funds available, the criteria for selection of projects / infrastructure will be of major importance. Here there was strong agreement on the factors which should be decisive.

- *A world-class researcher / research team.* MNCs have a global reach in terms of collaborating with university research. For most, researchers in Cambridge or Toronto are as accessible as those in Cork. Equally, whether the research is in quantum bits or food flavours, basic or applied research—'world-class' is what companies seek. Given the presence of world-leading MNCs in Ireland, parallel world-leading research should be built up. Here obtaining the right individuals to run the research is more important than the actual infrastructure itself. The performance track record of the individual seeking the infrastructural investment—and his/her history of working with industry—will be central. Specific points raised include:

    - The principal researcher or research group should have a good track record in making a return on previous investment — whether through collaboration, spinning-off companies or IPR activities.

    - Applications from a joint university / industry (or industry federation) partnership should be given special consideration. However the use of industry as a "fig leaf" by universities must be guarded against. Where proposed facilities make claims of relevance to industry groups or sectors, the target industries must be explicitly involved in assessing the relevance of the investment. Further, where large capital investment is to be made, industry representatives should be

involved in assessing the suitability of the equipment and its layout to the intended research.

- *Critical Mass:* Achieving critical mass is important, though it will vary depending on the area of research. There are too many sub-critical research activities currently supported in Ireland. While some progress has been made, there is still far too much unnecessary duplication.

- *Specialisation:* Related to the above point, Ireland cannot be world-class in all areas of research and there is a need to specialise in certain topics in which Irish researchers can reasonably develop world-class competence and which are also likely to be of economic relevance to Ireland.

- *The development of a Medical Devices "Knowledge Triangle":* possibly the most striking deficit in the medical devices' longer-term research infrastructure in Ireland are structures which bring clinicians, industry and universities together to consider and act on research needs. Critical to this will be the development of hospitals—and medical doctors—as an explicit part of research infrastructure.

- The creation of *long-term desirable careers* and career structures for those working in the research sector. Currently career options for those working in university research are weak. Again the development of new models of university-industry research governance could make a major contribution to developing career structures.

Software Research

In considering investment, it is critical that the very particular nature of software research infrastructure is recognised:

- Outside a small number of areas, such as test-beds and grids, the traditional modes of high investment in capital equipment are not that relevant.
- In addition, the major role of the software industry in convergent technologies and in sectors (finance, logistics, etc.) outside the traditional core software sectors should be taken into account.

Software research infrastructure is focused on people, space and their interactions and in creating what some have called a "research and innovation ecology":

- In terms of people, there is a need for facilities which will permit major training and updating of large number of software personnel who will undertake research / development work in the core software industries and the major software user industries: banking, manufacturing, etc.

- In terms of space, there is need for a number of large, serviced and flexible spaces around the country in which university research, development and specialist users can come together to develop an *innovation ecology*. The co-location of industry and university researchers is critical for developing cutting-edge research, if the research is to have a chance of being commercialised. Software has a half-life of probably five or six months, so that by the time it overcomes the barriers to exit from a university and has become 'industrially hardened', it stands little chance of commercial success.

DATA AND INFORMATION ON EXISTING INFRASTRUCTURE

Associated with this review, the HEA initiated a study to establish the status of the existing research infrastructure within the higher-education system. The study consisted of a survey designed to establish a Capital Research Infrastructure Database. A comprehensive set of survey documentation was issued to 24 higher-education institutions; of these, 24 institutions (7 Universities, 14 Institutes of Technology, and 3 other higher-education institutions) completed and returned the survey documentation to the HEA. This database served as a key resource for informing the 2006 Research Infrastructure Review.

Categorisation of research space is represented in the pie chart below. This chart represents an approximation of the proportion of research space occupied by researchers in higher education institutions in Ireland. It was generated on the basis of information submitted to the HEA as at August 2006. In many cases interdisciplinary research can be categorised into multiple disciplines, in this representation, however, the principal discipline area is selected for illustrative purposes only.

Equipment and Specialised Facilities

Information on items of research equipment was submitted by higher education institutions as part of the review. Key examples of those items, costing over €100K is summarised in Table 1 below. In addition a summary of a number of specialised facilities that now exist within research facilities in Irish higher-education institutions is given in Table 2 below. These lists of equipment and facilities are not exhaustive but serve to illustrate the current situation (as at August 2006).

Research Space in Higher-Education Institutions in Ireland categorised into research discipline areas.

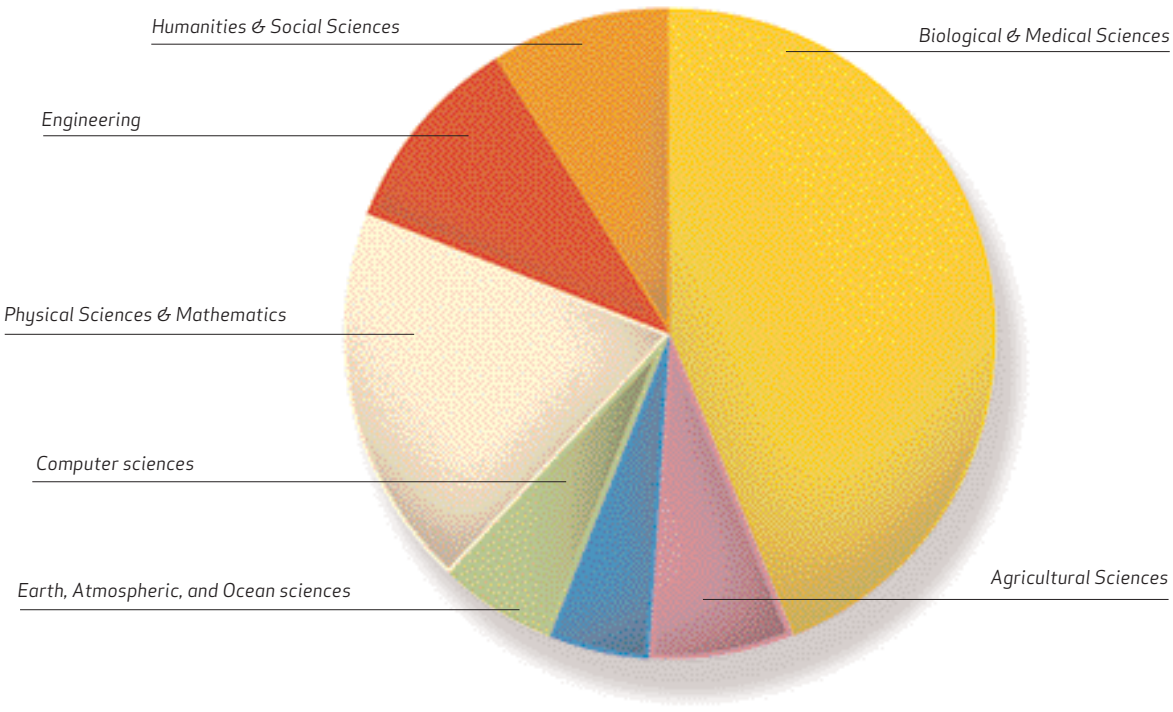


Table 1. Items of equipment valued at over €100K.
This list is not exhaustive but serves to illustrate key acquisitions. Numbers in brackets are approximate number of items valued over €100K, similar items of lower specification and cost are not listed here.

Type or Discipline Unit or System Cost	Examples*	Typical Approximate
Bioscience–Agriculture	Food Processing equipment: Microbrewery analytical equipment, Processing equipment, Dairy equipment, Packaging equipment , Bakery	Total cost €8,000,000
Biosciences–Molecular Biology	DNA sequencers (9) , Robot for DNA arrays (5), Scanner for arrays (3), WAVE nucleic acid analyser (1), Affymetrix system (3), Real time PCR (5), Genomics Software	Systems up to €360,000
Biosciences - Clinical	Gentra Autopure Purification systems Ultrasound System X-ray system Physiology movement analysis system	€2,200,000 €201,000 €150,000 €115,000
Biosciences–Protein analysis	High-throughput protein crystallisation system Auto High-throughput Antibody Isolation System ProteinChip Reader	€1,298,000 €931,000 €193,000
Biosciences–Proteomics	Peptide synthesisers and sequencers, Proteomics , Analyser System Supply of Protein Chip	€100,000 to €542,000
Biosciences–Imaging	Micro CT scanner 7T MRI Scanner - small bore 3T MRI Scanner - whole body Phosphoimager/flourescence imager, SGI (Silicon Graphics) high resolution imaging systems	€180,000 €1,150,000 €1,480,000 €127,000 €650,000 to €905,000
Biosciences–Cell biology & Microbiology	Cellomics Kinetic Scan system Microphotometry Analysis System Laser microdissection microscope Platelet Aggregation Analyzer (PAP) High Performance Flow Cytometers (10) Ultracentrifuges(~5) Microbiology Bioreactor Ultracut Cryostat Densitometer Small animal *in vivo* imaging system	€200,000 €146,000 €135,000 €154,000 €100,000 to €390,000 €100,000 €127,000 €108,000 €280,000 €229,000
Nanofabriaction and Nanotechnology	Dual beam FIB (focused ion beam) Focused Ion Beam Milling System X-ray microtomography Molecular Beam Epitaxy Physical Property Measurement System for magnetism (PPMS) Nanolithography system Shamrock Sputtering System Magnetometer Systems Electron Beam Lithography System (2) Pulsed laser systems Optical Equipment (several systems) Multibeam Sonar System	€2,000,000 €768,000 €900,000 €388,000 €367,000 €330,000 €250,000 €245,000 €222,000 €200,000 €100,000 to €127,000 €330,000

Table 1. Continued

Type or Discipline Unit or System Cost	Examples*	Typical Approximate
Engineering	Selective Laser Sintering (SLS) prototyping system	€370,000
	Nanoindenter	€250,000
	Particle Image velocimetry	€225,000
	Multiaxial Testing Machine	€211,000
	Axial Torsion Testing Machine	€170,000
	PNA network analyser testing system	€235,000
	Impact Testing Systems	€100,000 to €165,000
	Micrometric Precision Measurement	€159,000
	Corrosion testing Equipment	€119,000
	Automated Manufacturing Line	€367,000
Analytical instruments	X-ray diffraction systems (4), Chromatography systems, Ellipsometer, Rheometers, CCD detectors, Micro Thermal Analyzers, Differential scanning calorimeters, Etching systems, Particle sizers	€100,000 to €454,000
Biacore	Biacore biomolecule interaction analysis systems (2)	€189,000
High Performance Computing / ICT	HPC Opteron cluster	€1,400,000
	Wireless Testbed	€100,000
	Large Capacity Datasore	€500,000
	IBM Computer system	€127,000
	Gateway Servers (combined cost)	€180,000
Lasers	Lasers for multiple purposes including Femtosecond (2), Microbeam, Pulsed Laser Deposition System, Diode Pumped Solid State (DPSS) Laser, Excimer Laser Systems	€190,000 to €284,000
Microscope	Including Atomic force (2), Scanning tunnelling (4), Scanning electron (9), Scanning probe (3), confocal laser scanning (12), Transmission electron (2), Raman, Compucyte Laser Scanning Cytometer , Fluorescent (2), Light (2)	€200,000 to €480,000
Spectrometers	Including Mass spec (27), NMR (8), Raman (2), Voyager DE PRO biospectrometry (2), MS Quattromicro System, Spectrofluorimeter , Photo-electron, wavelength dispersive, X-ray fluorescence (WDXRF), Spectroscopic ellipsomer, CD spectrometer, Scanning Mobility Particle Sizer Spectrometer (SMPS), IR, Raman, ICP-optical emission.	€100,000 to €1,200,000
Earth, Atmospheric, and Ocean Sciences	Geophysics: Geometric Surveying System	€186,000
	Climate controlled Greenhouse	€120,000
	Low Speed Wind Tunnels	€110,000
	Climatic Chamber	€100,000

** numbers in brackets indicate multiple items costing over €100K in the data base.*
Source: Information submitted by institutions as part of the Research Infrastructure Review

Table 2. Examples of Specialised Research Facilities in Higher-Education Institutions
This list was compiled using information submitted by institutions and is not exhaustive. It serves to demonstrate capabilities that currently exist in the broad discipline areas listed.

Discipline	Type	Institution
Biosciences–Cell	National Cell & Tissue Culture Centre: GMP facility with Class 10,000 Clean rooms, Class 10,000	DCU
	Radioactive Lab. Category III laboratory for Pathogens	NUIM, TCD
	Smooth Muscle Research Centre including physiology and imaging.	Dundalk IT
Biosciences–Molecular Biology	Proteomics, Genomics and Bioinformatics capabilities (robotics, scanners, etc)	UCD, RCSI, UCC, TCD, NUIG
	Gene Vector Core Facility including GMP facility	NUIG
	X-ray Crystallography Facility	TCD
	Peptide Synthesis	RCSI
Biosciences –Analytical	Biacore	DCU, NUIG
Biosciences –Agriculture	Food Processing Facility	UCC
Biosciences	Botanic gardens, Herbarium and Plant Molecular Analysis Lab.	TCD
Biosciences–*in vivo*	Specific Pathogen Free preclinical facilities	TCD, NUIM, UCD, UCC
	Clean Conventional preclinical facilities	TCD, UCD, NUIG, UCC
	in vivo imaging apparatus	UCC
Biosciences– Clinical	Clinical Research Facilities at Beaumont Hospital; St. Vincent's and Mater Hospitals	RCSI, UCD
	Maternity Research Facilities	UCC
	Clinical Testing Suite for Oral Health Research and National Archives of Oral health data	TCD
	Picture Archiving and Communication Systems (PACs) for diagnostic imaging	UCD
Pharmaceutical	Pharmaceutical Formulation Pilot Plant	IT Tallaght
Pharmaceutical	Pharmaceutical Technology Centre	TCD
Nanotechnology	Microelectronics Technology Laboratory including fabrication room, clean room, photolithography room and advanced analytical instrumentation	TCD
	Nanotechnology facility, vibration free building with clean rooms, advanced instrumentation (under construction)	TCD
	Nanocharacterisation laboratories including Molecular Beam Epitaxy Growth facility	TCD
	Nanomaterial processing and characterisation facility, plasma optical characterisation, plasma etch laboratory and plasma diagnostics laboratory	DCU
	Laser Applications Facility including femtosecond, nanosecond and excimer lasers	NUIG
	Clean Rooms (class 1000/ class 10,000)	TCD, DCU, AIT, NUIG, UCC
	Nanofabrication Facility including E-Beam Lithography Laboratory, colloidal photonic crystal growth/patterning and characterisation laboratories	UCC

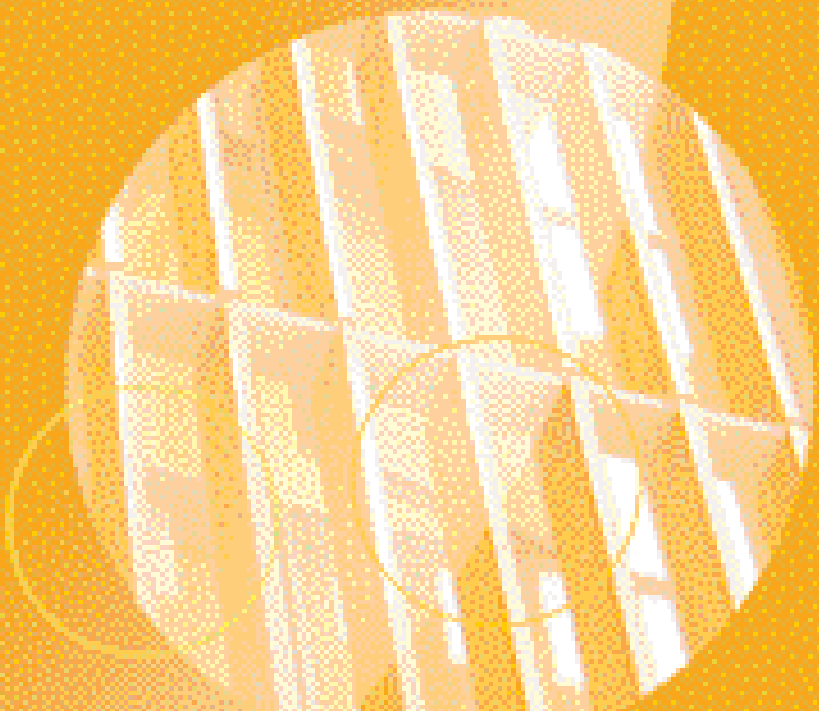
Table 2. Continued

Discipline	Type	Institution
Materials & Engineering	Surface Science Facility including focus ion beam milling facility	UL
	Semiconductor analysis and fabrication facility	UL
	Construction Materials and Structural elements research facility	TCD
	Material Processing Facility including ceramics characterisation, surface coating technologies,	DCU
	Composites Research Centre	UL
	Biomedical Engineering: Implant Testing facility	TCD
	Biomedical Engineering Centre: Polymer Processing, Analysis and Mechanical Testing Facility.	NUIG
Microscopy Analytical	Advanced Microscopy Research Facilities	several
	Specialist Analytical Facilities incl. Optical Characterisation and Spectroscopic Facility	several
Earth, Atmospheric, and Ocean Sciences	Green Building– controlled environment	UCC
	GIS (Geographic Information System) facility	NUIG, UCC
	Geocomputation facility	NUIM
	Mesopheric Cloud Physics analysis facility	NUIG
	Environmental Civil Engineering with Wind Tunnel and Tidal Basin	NUIG
	Mace Head Atmospheric Research Facility	NUIG
Marine	Fish Hatchery and Fish Cultivation Stations	NUIG
	Carron Research Outstation	NUIG
	Coastal and Marine facility including cetacean observation equipment and survey boats	UCC
	Virtual Underwater Laboratory and High Precision Deep Ocean Mapping System	UL
	National Maritime College Facilities	CIT
	Marine Research Vessels (access)	
Computer Sciences	High Performance Computing Facilities / Grid Computing	DIAS, UCC, TCD, UCD. NUIG
	Optical Communications Facility	DCU
	Localisation Research Centre	UL
	Virtual Reality Visualisation Facility	TCD
	Holographic Image Processing Facility	NUIM
	Anechoic Chamber	UL
Social Sciences	Irish Social Science Data Archive (ISSDA)	UCD
	Irish Elections Data Archive, Expert Surveys Data Archive, Spatial Data Archive	TCD, NUIM
Psychology	Computerised Digital Tracking System and related apparatus for behavioural studies	NUIM
	Multi-modal human-computer interaction laboratory	NUIM
Arts & Humanities	Extensive Manuscript Collections	TCD
	Copyright library (UK & Ireland)	TCD

Source: Information submitted by institutions as part of the Research Infrastructure Review

APPENDICES

RESEARCH INFRASTRUCTURE IN IRELAND
BUILDING FOR TOMORROW



Appendix 1 Outline and Overview of the Review

1. BACKGROUND TO THE REVIEW

Significant investment in research infrastructure in the higher-education sector will be made in coming years as part of the 'Strategy for Science, Technology and Innovation' recently approved by Government.

This investment should be informed by the views of key stakeholders so as to maximise cohesion and synergy in the development of a strong higher-education and research system which contributes to social well-being and economic development.

A review of the strengths and weaknesses of the existing research infrastructure, together with an assessment of how best to develop the necessary platform infrastructures, was carried out by the Higher Education Authority and Forfás as an important basis for informing future investment.

The definition of infrastructure in the context of this review is that used by the European Strategy Forum on Research Infrastructure (ESFRI), namely:

The tools that provide essential services to the research community for basic or applied research. They may concern the whole range of scientific and technological fields, from social sciences to astronomy, going through genomics or nanotechnologies. Examples include libraries, databases, biological archives, laboratories, clean rooms, communication networks, research vessels, satellite and aircraft observation facilities, coastal observatories, telescopes, synchrotrons, accelerators. They may be "single-sited", "distributed", or "virtual". What we are dealing with are the necessary tools for the future to do research in many areas at the cutting edge.

The review will reflect, on behalf of key stakeholders, an agreed needs package for the development of national infrastructure(s). The review will have regard to more developed infrastructure systems internationally and examine ten discipline areas:-

- Agricultural Sciences
- Arts & Humanities
- Biological Sciences
- Computer Sciences
- Engineering
- Earth, Atmospheric, & Ocean Sciences
- Media & Creative Arts
- Medical Sciences
- Physical Sciences and Mathematics
- Psychology and Social Sciences

2. THE REVIEW PROCESS

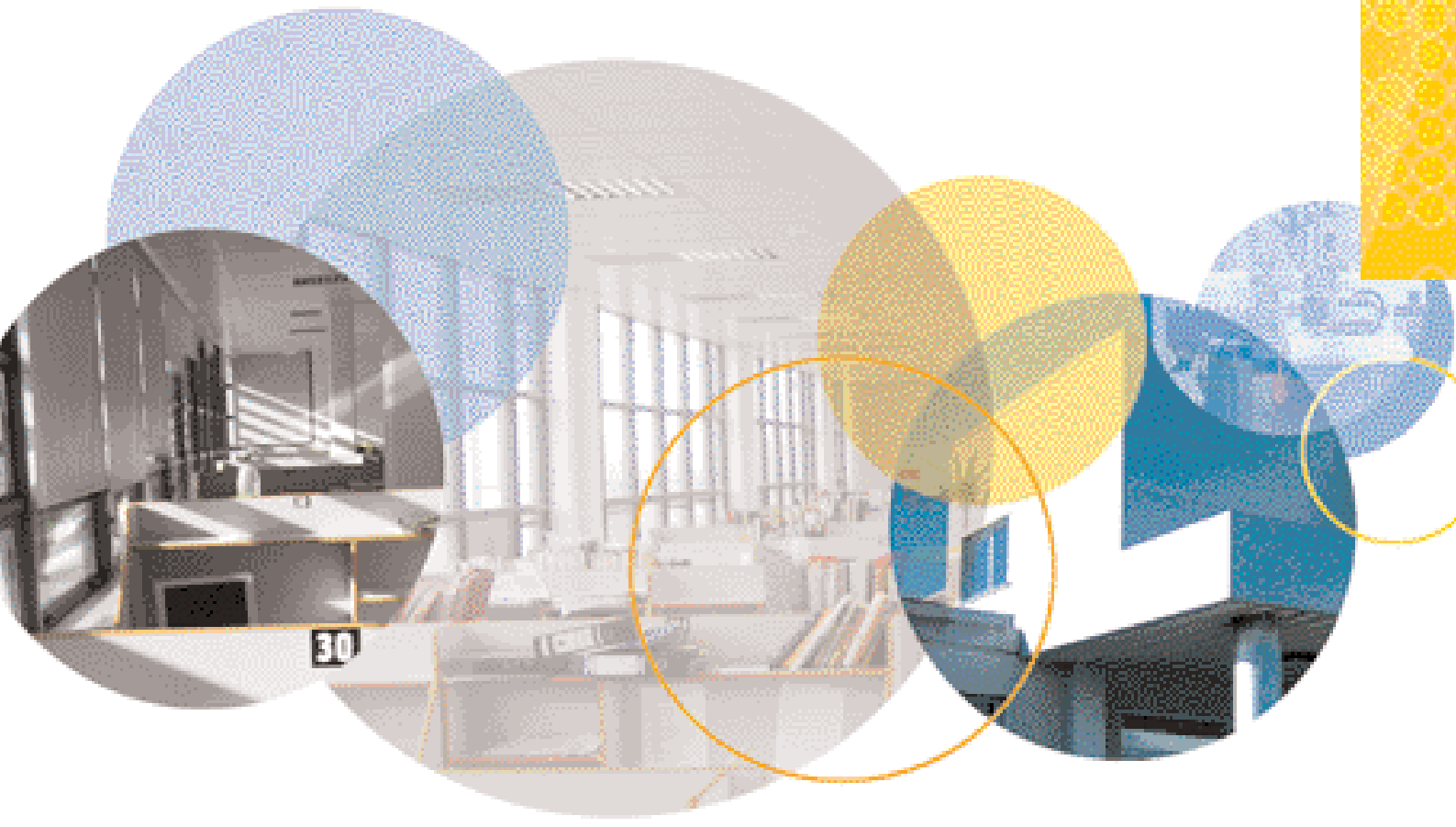
The review process, as agreed by the Higher Education Authority and by the Forfás Board, involved the following actions:

- Reviewing the status of the Higher Education Authority database of physical research infrastructure and updating it on the basis of submissions from the institutions. Classifying the condition of existing infrastructure as (a) good condition, (b) fit for purpose, or (c) no longer adequate
- Conducting wide-ranging consultation with the various stakeholders, including academic researchers, representatives of higher-education institutions, the Royal Irish Academy, research funding agencies, public-sector research organisations and industry
- Undertaking seventeen site inspections, by groups of international experts, across a sample of infrastructures
- Surveying the views of enterprise on higher-education research infrastructures. Eighteen research-performing companies were interviewed and a Forum to discuss the issue was attended by over fifty industrialists
- A National Stakeholders' Forum to hear the findings from the site inspections and the industry consultation, and to identify the key issues to be addressed
- Preparing a report which would set out the strengths, weaknesses and gaps in the existing infrastructure as well as recommendations for future investments and suggestions for greater utilisation of existing national and international research facilities on a multi-user basis.

3. GUIDANCE BY AN INTERNATIONAL STEERING COMMITTEE

An international steering committee, chaired by Dr. Hans Chang, was appointed by the HEA and Forfás to advise on the suitability of the review process and to oversee its implementation. The committee held its first meeting in September 2006. The committee attended the Stakeholders' Forum in October 2006 and listened to the views expressed at the meeting.

Based on the above inputs to the process, and taking cognisance of a number of relevant recent reports (such as the HEA's *Strategy for Science, Technology and Innovation, 2006–2013*) and of the work of the ESFRI, the steering committee prepared a report.



Appendix 2 List of International Site Visitors

Name	Affiliation
Prof John W. Barrett	Department of Mathematics, Imperial College London, UK.
Prof Michael Bøss	Director of the Centre for Irish Studies Aarhus, Aarhus Universitet, Denmark.
Prof Jonathan M. Bull	National Oceanography Centre, University of Southampton, UK.
Prof Ian Connerton	Northern Foods Professor of Food Safety, University of Nottingham, UK.
Prof William Dawson	Visiting Professor, School of Science and Mathematics, Sheffield Hallam University,UK. Formerly Research Director, Eli Lilly, UK.
Prof John Elliott	Emeritus Professor of Education, Centre for Applied Research in Education, University of East Anglia, Norwich, UK.
Prof Marianne Elliott Liverpool, UK.	OBE, Professor of Modern History and Director of the Institute of Irish Studies, University of
Prof Chris L. J. Frid	Chair of Marine Biology, University of Liverpool, UK.
Prof Peter J. Fryer	School of Engineering, University of Birmingham, UK.
Prof David Harper	School of Computing, Robert Gordon University, Aberdeen, UK.
Prof Brenda J. Howard	MBE, Head of Site, Centre for Ecology and Hydrology, Lancaster, UK.
Prof Klaus Jung	Head of the School of Fine Art, The Glasgow School of Art, UK.
Prof Ullrich Kockel	Professor of Ethnology and Folk Life, University of Ulster, Northern Ireland, UK.
Prof Lin Li	Chair of Laser Engineering, University of Manchester, UK.
Prof Peter Liss	School of Environmental Sciences, University of East Anglia, Norwich, UK.
Prof Alan Michette	Department of Physics, King's College London, UK.
Prof Bill Milne	Engineering Department, University of Cambridge, UK.
Prof Randall J. Mrsny	Welsh School of Pharmacy, University of Wales, Cardiff, UK. Founder and Chief Scientific Officer, Trinity BioSystems, California, USA.
Prof David Nethercot	OBE, Head of Department of Civil and Environmental Engineering, Imperial College London, UK.

Name	Affiliation
Prof David Newby	Centre for Cardiovascular Science, University of Edinburgh, Scotland, UK.
Prof Niels Ploug	Director of Research Unit for Comparative Welfare Studies, Social Forsknings Instituttet, Copenhagen, Denmark.
Prof Gordon C. K. Roberts	Henry Wellcome Laboratories of Structural Biology, University of Leicester, UK.
Prof Kevin J. Roberts	Brotherton Professor of Chemical Engineering, University of Leeds, UK.
Prof W. James Stirling	CBE, Pro-Vice-Chancellor (Research), Durham University, UK.
Mr Peter Stubley	Assistant Director for Academic Services, University of Sheffield Library, UK.
Prof Peter Tyler	Department of Land Economy, University of Cambridge, UK.
Prof Gert G. Wagner	Head of the German Socio-Economic Panel Study, Deutsches Institut für Wirtschaftsforschung, Berlin, Germany.
Dr Diego Walther	Max Planck Institut für molekulare Genetik, Berlin, Germany.
Prof George Watson	Emeritus Professor, Research Institute of Irish and Scottish Studies, University of Aberdeen, UK.
Prof Mark Welland	Nanoscience Centre, University of Cambridge, UK.
Prof Lawrence Whalley	Professor of Mental Health, University of Aberdeen, Scotland, UK.
Dr Bruce Whitelaw	Head of Division of Gene Function and Development, Roslin Institute, Scotland, UK.
Prof David F. Williams	Director, UK Centre for Tissue Engineering, University of Liverpool, UK.
Prof Eugene Wong	Emeritus Professor, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, USA.

Appendix 3 List of Contributors to the Review

- Alltech
- American Chamber of Commerce, Ireland
- Analog Devices BV
- APW Galway
- Athlone Institute of Technology
- Aughinish
- BD Medical
- Biologics Supply
- Biotrin
- Bord Iascaigh Mhara
- Boston Scientific
- Bristol-Myers Squibb
- Chester Beatty Library
- CIRCA Group
- COFORD
- Commergy
- Cork Institute of Technology
- Cosmogrid
- Council of Directors of Institutes of Technology
- Creganna
- Dawn Meats Group
- Diageo
- Digital Hub Development Agency
- Dublin City University
- Dublin Institute for Advanced Studies
- Dublin Institute of Technology
- Dublin Molecular Medicine Centre
- Dún Laoghaire Institute of Art, Design & Technology
- Dundalk Institute of Technology
- EBS Building Society
- Elan
- Engineers Ireland
- Enterprise Ireland
- EPA Inspectorate
- ESRI
- Expertise Ireland
- Failte Ireland
- FÁS
- FETAC
- Food & Drink Industry Ireland
- Galway-Mayo Institute of Technology
- Genzyme Ireland Limited
- Georgia Pacific Ireland Limited
- Gilead Sciences Limited
- Grid-Ireland
- Health Research Board
- HEAnet
- IBM Ireland
- ICHEC
- IDA Ireland
- Industry Research and Development Group
- Innocoll Technologies Limited
- Institute of Technology, Blanchardstown
- Institute of Technology, Carlow
- Institute of Technology, Sligo
- Institute of Technology, Tallaght
- Institute of Technology, Tralee

Intel

Intertrade Ireland

Iona Technologies

IRCHSS

IRCSET

Irish Academy of Engineering

Irish Business and Employers' Confederation

Irish Centre for Business Excellence

Irish History Online

Irish Medical Devices Association

Irish Medicines Board

Irish Pharmaceutical Healthcare Association

Irish Research and Development Group

Irish Software Association

Isotron Ireland Limited

IUA Librarians' Group

Letterkenny Institute of Technology

Limerick Institute of Technology

Líonra

Lucent Technologies

Magna

Marine Institute

Mary Immaculate College, Limerick

Mater Dei Institute of Education

Medtronic

Merrion Pharmaceuticals

Mr. Crumb

National College of Art & Design

National College of Ireland

National Disability Authority

National University of Ireland, Galway

National University of Ireland, Maynooth

NeuroCure

Newport Pharmaceuticals Limited

Oracle Corporation

Ordnance Survey Ireland

Organon Ireland Limited

Original Solutions Limited

Pharmaceuticals Ireland

Respironics

Riverwest Technologies Ireland Limited

Roche Ireland Limited

Royal College of Surgeons in Ireland

Royal Irish Academy

Science Foundation Ireland

SIFCO Industries

SR Technics

St. Patrick's College, Drumcondra

Stryker Instruments

The Irish Academy of Engineering

The University of Dublin (Trinity College)

The University of Limerick

Timoney Technology

Tridelta Plc

Tyndall National Institute

University College Cork

University College Dublin

Waterford Crystal Ltd

Waterford Institute of Technology

Wyeth

Appendix 4 Abbreviations & Acronyms

AIT	Athlone Institute of Technology
AVC	Audio Visual Connection
BMS	Biological and Medical Science
CBE	Commander of the Order of the British Empire
CCD	Charge-Coupled Device
CCTV	Closed-Circuit Television
CERN	Conseil Européen pour la Recherche Nucléaire
CIT	Cork Institute of Technology
COFORD	National Council for Forest Research and Development
COST	European Cooperation in the field of Scientific and Technical Research
CNEF	Cross National Equivalent File
CRANN	Centre for Research on Adaptive Nanostructures and Nanodevices
CRF	Clinical Research Facility
CSO	Central Statistics Office
CT	Computed Tomography
DCU	Dublin City University
DDI	Data Documentation Initiative
DIAS	Dublin Institute for Advanced Studies
DIT	Dublin Institute of Technology
DLIADT	Dún Laoghaire Institute of Art, Design and Technology
DMMC	Dublin Molecular Medicine Centre
DNA	Deoxyribonucleic Acid
DPSS	Diode Pumped Solid State
ECRIN	European Clinical Research Infrastructure Network
EISCAT	European Incoherent Scatter
EMBL	European Molecular Biology Laboratory
EPA	Environmental Protection Agency
ERI	Environmental Research Institute
ESA	European Space Agency
ESEM	Environmental Scanning Electron Microscope
ESO	European Southern Observatory
ESFRI	European Strategy Forum on Research Infrastructure
ESRF	Economic and Social Research Foundation
ESRI	Economic and Social Research Institute
ESS	European Social Survey
EU	European Union
EUPRO	European Union of Physics Research Organisations
FÁS	Foras Áiseanna Saothair
FETAC	Further Education and Training Awards Council
FIB	Atrial Fibrillation / Focused Ion Beam
FOM	Foundation for Fundamental Research on Matter
FRS	Fellow of the Royal Society
HEA	Higher Education Authority
HE	Higher Education
HEI	Higher Education Institution

HERD	Higher Education Expenditure on Research and Development
HPC	High-Performance Computing
HR	Human Resources
HRB	Health Research Board
GDP	Gross Domestic Product
GIS	Geographic Information System
GLP	Good Laboratory Practice
GMIT	Galway–Mayo Institute of Technology
GMP	Good Manufacturing Practice
GNP	Gross National Product
ICHEC	Irish Centre for High-End Computing
ICRIN	Irish Computing Research Infrastructure Network
ICPSR	Inter-University Consortium for Political and Social Research
ICT	Information and Communications Technology
IDA	Industrial Development Agency
IFSC	International Financial Services Centre
IoT	Institute of Technology
IPR	Intellectual Property Rights
IRCHSS	Irish Research Council for the Humanities and Social Sciences
IRCSET	Irish Research Council for Science, Engineering and Technology
IReL	Irish Research E-Library
ISSDA	Irish Social Science Data Archive
IT	Information Technology
ITB	Institute of Technology, Blanchardstown
ITC	Institute of Technology, Carlow
LIS	Luxembourg Income Survey
LIT	Limerick Institute of Technology
LYIT	Letterkenny Institute of Technology
MNC	Multi-national Corporation
MRI	Magnetic Resonance Imaging
NCAD	National College of Art and Design
NCG	National Centre for Geocomputing
NCPST	National Centre for Plasma Science and Technology
NDRC	National Digital Research Centre
NMR	Nuclear Magnetic Resonance
NREN	National Education and Research

Appendix 4 Continued

	Network
NUIG	National University of Ireland, Galway
NUIM	National University of Ireland, Maynooth
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
OBE	Order of the British Empire
OECD	Organisation for Economic Cooperation and Development
PACs	Picture Archiving and Communication Systems
PAP	Platelet Aggregation Analyzer
PCR	Polymerase Chain Reaction
PI	Principal Investigator
PNA	Peptide Nucleic Acid
PPMS	Physical Property Measurement System
PRTLI	Programme for Research in Third-Level Institutions
PSE	Physical Science and Engineering
R&D	Research and Development
RCSI	Royal College of Surgeons in Ireland
REMEDI	Regenerative Medicine Institute
RIA	Royal Irish Academy
S&T	Science and Technology
SBIR	Small Business Innovation Research Programme
SCPR	Social and Community Planning Research
SEM	Scanning Electron Microscope
SFI	Science Foundation Ireland
SGI	Silicon Graphics Inc.
SIF	Strategic Innovation Fund
SLS	Selective Laser Sintering
SMPS	Scanning Mobility Particle Sizer Spectrometer
SPF	Specific Pathogen Free
SRIF	Science Research Infrastructure Fund
SSH	Social Science and Humanities
SSTI	Strategy for Science, Technology and Innovation
TCD	Trinity College Dublin
TEAGASC	Agriculture and Food Development Authority
TEM	Transmission Electron Microscope
UCC	University College Cork
UCD	University College Dublin
UK	United Kingdom
UL	University of Limerick
US / USA	United States of America
VC	Venture Capital
WDXRF	Wavelength Dispersive X-Ray Fluorescence
WIT	Waterford Institute of Technology

Appendix 5 Higher Education Authority Members

Name	Professional Affiliation
Mr. Michael Kelly	Chairman, HEA
Professor Sarah Moore	Deputy Chairperson and Dean of Teaching and Learning, The University of Limerick
Professor Tom Boylan	National University of Ireland, Galway
Dr. Maurice Bric	Department of Modern History, University College Dublin
Dr. Thomas Cooke	Head of Community Links Programme, Dublin Institute of Technology
Cllr. Maria Corrigan	Member, Dún Laoghaire-Rathdown County Council
Mr. Michael Cotter	School of Education Studies, Dublin City University
Mr. Martin Cronin	Chief Executive, Forfás
Ms. Doreen Delahunty	Business Woman
Mr. Louis Dockery	Solicitor
Ms. Sheila Drumm	Principal, Dominican College, Sion Hill, Co. Dublin
Dr. Honor Fagan	Department of Sociology, National University of Ireland, Maynooth
Mr. Colm Hamrogue	President of the Union of Students in Ireland
Ms. Carol Herron	Home School Community Co-ordinator, Co. Cavan VEC
Dr. Pat Kelleher	Former Director of Cork Institute of Technology
Mr. Patrick J. Kirby	Group Commercial Director, Alphyra
Professor Elizabeth Meehan	Former Head, Institute of Governance, Queen's University Belfast
Professor Ciarán Murphy	Department of Accounting, Finance and Information Systems, University College Cork