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Review of Irish Membership of International Research Organisations (IROs)

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Executive Summary

In December 2014 a project team from the CIRCA Group Europe Ltd and the Fraunhofer ISI Institute (Germany) were commissioned to carry out a study of Ireland's membership, or possible membership, of 14 International Research Organisations (IROs). Ireland is already a member of 5 of these IROs, the membership subscriptions being paid annually by the Department of Jobs, Enterprise and Innovation (DJEI). The total annual budget for such memberships was €18.67m in 2014.

The 14 IROs to be studied included a variety of scientific areas. There were 6 IROs related to Physics/Astronomy/Space Science; 3 IROs were related to aspects of Advanced Materials Science; 3 IROs were related to Biology, and the remaining two programmes (COST and EUREKA) were not discipline specific. Nine of the IROs studies were already operational for some years, the remaining five were under development (one of these has since become operational).

The task was two-fold:

- To provide a comparative assessment of the costs and socio-economic benefits of membership of each organisation on the basis of defined assessment criteria
- To propose a ranking of membership options having regard to national research and innovation priorities, areas of emerging opportunity, funding constraints, and taking into account the organisations and sectors involved.

The project team gathered relevant information via a number of methods: desk studies, bibliometric analyses, surveys of researchers and stakeholders, interviews with key personnel in Ireland, and also internationally in France and Germany. The information gathered by the project team was either factual, or based on expert opinion, and in all cases was evidential in nature.

The data was analysed against a set of assessment criteria covering: science, education /skills / training, industry impacts, and STEM/Outreach. Profiles were developed of the benefits and costs of membership of each of these 14 IROs. A Benefit/Cost analysis, tailored to the specific features of this project was developed, and used to characterise the IROs, and to generate membership options based on value for money ranking.

From this analysis the following conclusions emerge:

- Five of the IROs studied do not warrant consideration for membership. Three of these are Materials Science organisations (ESRF, ESS, ILL) and two of them are Astronomy IROs (SKA and CTA). Membership should not be further considered at this time.
- Four of the existing memberships should be retained (ESA, COST, EUREKA, EMBC) and there is strong case for taking out two new memberships at minimal cost (ELIXIR and LOFAR).
- Significant benefits could be achieved for Ireland by joining the European Southern Observatory (ESO). However, the membership costs are substantial and would require a substantial increase in the relevant Departmental budget. This could only occur at very high opportunity cost from elsewhere in the Science, Technology and Innovation (STI) budget. As a consequence we do not recommend that Ireland takes membership in ESO.
- Full membership of CERN is not warranted. However, the case for joining CERN would be a strong one, if satisfactory membership conditions could be achieved at around the same cost as associate membership.

- The case for maintaining one of the existing memberships (EMBL) is weak, and serious consideration should be given to dropping this membership on the basis of Benefit/Cost analysis, and also to provide some budgetary space to facilitate Ireland joining several of the other IROs that have much more to offer.

Finally the authors also recommend a more structured approach to putting in place necessary support services, to ensure that those IROs that are chosen for membership can deliver on their full potential, in terms of benefits to the relevant research, education and industrial communities.

Chapter 1: Introduction

Project Brief

This report contains the results of a review of Ireland's membership of 14 International Research Organisations (IROs), which include 5 IROs of which Ireland is currently a member a further nine IROs which are being considered for membership. The study was conducted by a team of consultants from CIRCA Group Europe and Fraunhofer Institute ISI in the period December 2014 to May 2015.The full details of the brief provided to the CIRCA team, and of the IROs which are the subject of the review, are in **Appendix 1**. The outputs of the study provide the evidence base to inform decisions on continued membership of the current five IROs, and potential membership of some other IROs.

Table 1.1: IROs to be Reviewed

IROs of which Ireland is currently a member (List A)	IROs currently operational, of which Ireland is not a member (List B)	Other IROs under development of which Ireland is not a member. (List C).
(**ESA)** European Space Agency HQ in Paris. Multiple sites.	(**CERN)** European Organisation for Nuclear Research. HQ in Geneva, Switzerland	(**SKA)** The Square Kilometre Array Large radio telescope system. HQ in Manchester, England. Operational sites in Australia, South Africa.
(**EMBL)** European Molecular Biology Laboratory. HQ in Heidelberg, Germany. Four other sites.	**(ESO)** European Southern Observatory. HQ near Munich, Germany. Operational sites in Chile.	(**ESS)** European Spallation Source HQ in Lund, Sweden. Another site in Denmark. A high power neutron facility for materials research.
(EMBC/EMBO) European Molecular Biology Conference/Organisation HQ in Heidelberg, Germany.	(**ESRF)** European Synchrotron Radiation Facility HQ in Grenoble, France	(**LOFAR)** Low Frequency Array A large radio telescope system. HQ in the Netherlands. Five other sites planned. A possible site in Ireland (Birr).
EUREKA An industry focused inter-Governmental RDI programme. HQ in Brussels.	**(ILL)** Institut Laue-Langevin A high flux neutron source for materials research. HQ in Grenoble, France	**ELIXIR**. A European network of bioinformatic facilities. Hub and node model. Hub located at Cambridge, UK.
COST A Networking Programme of European Research activities. Administration HQ in Brussels.		**CTA** Cherenkov Telescope Array. Observatory for very high energy (VHE) gamma rays. HQ in Heidelberg, Germany.

Table 1.1 lists the IROs to be reviewed. List A consists of 4 IROs of which Ireland is already a member. List B consists of 4 IROs, currently operational, of which Ireland is not a member. List C consists of 5 IROs, of which Ireland is not a member, and which are under development.

The Policy Context

The Government Strategy for Science, Technology & Innovation (SSTI) 2006 to 2013 was a broad based strategy covering:

- Funding for R&D from basic to applied research,
- Commercialisation research across all sciences and disciplines as well as the Humanities and Social Sciences (HSS), and
- STEM (Science, Technology, and Engineering & Maths).

According to the draft new SSTI strategy consultation paper[1]significant steps have been "made in establishing a strong public research environment based on scientific excellence in a number of strategic areas, in many cases meeting and exceeding targets set out in the SSTI".

In 2011, to better focus scarce resources, a Research Prioritisation exercise was undertaken identifying 14 key areas which are now the major focus of national research, development and commercialisation strategy. (See **Appendix 7**). These 14 areas were deemed most likely to secure greater economic and societal impact, particularly in the form of job creation.

This led to the concentration of the majority of competitive research funding on these areas. It should be noted that underpinning basic research was also identified within the Prioritisation Process as a vital element of national investment in S&T.

So how does membership of International Research Organisations (IROs) fit in this context?
The consultation document for the new SSTI policy states that international cooperation helps:

- Develop links with top international research institutions and enterprise markets
- Reinforce Ireland's standing as a top-class research-performing nation

The areas of activity envisaged are:

- Recruiting high-calibre researchers to Ireland
- Facilitating collaborations with world-class centres of research excellence
- Raising international awareness and recognition of Irish science and high-quality research
- Learning from other countries that have focused on R&D and innovation as key national policies.

The classical offering of the major IROs (CERN, ESA, and ESO etc.) is access to instrumentation which no country could afford on its own. IROs are therefore high-level collaborations (usually between Governments) to mutually guarantee access to the equipment required by researchers in member countries. Collaboration inevitably occurs among users of these facilities. In principle, researchers

[1] Interdepartmental Committee on Science & Technology, (February 2015), Consultation Paper for Successor to Strategy for Science, Technology and Innovation.

could access these facilities without engaging in any of this collaboration, and industry users often do access in this way. These are also other IROs which offer other forms of central supports. For example COST and EUREKA offer an international coordination role, EMBL and ELIXIR offer training and networking, while others offer all of these.

Membership of International Research Organisations (IROs) is important because it can:

- Allow Irish researchers to access large scale research infrastructure/equipment that is beyond our national resources , e.g., ESA, CERN or ESO
- Assist collaboration, networks and partnerships, e.g., ESA, COST, EMBL and EMBC/EMBO
- Provide training on very advanced equipment and systems (most IRO organisations)
- Provide opportunities to undertake Ph.Ds. and post-doc research, e.g., CERN, ESO
- Facilitate sharing of knowledge and licences, e.g., ELIXIR
- Involve SMEs in high quality transnational research, e.g., EUREKA
- Provide procurement and related business opportunities for Irish companies, e.g., ESA, CERN and ESO.

However, as a small country with limited resources, Ireland has to be selective in its international collaborations and engagements.

Approach and Outline of Report

The approach adopted involves the development of a methodology capable of summarising the wide-ranging benefits that can be achieved through IRO membership in a quantifiable form. This is described in chapter 2. It involves the collection of data from five different sources to make assessment of benefit against a common set of criteria.

In chapter 3 we summarise the main findings of the data analysis. In doing so we also draw out broader implications for policy from membership of IROs.

Detailed profiles of each the IROs are contained in chapter 4. This is followed in chapter 5 by the application of cost benefit analysis. Detailed rankings of the benefits offered by IROs in each of the assessment categories are provided. These are then combined with the costs to give a value for money ranking of IROs.

The various strands of the analysis are brought together in chapter 6 where a set of options are analysed. From this we make recommendations on the approach to use of the Irish budget for membership of IROs that would deliver maximum value for money.

A second volume contains appendices which include, *inter alia*, detailed descriptions of our data collection and results.

Chapter 2: Methodology

We have devised and implemented a methodology where we assess the benefit to Ireland of membership in an IRO against a comprehensive set of criteria that is measured using multiple data sources. These benefits are compared to an annualised cost index in order to arrive at a benefit-cost ratio for each IRO. The ranking of these ratios, when set against a fixed national budget for IRO membership, yields the recommended set of IROs that will deliver maximum national benefit.

Box 2.1: Assessment Criteria

Science

1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?
3. Would/does membership add value to the impact of Ireland's research output/quality?
4. Would/does membership enhance international collaboration of Irish researchers?
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by becoming a member?

Education, Skills and Training

6. Would/does membership have positive benefits for education in Irish HEIs?
7. Would/does membership enhance the profile of human capital output from Irish HEIs?
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?

Industry

9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?

STEM/Outreach

15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?

Assessment Criteria

The benefits from membership of each IRO are measured relative to criteria in four areas: science, education/skills/training, industry, and STEM/outreach. The criteria are described by a set of 15 questions outlined in a framework adapted from one originally devised by the Department of Jobs, Enterprise & Innovation (DJEI). The questions are presented in Box 2.1.

Figure 2.1: Assessment of Benefits

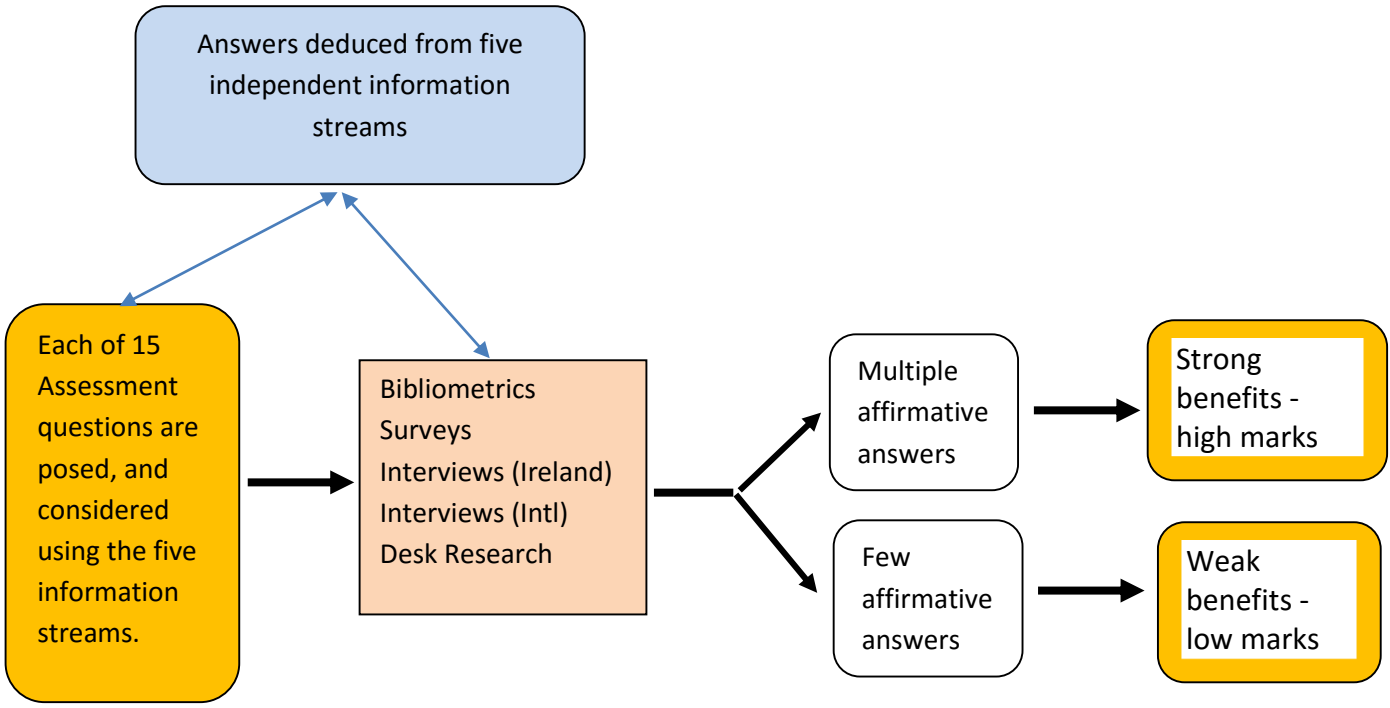

Fig 2.1 illustrates the method used to assess the potential benefits of Irish membership of each IRO. Each of the 15 assessment criteria was posed as a question requiring a "Yes /No" answer.

In our methodology, each of these 15 questions are deemed to have equal weight, and each of them are considered in the light of the information gathered in each of the 5 streams of evidential data listed above. Answers are deduced which are evidence-based. This assessment process is repeated for each of the 14 IROs in this study. If an assessment question receives an affirmative answer from one of the data streams - that is deemed to be a positive outcome (and it scores 1 benefit point). If a question receives multiple affirmatives from several, or all five of the data streams - that is a strongly positive result for that particular IRO.

When each of the assessment questions are considered in this way, an overall picture is built up of the magnitude of the benefits that would be likely accrue from membership of the IRO in question. The maximum total benefit score is 65.

Data Gathering methods

Bibliometric Data

Thomson Reuter's bibliometric database "Web of Science" (WoS) was used to search for publications during the 4 year period 2010 – 2013. In particular we searched for publications by researchers affiliated to the IROs of interest in this study. These publication figures were then linked to publications in the same fields of research by researchers affiliated to Irish research performing organisations (RPOs). Thus we identified the research community in Ireland that could potentially be interested in the research activities of 9 of the 14 IROs in this study. This data is factual and up-to-date. Two of the long established IROs in our study (COST and EUREKA) did not have authors who published using these affiliations. Furthermore three of the IROs under development (ELIXIR, SKA, and LOFAR) did not have any published authors using these IROs as their affiliated institutions. Our bibliometric study included the remaining 9 IROs. The number of publications from EMBC/EMBO, SKA, and ESS was small so that the bibliometric analysis was largely focused on the following 6 IROs – ESA, EMBL, CERN, ESO, ESRF and ILL.

Surveys

Five surveys were carried out using email and/or "SurveyMonkey" web based questionnaires.

The groups surveyed were:

Active Researchers: Researchers publishing most actively in fields in which the various IROs were cited in publications. As mentioned above these researchers were identified by means of an extensive bibliometric analysis, and 670 researchers were surveyed. A full description of the approach used is in **Appendix 3**.

Astronomy researchers in Ireland: This was supplementary to the above survey, which also included astronomy researchers. In this case a simple email survey was sent to 53 Irish astronomy researchers identified by their peers. The purpose was to obtain their views as to which of the 4 astronomy-related IROs they would prefer Ireland to join, and the reasons why.

Irish researchers who had participated in the COST programme. The Fraunhofer analysis identified 877 Irish participants in COST programmes. These could not all be included in the above survey of active researchers because their areas of activity were not relevant to the IROs and because the high numbers would bias the sample. A separate survey of these participants was conducted to seek their specific views on COST and is separately reported.

Research-active companies who are members of the Industry Research and Development Group (IRDG): A view from research-active companies was conducted in association with the IRDG. A customised survey was developed using the population of companies on the IRDG database and 89 responses were received. While this represents < 5% of the total number of companies surveyed it is likely to be a representative sample of research active companies.

Interviews (in Ireland)

Interviews were conducted with a wide range of stakeholders. These included Heads of Research in each Higher Education institution; executives of relevant RTD-related State agencies, other bodies representing research interests such as IBEC, IRDG, the Royal Irish Academy and the Institute of Physics. Almost all of these interviews were "face-to-face". A small number were through telephone interviews. For several of these meetings two Fraunhofer members of the project team travelled to Ireland and participated in the meetings. A summary of the outcome of these interviews is in **section**

3. A briefing on European Southern Observatory (ESO) was attended at TCD Dublin on March 26th at which ESO executives were met and interviewed.

Significant efforts were made to obtain views from industry groups. IBEC, Irish Pharm & Healthcare Association and the Industry R&D Group were contacted for their views and also to facilitate surveys, and an explanatory note on industry benefits was made available to these organisations for use with their members. IPHA circulated this information to their members inviting responses, but no responses were received. Similarly IBEC circulated their member associations, but no responses were received. IRDG also facilitated a useful survey of its entire database.

Interviews in France and Germany

18 experienced researchers and research leaders in Germany and France were interviewed by telephone. Both Germany and France are members of at least 5 of the IROs in the study. Scientists from these countries, who are active in fields relevant to IRO domains, are well placed to identify the benefits which accrue from IRO membership. All of these interviews delivered "expert opinion". Although this cannot be described as factual data, it is "evidential" data to the extent that it is based on in-depth expertise, and extensive experience.

Desk Research

Initial background information was provided by DJEI, by means of soft copy and hard copy documents. Further information was gathered from IRO web sites, other relevant web sites, and from stakeholder organisations (Institute of Physics, Research groups etc.). This data is generally factual.

Analysis.

The benefits of IRO membership are derived for each IRO as described in the previous sections. The costs of membership are expressed as an annual recurring cost. The actual membership fee levied will generally bear some relationship to the size of country, as measured by GDP/GNP, and may also involves some element of negotiation. Upfront one time charges may be levied on joining an IRO. Where this occurs we incorporate this amount into the annual fee by amortising the upfront charge over a decade. Our enquiries have established that Ireland could negotiate such an arrangement for upfront charges.

We have been asked to take cognisance of national research prioritisation in assessing the benefits of IRO membership for Ireland. In particular we have been asked to assess the extent to which membership might deliver benefits in the 14 priority areas. In order to do so we weight the science benefits. Where an IRO can deliver scientific benefits that are a direct match with some or all of the 14 priority areas the science benefit is given a weight of 1. Where there is a partial match there is a weighting of .5. Where the science benefit does not match with the priority areas but makes a contribution to the underpinning science there is a weighting of .1. This follows the recommendations in the Report of the National Research Prioritisation Exercise which advocated that the majority of funding be directed at the priority areas with the remainder going to support underpinning science and policy research.

There is potential for benefit to accrue to Irish companies not involved in R&D activity arising from Irish IRO membership. This could occur, for example, through the award of procurement contracts to

Irish firms for equipment and services. In order to take account of this cost recovery we use available evidence on outcomes and potential to assign an adjustment factor to the cost of Irish membership.

When benefits are compared with costs we get a value for money ratio of befit to cost. By ranking IROs according to this ratio we can order from most to least desirable. If the budget is used according to this ordering until it is exhausted maximum benefit will be achieved from IRO membership.

We take account of adjustment for National Research Prioritisation and adjustment for cost recovery when doing this ranking.

Chapter 3: Main Findings of Data Analysis

In this chapter we provide a summary of the outputs of the bibliometric analysis; researcher surveys, industry surveys; interviews with researchers, HEIs, Governmental Agencies; desk research, and data analysis. The summary is presented in the form of answers to some of the questions (Box 2.1) posed in the assessment framework. The appendices provide more detail on this fieldwork, its collection and analysis. We begin with a broad overview of the potential offered by membership of IROs.

Potential to Benefit from IRO Membership

The number of researchers who can benefit from the organisation: The proportion of researchers who can benefit from the different IROs varies very significantly. ELIXIR and EMBC/EMBO, for instance serve a large proportion of the life science sector which is a major area of Irish research activity. The astronomy organisations (CTA, ESO, LOFAR and SKA), on the other hand serve a relatively small cohort of researchers. From this it is apparent Ireland hosts a high level of research (as measured by publication activity) in biology/biotechnology and medicine but a relatively low level of activity in certain other fields.

The degree of dependency on IRO facilities: Some areas of research are highly, if not completely, dependent on the facilities available from IROs. Research in astronomy, and in certain areas of physics, is effectively not possible other than through agencies such as ESA, ESO or CERN. These organisations are the mechanisms for involvement in 'big science' and such involvement is effectively not possible without membership. Conversely, although the services provided by ELIXIR, EMBL and EMBO are highly valuable within the life-sciences, the degree of absolute dependence on these IROs within this sector is low.

The Societal Dimension: Some IROs address the big questions on which international science has been engaged for centuries, such as the origin of the universe and the nature of matter. There is therefore a policy question as to whether Ireland should contribute to international efforts towards their solution. Related to this is the question of whether Ireland may be the only Western European non-member of some organisations. To quote one Irish agency executive:

> "*We cannot expect to adopt a 'free-rider' approach on the work of others – we must contribute to global research, particularly if we wish our researchers to be viewed as leaders, not followers.*"

Comparisons with other competitor countries: Related to this is the question of membership policies in other countries. Table **A4** (**Appendix 3**) shows the membership status of 33 countries for 7 of the IROs of which Ireland is not a member (LOFAR and CTA are not included, as they are structured differently). Three EU countries have memberships of all 7 IROs (Italy, UK, and The Czech Republic). On the other hand some advanced and relatively wealthy countries such as France, Germany, Finland, Sweden, Norway, and Netherlands have only selected memberships. Most countries appear to select IROs on a "case by case" basis, which is the approach which is now being taken by Ireland. . The R&D expenditure by the Irish Government and its Agencies on R&D for the year 2013 is €732.6m. An estimate provided by Science Foundation Ireland suggests that about 1/3rd of this expenditure (approx. €241m) is fully open to competition by the Irish research community, with expert international peer review. Current Government expenditure on IRO memberships (~ €18.68m)

therefore amounts to ~ 2.5% of total Government R&D expenditure, and ~ 7.7% of "openly contested" R&D expenditure.

The view of the European Commission: EvaRIO (Evaluation of Research Infrastructures in Open innovation and research systems) is a Coordination and Support Action project funded by the European Commission under the 7th Framework Programme. EvaRIO developed an evaluation framework in order to provide guidelines for policy makers to optimise the resources dedicated to IROs. Since the early 2000s, the development and the coordination of large research infrastructures (IROs, also sometimes referred to as Research Infrastructures, RIs) have been increasingly recognized by the European Commission as an essential pillar of the building of the European Research Area, and hence of a competitive and dynamic European knowledge based economy. The Commission[2] states that "*(t)he processes of identifying, funding, designing, developing, constructing, managing and sharing such infrastructures are complex and costly. Yet the efficient and timely realisation of all these processes is vital to the healthy development and more rapid implementation of the European Research Area (ERA).*"

In summary the perceived benefits of IROs can be wider than the direct impacts on those researchers and enterprises that interact directly with them. Such wider benefits are not easily measurable but are, nevertheless, real. They include:

- IROs are platforms for open source knowledge exchange
- They are catalysts of collaborations and networks
- They have positive impacts on regional creativity.

As such, IROs are significant assets in the European RDI landscape. Membership of IROs has, of course, to be tailored to available resources. But in the development of Ireland's strategy in relation to IRO memberhsips, such wider, intangible benefits should not be overlooked.

Science

1. **Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?**

Our desk research has confirmed that membership of the IRO is essential to gain full access of the facilities, equipment and collaboration opportunities. A number of IROs have large procurement budgets that operate a formal or informal policy of 'juste retour' in relation to their memberships. Such a system operates in ESA, CERN and ESO. Irish researchers have developed links with IROs and with other European researchers without Ireland being a member, but this not a long term solution where the IRO is important to Irish science. This has been confirmed by comments from several experienced researchers during our interviews.

2. **Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?**

[2]EC, 2010. A vision for strengthening world-class research infrastructures in the ERA, Bruxelles: European Commission.
Available at: ec.europa.eu/research/infrastructures/pdf/era_100216.pdf.

The bibliometric analysis identified a significant cohort of active researchers in areas relevant to 6 IROs – ESA, EMBL, CERN, ESO, ESRF, ILL (see **Appendix 4** for details). Three IROs (CTA, LOFAR and ELIXIR) are new programmes and consequently have a low profile in the research literature. The number of publications detected for SKA, EMBC and ESS is very low. COST and EUREKA were not included as they are coordination programmes and their scope covers all fields of science.

It is clear that for 12 out of the 13 research fields identified through this search, the number of publications from Irish based researchers exceeds the collective number of research publications of the 6 IROs. Thus the Irish research system has significant capacity in IRO-relevant fields. For the research field "Medicine" the number of Irish publications greatly exceeds publications of the IROs. For the research field "Physics", however the number of publications from IROs is greater than the corresponding number of Irish publications by a factor of almost 2. This highlights the importance of IROs such as CERN, ESA and ESO in the performance of research in certain areas of physics and astronomy.

In general we can say with confidence there is a substantial, active research community in Ireland publishing papers in those research fields where IRO staff also publish. This community is certainly capable of benefitting from Ireland's membership of certain IROs.

3. Would/does membership add value to the impact of Ireland's research output/quality?

There are several IROs which very clearly contribute to national research output and/or quality and several which could do so. Among these, COST is the organisation with the most impact. Almost 90% of the researchers surveyed indicated COST as valuable, followed by EUREKA and ESA. COST was also identified in the HEI interviews as being a very useful programme for initiation of research collaborations by new faculty.

There is a further group of 7 IROs (EMBL, EMBC/EMBO, CERN, ESRF, ESO, ELIXIR and LOFAR), that attract a moderate level of interest among the surveyed researchers (between 12% - 23% of researchers); finally there is a group of 4 IROs (SKA, ESS, CTA, ILL) that are of interest to < 10% of researchers. Note that the survey included researchers in all fields.

The responses to the individual IRO organisations are outlined in **Table 3.1**. In summary, the researcher survey shows that there is a reasonably high level of awareness of IRO services overall, with the lowest levels of awareness being of the new IROs (ELIXIR, ESS, ILL) and the highest among the 'big brands' (COST, ESA, ESO and CERN).

The extent of awareness of an IRO is relevant in two ways. It is an indicator of the degree to which the IRO services are promoted by the responsible Irish agencies (if Ireland is a member); and also an indicator of the relevance of these services. IROs offering very useful services or facilities are likely to be known to potential users, with the caveat that new IROs (e.g. ELIXIR, CTA etc.) will not be known even to users who could value their services. In general, the older high-profile IROs are known to the majority of researchers, with COST, ESA, ESO and CERN leading the field at ~90% awareness (measured as a combination of 'very aware' and 'generally aware'). Among astronomy researchers, there is a high level of awareness (77 to 97%) of all four astronomy IROs.

Table 3.1: Survey Answers from Irish Researchers

	Column 2	Of those who responded 'YES' in Column 2				
	It is of interest to you in your research[1]	**Awareness of services[2]**	**Participation In services**	**Awareness of Irish membership**	**Important or vital**	**Main source of information**
Cost – a	238 (88%)	94%		92%	50%	CRO[4]
Eureka – a	116 (41%)	56%	27%	46%	18%[3]	CRO
ESA – a	105 (39%)	93%	59%	89%	47%	ESA
EMBL – a	60 (23%)	36%	53%	27%	37%	n/r
EMBO – a	54 (21%)	87%		67%		n/r
ESRF – b	54 (21%)	81%	28%	67%	90%[5]	n/r
CERN – b	51 (19%	94%	57%		48%	n/r
Elixir – b	40 (15%)	28%	75%	n/r	75%[5]	n/r
ESO – b	30 (12%)	97%	48%	90%	67%	n/r
ILL – b	24 (9%)	58%	25%	50%		n/r
LOFAR - b	32 (12%)		n/r	n/r		n/r
			Interested in services			
SKA – c	27 (10%)	96%	90%+	n/r	64%	n/r
ESS - c	24 (9%)	Low	100%	n/r	~80%	n/r
CTA – c	22 (8%)	77%	48%	n/r	67%	n/r

Notes: a. Irish membership; b. Currently in operation; c. Planned. n/r: not relevant.
1. Or your professional development. 2. Very or generally aware. 3. An additional 56% regard it EUREKA as useful. 4. College Research Office 5. Includes access to essential equipment

The low level of researchers (36% of all researchers surveyed) who are 'very aware' of EMBL services should be noted, particularly as a low level of promotion of EMBL services was highlighted in a 2008 review[3] of EMBL. This must also reflect a lower level of relevance of EMBL to this cohort of researchers.

4. Would/does membership enhance international collaboration of Irish researchers?

In general it can be said that membership and involvement in IROs stimulates new international collaborations for researchers. While this number can be small, they range from leading Irish research teams to those beginning the process of cultivating new networks and international collaborations.

The main observations on international collaboration are noted in the following elaboration of individual IROs.

COST: The major advantage was seen as being the opportunity to network, and this is also reflected in the interviews with Heads of Research in the colleges, who see it as a very important mechanism to enable network development, particularly for new researchers.50% of respondents regarded it as very

[3] CIRCA Review. 2008

or extremely important in '*developing international research collaborations*' and only 2% regarded it as unimportant in this role.

EUREKA: Only 31 of the surveyed researchers had actually participated in the programme. For these reasons, only 18% of researchers regarded it as being an important or vital programme, although 56% regarded it as useful. The majority of researchers receive information on the programme, mainly through their college research office. It should be noted however that EUREKA is a "close-to-market" programme and is of limited interest to much of the basic research community. It should also be noted that the involvement of Irish companies in EUREKA is relatively small – on average about 3 companies per year. Enterprise Ireland regards EUREKA as a low priority for Irish companies.

ESA: 47% of survey respondents regard ESA as very or extremely important with only 12% regarding it as unimportant in this role It is also regarded as important in 'developing international research collaborations', , .

EMBL: Of the 23% who said that EMBL was on interest to them, 37% in turn regarded it as of moderate importance in 'developing international research collaborations'

EMBO: Of the 21% who said that EMBO was of interest to them 67% in turn stated that it was regarded as being of slight or moderate importance in developing collaboration networks.

ESRF: If Ireland was to become a member, 52 respondents indicate interest in the following services: 21 Irish researchers would be interested to partner with ESRF researchers; 47 would seek access to 'beam-time'; and 12 would attend ESRF conferences or workshops.

CERN: CERN was highly valued as a mechanism to develop international research collaboration with 50% regarding it as being very or extremely important. The forms of this interaction are very varied: 34 researchers collaborate with CERN researchers; 28 had benefited from fellowships for their staff or students; and 27 had attended seminars or workshops. A submission was made by the Institute of Physics on the importance of CERN membership and is available at http://www.iopireland.org/publications/iopi/file_63378.pdf.

ESO: If Ireland was to become a member of ESO, the 30 respondents indicated that the services which would be of interest would be: 21 would seek access to ESO telescope time; 28 would seek access to ESO expertise; 21 would engage in research collaboration with ESO researchers; 20 would seek fellowships or training for their staff or students; or school outreach programmes. As a source of support for their research, 45% regarded ESO as being vital, 21% as important, and 31% as useful. Extensive comments were received on the value of ESO including a submission from the Institute of Physics which is available at http://www.iopireland.org/publications/iopi/page_63463.html

ILL: Five researchers had been involved in collaborative research with ILL in various areas (e.g. gamma-lens use; and neutron reflection experiments) and students of one PI had also been involved in research at ILL.

LOFAR: Almost all of this cohort of 32 researchers would seek involvement with LOFAR if Ireland was to become a member: 18 (60%) would seek access to LOFAR telescope time; 23 would participate in research consortia; 20 would collaborate with the planned LOFAR station in Birr; and others would

become involved in LOFAR programmes for students; or school outreach programmes. Note that LOFAR is a radio telescope facility, unlike ESO which is concerned with optical astronomy.

CTA: If Ireland was to become a member of CTA, the services which would be of interest would be: 11 would seek access to CTA telescope time; 12 would seek access to CTA expertise; 16 would engage in research collaboration in CTA projects; 21 would seek engagement in student fellowship or school programmes.

5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by becoming a member?

The Irish interviews identified a widely held view among the research community that Ireland does not contribute its fair share to European scientific endeavour and that this is an argument for joining certain IROs. On the other hand, many of the public research and development organisations argue that membership should be based on measurable benefits related to cost.

The French and German interviews confirmed that research performed at CERN or with CERN has an extremely high international reputation and a very high impact on careers. It is important for publications and for establishing scientific contacts and networks. CERN is now a "world" facility not just a European facility. Membership would add to Ireland's commitment to being a country of research excellence.

Education, Skills and Training

6. Would/does membership have positive benefits for education in Irish HEIs?

The interviews suggest that membership of IROs has immediate and long term benefits for any researcher at any level who avails of large scale equipment usage, training or collaboration opportunities of the IRO. New collaborations extend existing networks and create further opportunities for colleagues and team members of the Irish collaborator. In addition, there will be the diffusion of research results, exposure to other IRO project results and new ideas to colleagues and students in the HEIs.

7. Would/does membership enhance the profile of human capital output from Irish HEIs?

Yes, in general students studying under internationally recognised scientists benefit from the experience and such scientists attract very high quality students in Ireland and internationally.

In addition, many of the interviewees commented that researchers with CERN and ESO experience (e.g. hardware development, computing skills, and data analysis) easily find jobs in industry, as the specific skills acquired at either IRO cannot be gained elsewhere.

8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?

Yes, but it must be borne in mind that the numbers of such trainees are small each year, probably in the order of 10 per IRO, and that the opportunity is mainly in the large IROs such as CERN, ESO, EMBL etc. Equally, it should be noted that the opportunity is for the best young researchers to work with the best in the world, and with the best equipment available. It is an efficient way of developing international level expertise provided the areas are important to Ireland.

Industry

9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?

It is difficult to answer this question due to the low level of response from industry. The only organisations which were indicated as being of interest to more than 10% of industry respondents are Eureka, COST and Elixir. However, the experience of Irish involvement with ESA would suggest that Irish companies are capable of taking advantage of membership of other IROs also. Both CERN and ESO offer opportunities for supply of a wide diversity of high-tech products and services, while ELIXIR offers potential for involvement in collaborative research. There is no reason to suggest that Irish industry would be less active or successful in these programmes than it has been in ESA. Information that we received from CERN confirmed that about 30 Irish companies have already been awarded contracts within the past 5 years to supply goods or services to CERN. Although CERN gives priority to companies from its member states, it is also open to doing some business with companies from other states on a "value for money" basis. It is reasonable to suppose that with membership of CERN this business activity would increase. A spokesperson from CERN has said to us as part of this evaluation ..." This is a very good starting point to building up an industrial collaboration between CERN and firms in Ireland. We would expect that this collaboration with industry in Ireland to be strengthened and enhanced through Membership."

10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?

There are clear opportunities in some of the IROs and particularly CERN (which has a *juste retour* policy), and ESO (which does not have a *juste retour* policy, but which will provide supports to encourage industry in member countries which have low levels of industry contracts). ELIXIR is mainly offering collaboration and other services and has little need for direct purchase. LOFAR is a special case in that it is the only IRO which will have an active node in Ireland which is uniquely involved in servicing the IRO. Although the main equipment required will be supplied by the Dutch managers of LOFAR, other needs are likely to be locally supplied. For example the structural foundations for the LOFAR equipment will be sourced from local experts in foundation engineering. In addition, LOFAR (and ESO) will be major generators of massive data-sets which will require analysis. Industry and other sources interviewed noted the particular value of participation in this research. To quote one major Irish company CEO "*LOFAR will be a proving ground for new approaches in transmission, correlation and analytics, way ahead of their general application by industry… LOFAR scientists will continue to improve the existing systems which are a combination of hardware and software, and Irish graduates and post-docs will have exposure to these problems, and I believe will benefit Irish industry*"

11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?

Yes. We have already mentioned above the example of CERN which would be likely to increase its socio-economic interaction with Irish companies in the event of Irish membership. Our desk research has confirmed that the socio-economic benefits arising from interactions with IROs is greater when the quality of the relationship between the supplier and the IRO is stronger. This applies at the level

of individuals and companies, but it also applies in a more general way to countries, as confirmed by the European Commission's EvaRIO report.

12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?
As noted above, this is not relevant to all IROs but does apply to ESA, ESO, CERN, and CTA.

13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?

As noted above, this is not relevant to all IROs but the larger facility-based organisations (CERN, ESO etc.) do offer these opportunities. The experience of ESA is that Irish companies have been effective in finding and exploiting these opportunities. It has been pointed out in interviews that ESO and CERN both offer greater opportunity for participation by companies with developing technologies. This is because, as land-based organisations, they can trial technologies at earlier stages of development than ESA.

14. Would/does membership of the organisation support and promote collaboration between individual companies and between companies and 3rd level research?
This is not a particular purpose of either of the major facility-based IROs. However ELIXIR will certainly provide this opportunity and both Eureka and COST are already doing so.

STEM/Outreach

15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?
All of the organisations which are indicated as membership candidates offer these opportunities to some extent. Both ESO and CERN have outreach and education programmes; while LOFAR would provide a very strong and permanent platform for education in that it will be based in Ireland and its plans already include a visitor centre. ELIXIR has less opportunity for such action, but would have some level of such involvement.

Summary of the Surveys and Irish, French and German Interviews

In addition to our web and email surveys, we also carried out many hours of desk study, and spent about 30 – 40 hours involved in interviews and consultations with some very experienced researchers and research leaders in Ireland and internationally. Because of varying perspectives and viewpoints, it is not easy to summarise the total outputs of these interviews. The comments below capture some of the flavour of the comments we received from these interviews. **Appendix 5** contains more detailed points and some more general comments.

- The goal should be for Ireland to be seen as the best small economy for turning research investment into long term impact on societal outcomes.
- Ireland's exploitation of international scientific infrastructures is too low.
- There is strong support for membership of ESA and COST.
- Strong interest in, but also some mixed views, about EMBL, CERN, ESO, and ELIXIR.
- EUREKA is valuable for Irish SMEs, of less interest to the HEI sector.

- SFI promotes both EMBL and EMBO, but the interest level among the research community seems to be low.
- Membership of certain IROs (e.g., ELIXIR) facilitates access to substantial H2020 Research Infrastructure funds through ESFRI[4].
- There is a lower level of interest in ESRF, ILL, LOFAR, ESS, SKA, and CTA.
- The priority for the Synchrotron researchers is not IRO membership, but support for Trans National Access (TNA) to a variety of IROs via H2020.
- Both CERN and ESO are important to groups of researchers in Ireland. Apart from their scientific benefits, they both have effective outreach programmes.
- German and French researchers are very positive about the benefits of membership of CERN, ESO, ESRF, and ILL. For example, research in cosmology and galaxies requires experiments at ESO.

National IRO Support Services

The cost of participation in IROs includes not only the membership and related fees due to the IRO itself, but also the costs of the supports that are required to ensure that Ireland gets the full benefits from membership. These supports are of the following nature:

IRO administration and representation costs: Membership of IROs will generally entail participation in governing boards and (depending on the scale and complexity of the IRO) on sub-boards dealing with finance, fellowships, strategy etc. This will require allocation of staff from a responsible Department/Agency to service these boards. There will be an allocation of time for these staff to attend meetings and/or provide information and inputs required to ensure that Irish needs and expectations for membership are met. This is a vital aspect of involvement in IROs and it is important that the Irish representatives have direct knowledge of Irish needs. The resource requirements for these activities is difficult to calculate without knowledge of the detail of the IRO administration processes, including number of committees requiring representation, frequency of meeting and the nature and format of information required.

IRO services promotion. Membership of an IRO is of limited use if potential Irish beneficiaries are not aware of the opportunities available. It should be noted that the majority of companies surveyed were not aware of the services and programmes offered by COST, Eureka or EMBL, of all of which Ireland is a member. Although the research community is better informed about IROs, there are still some indicators of concern.

Promotion of IRO services is generally conducted by a Government agency (e.g. EI or SFI) with access to communication channels to target beneficiaries. Enterprise Ireland, for instance, is promoting COST in association with its function of managing national H2020 participation. The high levels of researcher awareness of COST (94%) would suggest that this promotion is effective in the research community, but less so among companies (37% aware). EMBL promotion is handled by Science Foundation Ireland and only 36% of 'interested' researchers were 'very aware' of the services offered by this IRO. In summary, promotion of IRO services is a complex task as the beneficiaries are often diverse, and

[4] ESFRI = European Strategy Forum on Research Infrastructures

the services are specialised and often occasional. If Ireland is to participate in further IROs, a system must be put in place to ensure that effective and comprehensive promotion of IRO services is undertaken. Once again, the scale of activity to achieve this must be related to the scale of services offered by the IRO, and to the diversity of beneficiaries among different sectors and organisations.

Outreach Activities. Some IROs offer significant activities in outreach to the public and schools with attendant benefits to Ireland in encouraging participation in science, and in supporting teaching programmes. This activity must also be supported appropriately at a national level. This can be done through existing agencies (SFI, Dept. of Education etc.), but it will require some additional funding and staff resources even if the IRO provides staff and materials.

Supports for IRO participants. When interested Irish participants have been made aware of useful opportunities, Irish agencies must able to provide appropriate supports to ensure effective participation. The forms of supports include:

Travel grants: The simplest form of participation is attendance at IRO meetings, conferences and training sessions. Researchers and companies may also require travel support to use IRO equipment and expertise for specific experimental purposes. Irish researchers and others will require support for this travel.

Fellowships & Studentships: Support for longer stays by students or researchers at IRO facilities may require supports both for travel and subsistence over longer periods. Note, however, that some IROs provide such fellowships to member countries.

Collaboration grants. A major purpose of many IROs is to facilitate collaboration among member country researchers, usually focussed around use of IRO equipment. Grants to facilitate such research collaboration may also be necessary.

Some of these forms of support are already in place through SFI and IRC, but additional funding, or additional measures may be required depending on which IROs might be joined.

Supports for IRO procurement. A major benefit of the larger IROs (ESA, ESO, CERN etc.) is that Irish companies could have protected access for supply of goods or services to the IRO. The only IRO (of which Ireland is currently a member) which provides this opportunity is ESA and it has been shown to be a significant benefit for Irish companies and a major justification of Irish membership. If Ireland were to join ESO or CERN, a process for promotion of procurement opportunities and for supporting this process would have to be developed. The supports required are diverse, and include informing and training companies in the relevant procurement procedures and processes; ensuring that potential bidders for IRO contracts are in compliance with IRO specifications; and promotion of tender opportunities etc. This will require a significant resource within Ireland. The experience of catering for ESA opportunities will be a definite advantage, and it may be that some synergies may be found between the existing ESA support resource and supports needed for other high-tech IROs such as ESO or CERN. It is noted that the existing ESA supports are deemed (in the recent review (Evaluation of Ireland's Involvement in the European Space Agency, March 2015, by Technopolis) to be under-resourced. In summary, membership of additional IROs will require extra manpower within appropriate agencies; and also financial resources for servicing membership, for promotion, for supporting Irish participants, and for supporting Irish companies to bid for procurement opportunities.

Costs of these National Supports

The above portfolio of national supports is already in place for ESA, and is provided by a team of 5 people – 2 from DJEI, and 3 from EI (or about 4 persons FTE). The estimated costs of these services(including significant travel budgets to multiple overseas monthly meetings held in Paris or Rome) is in the range~3 - 4% of the ESA annual membership costs. This serves as an indicator for the national support costs of other IROs where significant procurement opportunities may exist for Irish contractors – e.g. CERN, ESO. Such costs would be lower for other IROs – e.g. COST, EUREKA, EMBL, EMBO/EMBC, ELIXIR, and LOFAR. In the case of these IRO's, a reasonable estimate of support costs would be the costs of one Departmental or Agency staff member (full time or part time, as the case may be) who is responsible for representation and promotion of the IRO in question, including some travel and promotion costs.

Membership of additional IROs will require support in Ireland, particularly where competitive industrial procurement contacts are available and where researchers can gain considerably through new collaborations and partnerships.

The average IRO requires representation and policy inputs from Department officials and the scientific community. Typically, this involves 20% - 50% of one person's time. Experience from other countries strongly indicates that two sorts of additional supports are necessary to ensure Ireland gains the optimum advantage from its membership:

1. A scientific coordinator to promote and coordinate the scientific, training and collaboration opportunities of membership. Finland took a number of years and the establishment of a special scientific unit to derive real benefit from its membership of CERN. Typically such a unit requires funds to resource its efforts in supporting research staff, visits and training.
2. A procurement unit, with strong industrial linkages, to assist SMEs secure meaningful supply contracts. Israel has been very successful in securing a 'juste retour' from CERN. For example Israeli governmental agencies organised an "Israel Innovation Day" at the CERN premises in Switzerland in October 2013 at which selected Israeli companies were able to display their products/services and technologies directly to CERN scientists and procurement officers. See http://itrade.gov.il/switzerland/events/israel-innovation-day-cern/

Ireland's experience with ESA supports the two points above. Ireland has 3 people at the procurement level and two part-time people performing the representation role. Their work is very successful.

Chapter 4: IRO Profiles and Benefit Assessment

In this chapter we provide a brief profile of each of the 14 IROs under review with a focus on reasons for and against Irish membership of each. Each of the 15 criteria set out in the Terms of Reference and captured in our assessment criteria is addressed by a brief statement of the key facts or validated opinions emerging from the range of interviews, surveys, bibliometric analyses and secondary sources used in the methodology

The robustness of the data used and the analysis undertaken was verified by the individual team members undertaking the analysis separately, comparing results and discussing differences. The effect of any differences was also assessed in terms of their impact of the outcomes. In reality the differences were minor and had insignificant impacts on the outcomes. So the outcomes are robust and reliable.

European Space Agency - ESA

Background

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. ESA is an international organisation with 20 Member States. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

Main Features and Research Themes

ESA's programmes are designed to find out more about Earth, its immediate space environment, our Solar System and the Universe, as well as to develop satellite-based technologies and services, and to promote European industries. ESA also works closely with space organisations outside Europe. ESA's work is relevant to scientists and engineers of many disciplines, and also to information technologists.

Structure

ESA is an inter-governmental organisation. The Council is ESA's governing body and provides the basic policy guidelines within which ESA develops the European space programme. Each member country is represented on the Council and has one vote, regardless of its size or financial contribution. ESA is headed by a Director General who is elected by the Council every four years. Each individual research sector has its own Directorate and reports directly to the Director General.

ESA headquarters are in Paris which is where policies and programmes are decided. ESA also has sites in a number of European countries, each of which has different responsibilities. ESA also has liaison offices in Belgium, USA and Russia; a launch base in French Guiana and ground/tracking stations in various parts of the world.

There are around 2,200 staff working for ESA, from all the member countries and include scientists, engineers, information technology specialists and administrative personnel. ESA's mandatory activities (space science programmes and the general budget) are funded by a financial contribution from the entire Agency's Member States, calculated in accordance with each country's gross national

product. In addition, ESA conducts a number of optional programmes. Each Member State decides which optional programme they wish to participate in and the amount they wish to contribute.

ESA's budget was €4,102 million for 2014 and it operates on the basis of geographical return, i.e. it invests in each member country, through competitive procurement contracts for space programmes, an amount that is more or less equivalent to each country's contribution. Furthermore, ESA has an SME database which gives SMEs the opportunity to communicate their services and facilities to both ESA and also many other companies in Europe.

Further information at: **http://www.esa.int/ESA**

Membership Fees

Irish fees for mandatory programmes were €9.1m in 2014, up from €4.1m in 2000; and contributions to optional programmes were €8.6m in 2014 up from €3.1m in 2000.

Table 4.1: ESA Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes. Membership is also necessary to participate in optional programmes. Contributions to optional programmes were €8.6m in 2014
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but it is a small base (number: 30-50 researchers). Currently 32 researchers are involved in ESA and this number has grown since 2010
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it confirms our high tech development capability.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, high prestige values. And fits with Government strategy for economic development and H2020.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, participation has high value to our high tech image and assists in attracting FDI and encouraging HPSUs.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, HEI involvement enhances their international reputation.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Yes
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	Yes, proven in four evaluations since 2000 and over 90 companies have been involved. At the end of 2014 more than 45 Irish companies were actively engaged on ESA contracts.

10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	Yes, they already have. The 45 Irish companies involved in ESA had a turnover of €17m in 2008 which is projected to be €70 million by 2015. Related employment is set to grow from 1,300 in 2008 to a projected 2,000 in 2015. Enterprise Ireland fully supports Ireland's membership of ESA.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	A number of ESA projects have direct relevance to public policy programmes such as ESA's Earth Observation programme, which can monitor and manage relevant environmental and societal issues related to climate change, including natural disasters such as flooding, and provide information for agriculture and forestry land use.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Yes – pro-rata procurement opportunities, which requires additional Irish support from Enterprise Ireland
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, 32 Irish researchers are involved in development projects which could result in some new spin-outs
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes, as they are largely development projects requiring high levels of scientific/engineering inputs.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Yes, large media and youth interest in ESA's activities. Ireland is also involved in ESA's European Space Education Resource Office's (ESERO) education project for STEM and this has led to a ESERO office in Dublin co-funded by SFI.

Summary

By any measure Ireland's membership of ESA is very positive – it recoups its membership fee, helps develop the expertise of Irish companies, helps generate increased turnover in Irish companies, generates new jobs at a lower cost than other national supports, supports researchers in the third level sector, enhances Ireland's technical reputation internationally, and encourages secondary level students to pursue careers in STEM. Membership should be continued and more optional programmes should be joined provided the benefits are maintained. It should be noted that there are necessary support costs. ESA requires 5 people (4 full time equivalents) to manage Ireland's participation in ESA, this is a cost of at least €400,000- €450,000 per annum[5]. The recent report by Technopolis states that an additional 2 staff would help exploit Ireland's current investment more fully.

[5] *Based on a Principal Officer's salary (€80,000) plus Enterprise Ireland's overheads of 40% = 112,000 per annum. The travel cost involved may be more than average EI travel costs.*

EUREKA

Background

EUREKA is an intergovernmental network launched in 1985, to support market-oriented R&D and innovation projects by industry, research centres and universities across all technological sectors. It is composed of 41 members, including the European Union represented by the Commission. It is distinguished from other European programmes by its focus on linking knowledge acquisition to early exploitation in the market place. It makes a significant contribution to building the "European Research Area".

Main Programmes

EUREKA facilitates collaboration between participating companies. Funding generally comes from the companies themselves and from the EUREKA member countries via national industrial R&D support schemes (in the case of Eurostars projects, there is also some funding from the EU Commission). The internationally recognised EUREKA label adds value to the selected projects and gives participants a competitive edge in their dealings with financial, technical and commercial partners.

The EUREKA programme consists of a number of sub-programmes.

- **Individual EUREKA projects** are led by SMEs (bottom-up) and involve a partnership of at least 2 EUREKA member states and are market oriented. Partners can consist of SMEs, large companies, research organisations and universities.
- **EUREKA Clusters** are long-term, strategically significant initiatives. They usually have a large number of participants and aim to develop generic technologies of strategic importance to Europe, particularly in ICT, Energy and Biotechnology.
- **EUREKA Umbrellas** are thematic networks within the EUREKA framework which focus on a specific technology area or business sector. The main goal is to facilitate the generation of EUREKA projects in its own target area.
- **The Eurostars Programme** is a Joint Programme involving EUREKA and the EU Framework Programme /Horizon 2020. Eurostars aims to combine the better of two worlds with a bottom-up approach, a central submission and evaluation process, and synchronized national funding in 33 countries. Eurostars projects must involve at least two participants (legal entities) from two different Eurostars participating countries. In addition, the main participant must be a research-performing SME from one of these countries. The consortium should be well balanced, which means that no participant or country will be required to invest more than 75% of the total project costs.

  A Eurostars project should be market-driven; it must have a maximum duration of three years and be within two years of project completion. The product of the research should also be ready for launch onto the market on completion. For the duration of Horizon 2020 (2014 – 2020) a budget of €1.15 million EU is foreseen, with the remaining funds coming from member countries and participating companies.

Structure

The structure of EUREKA has many similarities to the structure of COST. There are ministerial conferences, a High Level Group (HLG) – the main decision making body - an executive group (EG) which implements the decisions of the HLG, and National Project Coordinators (NPCs) who run the national EUREKA offices at an operational level, and who are in direct contact with the project participants.

Further information at:

http://www.enterprise-ireland.com/en/Research-Innovation/Companies/Access-EU-Research-Innovation-reports/EUREKA.html

Membership Fees

The Irish membership fee is €33,000 per annum.

Table 4.2: EUREKA Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it confirms our high tech development capability.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, high prestige values. It also fits with Government strategy for economic development and H2020.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, participation has high value to our high tech image and assists in attracting FDI and encouraging HPSUs.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, HEI involvement enhances their international reputation.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	No, not relevant.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	Yes, it stimulates and supports Irish SMEs to undertake R&D. For example in Eurostars 72% of project partners are SMEs and all projects are led by SMEs.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	No, it is a competitive, non-funding programme. It facilitates partnerships.

11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	Yes. Enterprise Ireland believes that EUREKA is minor but useful R&D programme for its clients. The "EUREKA label" is also of benefit to SMEs in that it can be attractive to potential investors and assists in securing national R&D funding from Enterprise Ireland.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Not relevant.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, through partnership with other SMEs.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	No.

Summary

Ireland's membership of EUREKA is positive – it is very low cost and it stimulates partnerships in high quality R&D projects. Enterprise Ireland believes that EUREKA is a practical and useful R&D programme for its clients. However, although EI provides grants of >€1m p.a. in support of EUREKA participation, it regards EUREKA as of minor relevance in its overall efforts to encourage industrial R&D. This is because the level of Irish participation is low – in the past 20 years only about 60 Irish companies have participated in EUREKA projects. This is despite the fact that 40% of IRDG members said they were interested in EUREKA, and 13% were very aware of EUREKA. It encourages international partnership, networking and collaboration, and adds international market learning to Irish SMEs. The endorsement of EUREKA can be of benefit to Irish SMEs. More promotion could be beneficial. Membership should be continued.

Cooperation in Science and Technology - COST

Background

COST is the oldest and widest European intergovernmental framework for transnational Cooperation in Science and Technology. It is a pan-European networking instrument, which is also open to global cooperation, based on mutual interest.For more than 40 years COST has supported the networking of research activities across all its Member countries (36 today) and beyond. Cost plays an important role in building the "European Research Area".

Main Features and Research Themes

COST does not fund research itself, but funds networking activities carried out by COST participants. It is open to all disciplines and organisations, big and small, public or private. It is also open to researchers at all career stages – young researchers and experienced researchers.

COST has links to the European Framework Programme (now Horizon 2020). COST's budget comes largely from this source. COST received a budget of ~ €250 million from FP7 in the period 2007 – 2013. It expects to receive increased levels of funding from Horizon 2020. COST networking support is approx. €5,000 - €6,000 per annum, per member country, per COST Action.

COST Actions are bottom-up science and technology networks, open to researchers and stakeholders**,** with a four-year duration and a minimum participation of five COST Countries. COST Actions are implemented via a range of networking tools, such as meetings, workshops, conferences, training schools, short-term scientific missions (STSMs) and dissemination activities**.** There are currently ~ 300 COST Actions in operation.

COST operates mostly at or towards the "Basic Research" end of the "Research – Innovation" spectrum. COST manages its work on the basis of "COST ACTIONS". A typical "COST ACTION" receives financial support averaging €130,000 per year for a four-year period. COST ACTIONS are classified into 10 S&T domains, which cover the entire research spectrum. These include: Biomedicine, Food, Forestry, Materials, Chemistry, Earth Systems, ICT, Transport and Social Sciences. There is also a domain for multi-disciplinary work.

Structure and Membership Fees

COST is an inter-governmental organisation. The main features of its overall governance are:

(1) **Ministerial Conference:** Every five years, a COST Ministerial Conference reaffirms its support for COST as a unique instrument for leveraging nationally-funded research activities.
(2) **Committee of Senior Officials (CSO)**: is a decision-making body within the COST Association. It is responsible for the strategic development of COST. It is composed of representatives from COST Member Countries and the Cooperating State, Israel. The CSO has full power to achieve COST's goals. In particular, it decides on the overall COST strategy and policy.
(3) **Executive Board (EB, former "JAF")**: the group consists of at least seven members including the CSO President and the Vice-President. Its role is to supervise and monitor COST operations.
(4) **COST National Coordinators (CNC):** Each COST Member Country and the Cooperating State nominate one COST national coordinator. The role of the National Coordinator (CNC) is to nominate delegates to Domain Committees, and COST Action Management Committees, while accepting the COST Actions' Memorandum of Understanding and to advise and inform scientists and institutions in their countries on all COST related matters.

Further information at: http://www.enterprise-ireland.com/en/Researchers/EU-Programmes-and-Networks/COST.html

Membership Fee

The membership fee is approx. €1,600 per annum.

Table 4.3: COST Assessment Criteria	
Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, Ireland currently participates in about 190 COST Actions.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it confirms our high tech development capability.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, the main benefit of participating in COST is the opportunity it provides for Irish researchers to join international networks of peer researchers, working on research topics of mutual interest. It is widely recognised that active participation in such research networks is a key factor in building a research reputation, and in building a successful research career.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Generally no, participation has high value to our high tech image and assists in attracting FDI and encouraging HPSUs.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, HEI involvement enhances their international reputation. Such networks can, and sometimes do, form the basis for an application to research funding programmes such as Horizon 2020.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	No, the projects (work) is located in Ireland
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	Yes, in principle all COST actions are open to researchers from industry, and industry is capable of taking part.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	No, not relevant.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	Yes
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	No, not relevant.
13. Would/does membership of the relevant organisation provide access to capabilities which	Yes.

will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes, as they are largely development projects requiring high levels of scientific/engineering inputs.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	No.

Summary

By most measures, Ireland's membership of COST is very positive –it helps develop the careers and expertise of Irish HEI researchers, encourages collaboration and networks, enhances Ireland's technical reputation internationally and its costs are low. Our survey of Irish COST participants shows that they are very supportive of COST and fully appreciate the opportunities it supports. Although the number of company participants is believed to be relatively low, it is considered valuable to Irish companies. It is very difficult to be definite about the number of Irish company participants because the participants in each COST Action are identified by country (e.g. France, Germany, Ireland etc.).

The support costs are very low in comparison to the number of Irish researchers involved and the importance of COST in their career development. The national support is one person in Enterprise Ireland. Membership should be continued and more optional COST Actions should be joined provided the benefits are maintained.

European Molecular Biology Laboratory - EMBL

Background

EMBL was established in 1974 as a European Inter-governmental research organisation to strengthen basic research in molecular life sciences. Its primary function is to operate a high quality research institute in which member country researchers and students may work to enhance their skills and networks. It has also been active in developing research facilities in areas of European need. It currently has 21 member states, and several prospective and associate members.

Main research themes

- Cell Biology and Biophysics
- Developmental Biology
- Genome Biology
- Structural and Computational Biology
- Mouse Biology
- Bioinformatics

Structure

EMBL has 1400 research, technical and admin staff on five sites. The main Heidelberg site houses four research units. Two structural biology outstations in Grenoble and Hamburg are located adjacent to synchrotron and neutron radiation facilities, and undertake research and also provide the infrastructure and assistance to life science researchers seeking access to these facilities. EMBL also founded the European Bioinformatics Institute (EBI), in Hinxton in England, which designs, builds, maintains and provides data resources and bioinformatics tools to a global user community, and has research on extraction and analysis of biological data. The outstation in Monterotondo, Italy, is devoted to the study of mouse biology and has expertise in mammalian physiology and mouse models of human disease.

EMBL core mission is to:

- Perform high quality basic research in molecular biology
- Train scientists, students and visitors at all levels through courses, conferences and workshops.
- Provide Post-grad training.
- Provide training on advanced instrumentation, and also provide access to specialized instrumentation, for scientists in:
    - Advanced light microscopy, and Electron microscopy
    - Chemical biology
    - Flow cytometry
    - Transgenics, Genomics, Proteomics and Protein expression and purification
    - Monoclonal antibodies
- Provide a range of other vital bio-informatic and other services to molecular biology researchers (www.embl.de/services_general/index.html).
- Develop new instruments and methods as part of their R&D activities.
- Transfer this technology to industry through their affiliate company Emblem which holds and licenses patents on EMBL technologies.

Industrial opportunities

In addition to the research and training opportunities, EMBL develops new technologies and instrumentation which are available for licence to member states through EMBL Enterprise Management Technology Transfer GmbH (EMBLEM). It also houses scientific core facilities which are mainly used by EMBL researchers but are also accessible to visiting scientists and industry. Currently, EMBLEM manages a portfolio of 250+ patents/copyrights and 400+ license contracts. Its technology portfolio includes enabling technologies, molecular tools and techniques, instruments and devices as well as software programmes and databases. However, these are much specialised technologies mainly relevant to laboratory processes (e.g. mouse models, lab software and reagents). The indications are that such licenses tend to go to large European scientific manufacturing companies and there are few opportunities for small countries and companies. Due to the nature of the research, there is little opportunity for component sub-supply, and no *juste retour* system is in place.

Further information at: http://www.embl.de

Membership Costs

The Irish membership fees are €1.14m per annum.

Table 4.4: EMBL Assessment Criteria	
Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Although there is a significant base of life science researchers and its application is a national research priority, the range of opportunities for interaction with EMBL is small. Interaction with EMBL is facilitated through Alumni Associations.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it assists international collaboration. It stimulates and supports Irish researchers to undertake R&D through • Participation in EMBL research networks as collaborators, staff or students • Participation in EMBL conferences or courses.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, high prestige values. And fits with Government strategy for economic development and H2020.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, more so in the research world than with companies. EMBL is regarded as a top world institute and an EU flagship in this field.Ireland is represented on the EMBL board by SFI.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, Irish third level organisations and individuals can benefit from EMBL membership through: ○ Training on advanced instrumentations through visits or courses. ○ PhD and Post-Doctoral Programmes. Currently 240 students are enrolled in a four year PhD programme, including Irish students. Students of all Nationalities may apply, but only those from member states are eligible for internal EMBL fellowships.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes. There is a unanimous view among the research community that experience of EMBL is a major benefit to researchers during their training, i.e. the potential impact of EMBL on training of Irish researchers is therefore significant.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Yes. EMBL has developed several facilities which support European life science research, including the European Bioinformatics Institute (EBI), Mutant Mouse Archive etc. Access to these is facilitated by membership.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	No. However, it should be noted that EMBL is by definition a basic research facility and direct commercial interest in its research programmes would not be expected.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	No.

11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	No.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	No.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	No.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	No.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Membership can support Irish STEM activities by secondary school teacher training and development through lab placement programmes and courses with the objective '*to bring concepts of molecular biology into the classroom*'. EMBL also produces student magazines.

Summary

EMBL was established to become a flagship centre of expertise in Europe in the molecular biology area, and to develop and enhance the quality of member country expertise. It has undoubtedly maintained this role; it attracts the best researchers, provides collaboration opportunities, and continues to train high quality researchers. A small number of Irish researchers have worked or been trained in EMBL, and some have filled senior positions and/or lead large collaborative projects. However, it is arguable that its role has become less critical over time as many member countries, including Ireland, have developed their own capabilities and institutes.

The issue for this study is whether the benefits to Irish researchers are justified by the cost. For this purpose, CIRCA has been provided with a series of questions through which these benefits should be reviewed. If this yardstick is applied, in our view EMBL does not justify the cost of membership due to the small scale of participation. EMBL is unusual among the IROs in that it provides few direct services to its members. The other IROs can be broadly grouped into those which either provide major items of equipment (CERN, ESA etc.); and those which provide central coordination, training or other services (e.g. COST, EMBC/EMBO, Elixir, Eureka etc.). EMBL does neither of these. The membership fee is mainly allocated to performance of research within EMBL laboratories. Member country researchers may participate in this research if they meet the high quality standards which rightly apply. EMBL does provide some other services such as short-term training, conferences and fellowships. It has also been active and effective in developing valuable facilities for support of research. These include EBIS and the Mutant Mouse facility, and more recently the ELIXIR programme.

Two reviews within the last 10 years have shown that Irish researchers are generally unaware of EMBL and its offerings, and this is unsurprising as the benefits are available to only a very small group of researchers.

In summary, if the template is applied to EMBL, the membership fee of €1.14m does not represent good value for the overall Irish research community. However, it should also be recognised that

withdrawal from EMBL would have significant political consequences. It would undoubtedly be presented by some as an indication that molecular biology is not a national priority. Given the nature of EMBL and the fact that its alumni are among the leaders in EU life science research, major figures in international research and other organisations would likely be drawn in, and significant negative media attention would undoubtedly result. This would need to be carefully considered in making a decision to withdraw.

European Molecular Biology Conference – EMBC/EMBO

Background

EMBC was established in 1969 to support the activities of the European Molecular Biology Organisation (EMBO) which had been setup by leading molecular biology scientists in 1964. The original goal of the founding researchers was *"… to promote molecular biology in Europe and neighbouring countries by fostering talents, disseminating new ideas and knowledge among European scientists and by encouraging cross-boundary collaborations*."

Main research themes

EMBC covers all areas of molecular biology.

Structure

The European Molecular Biology Conference (EMBC) is an inter-governmental organization comprising 27 Member States including most of the European Union and some of the neighbouring countries. It is a high-level body through which member countries agree on activities to be undertaken to promote and support molecular biology in Europe. These activities are executed on behalf of EMBC by EMBO. They include a disparate range of education and training, awareness-raising and publishing activities.

The European Molecular Biology Laboratory (EMBL) was created by EMBC in 1974 as a Special Project and is now an independent organisation of which Ireland is also a member. However, EMBO and EMBL work closely together and '*synergize their efforts to advance the molecular life sciences in Europe*'. They are also located on the same site in Heidelberg, Germany.

The main elements of the EMBC General Programme are:

- **EMBO Long-term Fellowship Programmes:** supports 500 post-doctoral fellows per year.
- **EMBO short-term Fellowship Programmes** (1 week – 3 months for under and post-graduate students): supports 200 short-term fellows per year.
- **Young Investigator Programme** which supports *'young group leaders in Europe who are in the first phase of setting up their independent laboratories'*. It funds the establishment costs, visits to collaborators etc. 250 scientists have been supported since 2000.
- **EMBO Courses, Workshops, Symposia and Lecture Programmes:** provides support for top scientists to run relevant events. EMBO supports approximately 75 such events per year and approximately 8,000 scientists participate.
- **EMBO Science Policy Programme**, which is aimed at contributing towards a European view in life science research policy by coordinating interaction between researchers and policy-makers.

- **EMBO Scientific publications** which include the EMBO Journal, EMBO reports, Molecular Systems Biology and EMBO Molecular Medicine. These are among the top 30 scientific publications in their field.
- **Other special programmes** such as, Women in Science and Strategic Development Installation Grants (to support new research labs in peripheral countries).

EMBO is run by scientists and it currently has more than 1700 members, who are leading life scientists in Europe and worldwide. Seventy-nine EMBO Members have been honoured with the Nobel Prize. The EMBO Members guide the organization's programmes and activities.

Further information: http://embc.embo.org/

Membership costs:

The Irish membership fees are €210,000 per annum.

Table 4.5: EMBC Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes. A significant number of researchers are involved in this field and its application is a national research priority.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it assists international collaboration.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, high prestige values. And fits with Government strategy for economic development and H2020.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, more so in the research world than with companies.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, Irish third level organisations and individuals can benefit from EMBC membership through: ○ Participation in conferences, workshops ○ Development of networks.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, through conferences and workshops
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	No, not relevant
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	No.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services,	No.

and/or new technologies required for new projects and developments?	
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	No.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	No.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	No.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	No.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Little effect on STEM.

Summary

Irish research performance in molecular biology is of very high quality in terms of publications and citations. EMBC membership is important in that it provides many researchers with the opportunity of participating in European and international conferences, workshops and seminars, thus encouraging more networks, collaborations and partnerships. But, as with EMBL, the level of awareness and interest among Irish scientists is low. This is a surprising result as EMBC, and its executive organisation EMBO is effectively led by researchers and its views are defined by researcher opinions. It illustrates the challenges in promoting any IRO membership. Dedicated supports are necessary but they have to match the potential benefits.

There are no industrial opportunities or benefits other than the indirect benefits of the overall enhancement of the research quality and level of activity of molecular biology in Ireland that may assist in attracting FDI to Ireland.

CERN

Background

The primary mission of CERN is to understand the fundamental nature of the universe, basic research in which 14 Nobel prizes have been awarded in the last 50 years. In 2012, CERN announced the discovery of the Higgs boson particle, the proponents of which received the 2013 Nobel Prize for physics.

Main research areas/programmes

The technology developed through this research has given us accelerators and new detectors, as well as making major contributions to micro-electronics and computing. Accelerators are important for radiotherapy in medicine, materials engineering, and imaging atomic structures in biology and chemistry. Detectors have applications in security, non-destructive testing, and medical imaging. Micro-electronics and computing developments at CERN push the boundaries of ultrafast data acquisition and processing (Big Data).

Technology that we take for granted today, such as the Web, touch-screens, and medical PET scanners (developed 40 years ago), all have their genesis in fundamental research at CERN.

CERN is heavily involved in **Applied Science, for** example*:*

- **Medicinal:** The focus at the moment is on imaging equipment and Hadron Therapy for cancer (CERN is working to develop cheaper forms of this new therapy that can destroy more cancerous tissue without damaging nearby healthy tissue – the technology is currently very expensive and only available at 32 hospitals worldwide).
- **GRID computing and big data collection** (CERN is expanding its data centres around the world).

Key equipment includes the **Large Hadron Collider (LHC**), the largest and most powerful particle accelerator in the world, which is 27km in circumference, capable of resolving particle positions to one tenth the width of a human hair. An **Antiproton Decelerator (AD)** which is an 'antimatter factory' – the only source of low energy antiprotons in the world. It measures the properties of antimatter to high precision and the **ISOLDE Facility** is a world-leading laboratory for the production and study of radioactive nuclei. It uses radioisotopes as probes to produce better semiconductor materials by studying doping, diffusion, and radiation damage, and to investigate materials for use in spintronics. It is also used to investigate biological systems (e.g. heavy-metal toxicity, water transport in plants).

Structure and Education Programmes

Founded in 1954, the CERN laboratory sits astride the Franco-Swiss border near Geneva. It was one of Europe's first joint ventures and now has 21 country members. Members have special duties and privileges. They make a contribution to the capital and operating costs of CERN's programmes, and are represented on the CERN Council, which is responsible for all important decisions about the organization and its activities. On-site training and visits contribute to ensuring a greater number of internationally experienced scientists. Currently, there are

a. 189 Technical Student Programme (120-140 people per year in IT and engineering),
b. 178 Doctoral Students (40-50 people are recruited each year – 50% in physics),
c. 33 Administrative Students, and
d. 635 Fellows employed at CERN (150 people recruited p.a. for2-3 years).

These are competitive positions, but all countries tend to represented. These education and training programmes would all be open to Irish nationals in the case of Irish Membership or Associate Membership, together with employment opportunities on the CERN staff - 2,500 staff (1,500 permanent and 1,000 on contracts).

Further information at*: http://home.web.cern.ch/about*

Membership Fees

Full membership fees are based on GDP and are currently €10 million per annum for Ireland. In addition to Full membership there are two options. These options are:

Option A: The Council may admit applicant states as an "**Associate Member leading to full membership"** (a common route of entry for members). This is a pre-stage membership for duration of 2-5 years after which the applicant joins as a full member. Associate Membership is governed by an

Association Agreement between CERN and the country concerned. It is only at the end of the pre-stage Associate Membership that formal accession to the Convention arises.

With "Associate Membership leading to full membership" a minimum of 25% of the full membership costs as calculated by the NNI formula (or at least 1m CHF) is paid in year one. This is increased incrementally over subsequent years until 100% of the full membership cost is reached usually over 4 years. Obviously there are reduced benefits during this period.

Option B: **'Regular ' Associate Membership** is a more static form of associate membership which is made available largely for non-European states. It is not limited in time and is reviewed every 5 years. 10% of a full membership contribution is required. In Ireland's case this would be 1.2m CHF (€0.984m approx.) on the basis of the 2015 estimate referred to above. CERN agreed that it may be possible for Ireland to join on this basis and that Ireland could subsequently change its membership to full membership at a later stage. Also CERN's 'juste retour' on procurement may be extended to associate membership. The details of this option would have to be explored with CERN.

An **"Observer status"** has been granted in the past, mainly to other international organisations, but it is being phased out and is not deemed a viable option for a sovereign country seeking real benefits in terms of researcher access etc.

Irish Research at CERN includes:

- An experimental Particle Physics group was established at University College Dublin (UCD) in 2002, involved in the LHCb and CMS collaborations (experiments).
- The Theoretical Physics Group at Trinity College Dublin carries out research of direct relevance to the CERN particle physics programmes.
- Since 2010, Ireland (Dublin City University) is a member of the ISOLDE Collaboration.
- Ireland has a strong interest in Grid technology, reflected in its memberships of CrossGrid and EGEE.
- St Luke's Hospital in Dublin is currently trialling a cancer treatment derived from CERN research.

In 2014 there were 22 scientists/engineers/students from Ireland in CERN. CERN has a collaboration agreement with Ireland however there has only been limited interest so far by Ireland e.g.:

- Between 1998-2013 Ireland had 5 participants on CERN's Teacher Programme compared to 33 from Malta, and 1 summer student while Cyprus had 2
- Currently there are 5 'CERN users' from Ireland (on par with Iceland).

Table 4.6: CERN Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Technically Yes, but Irish researchers do participate through collaborations with existing CERN members
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, Ireland has a community of about 50 theoretical and experimental particle physicists. Additional Irish scientists have contributed to data management and the

	computing infrastructure (the Grid). The Institute of Physics in Dublin strongly supports Ireland's membership of CERN.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, it confirms our high tech development capability.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, high prestige values, but not a national research priority.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, participation has high value to our high tech image and assists in attracting FDI.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, HEI involvement enhances their international reputation.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but it is a secondary effect through enhanced teaching.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Very limited, small numbers.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	Yes, primarily precision engineering, data analytics and health.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	Yes. Although 16 Irish companies have secured CERN contracts in 2014 (see Appendix 7) membership would greatly enhance these opportunities
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	It should be similar to ESA.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Yes – pro-rata procurement opportunities, which requires additional Irish support from Enterprise Ireland.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, similar to ESA.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes, but likely to be limited.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Yes, large media and youth interest in CERN's activities. Good STEM programme – visits, teacher courses etc. and 2 exhibitions in Ireland (Galway and Dublin) had 20,000 visitors in 2012 and 2013 respectively.

Summary

There are significant reputational, scientific and industrial advantages in joining CERN as noted above. There are economic opportunities for SMEs to tender for general procurement contracts and also in

niche hi-tech areas. These contacts will open other opportunities for the successful SMEs as happens in ESA contracts. Thus, membership fees could be recouped, e.g., Israeli has used 'in kind' contracts to ensure between 90-130% of its expenditure (between 2000 and 2011) – a good example to copy. Reports indicate that every €1 paid to industrial firms (through CERN contracts) generated €3 of additional high quality business for the companies[6].

On the less positive only a small number of academics are involved in CERN-related research and this would be a disproportionate benefit relative to the annual cost. Also many projects require additional institutional inputs which can only come from the national STI budget. Similarly the benefits of any training or STEM activities would be relatively small. Also SMEs would require support to secure any '*juste retour'* on contracts. It has been argued to us that small countries are not scaled down versions of large countries, and consequently CERN's membership fee structure better suits large countries with significant larger populations of potential beneficiaries (mainly academics). The small number of potential Irish beneficiaries would incur a disproportionately higher cost than large countries. An Associate Membership might be more appropriate for small countries, particularly Ireland.

European Southern Observatory - ESO

Background

The European Organisation for Astronomical Research in the Southern Hemisphere, usually abbreviated to European Southern Observatory (ESO), is an inter-governmental organisation with 15 Member States. It designs, constructs and operates powerful ground-based telescopes and observing facilities and also plays a leading role in promoting European and international cooperation in astronomical research.

Main research areas/programmes

A major attraction of ESO is the wide diversity of its facilities and activities which cover almost all areas of astronomic research either directly or through its extensive collaborations with other organisations. Applications of ESO activities include Astrophysics, fibre lasers, dynamic scheduling software, data archiving/ mining, automated data reduction pipelines, and optics.

Irish Research at ESO

As Ireland is not a member, Irish researchers have limited access to ESO. Researchers in the CIRCA survey report usage of public data available from ESO, and also participation in ESO projects through collaborators in member countries. There have also been interactions through joint collaborations between ESA and ESO, whereby Irish researchers involved in an ESA project also become involved in ESO projects. For example, through this means NUI Maynooth has made inputs to the design of the ALMA (see below) as core team members of the European Space Agency missions Planck and Herschel. NUI researchers also collaborated with the Space Research Organisation of the Netherlands (SRON) on the design of the ALMA receivers.

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[6] *Le Goff, Jean-Marie (2011). The impact of CERN on High-tech developments. Workshop: Research infrastructure for industrial innovation, Brussels.*

Structure

ESO technical/administrative headquarters is in Germany and its 3 observatory facilities are in Chile:

- The La Silla site has optical telescopes, including the world's foremost extrasolar planet hunter- HARPS (High Accuracy Radial velocity Planet Searcher), a spectrograph with unrivalled precision.
- The Paranal site hosts the Very Large Telescope array (VLT) - a major facility of European astronomy.
- The Atacama site hosts the Atacama Large Millimetre/submillimetre Array (ALMA) - which is currently the largest ground-based astronomy project.
- The planned European Extremely Large Telescope (E-ELT) will be the largest optical/near-infrared telescope in the world and will gather 13 times more light than the largest optical telescopes existing today. The construction is expected to be completed in 2024.

Membership Fees

There are several elements to the overall cost of membership[7]:

- A once-off entrance fee for joining ESO, which would currently be €12.7m.
- A separate once-off entrance fee for the European Extremely Large Telescope (EELT) project of €1.9 m.

These entrance fees reflect the contributions made by current members in the past. However, payment of these fees can be accommodated over a 10-year period and annual payments can potentially be phased in any way by agreement with the ESO Council.

- An annual membership fee of €1.8m (2015 prices). The fee is based on the Irish Nett National Income (NNI) as calculated by OECD. Payment of the annual fee is required in full each year.

The full costs for Ireland over the first 10 years would therefore be €3.26m per year.

The process of becoming a member would take at least a year. ESO is a body established under an intergovernmental treaty and will therefore require a more formal process of accession. There is an initial phase of formal application; a negotiation team is then appointed by ESO and a counterpart group by Ireland. There are existing templates for an agreement which would form the basis for this process. The issues for discussion would typically be the fees, and the phasing of payments over 10 years, and possible industrial or scientific in-kind contributions as part of the one-off entrance fee. The latter are limited to a max of 25 % of the total amount according to ESO Council policy.

Further information at: ***www.eso.org/public/about-eso/esoglance/***

[7] Information from Claus Madsen, Cabinet of the DG, ESO

Table 4.7: ESO Assessment Criteria	
Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes. But note that because of collaboration between ESA and ESO there are already minor opportunities for Irish researchers who are involved with ESA to interact with ESO.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes. It is a small base (approximately 50 PIs) but very active. Also, 23 of 37 researchers indicated this IRO as the preferred option for membership in a CIRCA survey. Among the astronomy IROs, ESO offers by far the most relevant and diverse range of operations and facilities for Irish researchers.
3. Would membership add value to the impact of Ireland's research output/quality?	Yes, effective involvement in astronomy research is not possible in any meaningful way without access to facilities such as are available through ESO.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes. It would allow Irish researchers to become members of major consortia formed to use ESO facilities.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by membership?	Yes, ESO offers the possibility of involvement of Irish researchers in one of the grand international scientific challenges, which is fundamental research on the origins of the universe. Also, in relation to reputation, ESO is a European initiative and Ireland will be the only non-participant country in Western Europe when Norway completes its membership process.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes. ESO is a major creator of 'big-data' and requires significant support in data analysis, which is a priority area for capacity development. ESO projects will provide real problem-solving opportunities for students and represent an excellent training opportunity in a field of foreseen skill needs.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Yes, the major ESO facilities are in Chile, with some activity in the HQ based in Germany. ESO would pay the costs of participation by Irish project members, and would potentially employ Irish staff. They also offer fellowships
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	ESO projects will require a hugely diverse range of technology and service needs, and there are therefore a huge range of 'relevant fields'. While it is not possible to be definitive, based on experience in the comparable ESA, there is no reason to believe that Irish industry

	could not take full advantage of the opportunities which membership would provide.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	Yes. The annual procurement budget is ~€120M, and a €1.1 billion E-EL telescope is in development. Although there is no *juste retour* policy as in ESA, significant efforts are made to ensure that member countries are awarded contracts at least in line with their contribution.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	The best comparison that can be made is with ESA. A similar impact can be predicted. It is also noteworthy that because of the ground-based nature of ESO facilities, technologies at lower TRL levels can be used, which provides further opportunity for trialling of technologies.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Yes – there is an active programme to encourage engagement of all forms of industry.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes. It can be reasonably predicted that the impact would be similar to ESA. ESO is one of the most sophisticated scientific organisations in the World, and will be a major user and creator of cutting edge technologies in a wide range of fields
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes, as with ESA, the development projects supported by ESO will require high levels of scientific/engineering inputs.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Yes, the organisation has an active outreach programme. Also, astronomy and astrophysics are areas of significant interest for the public and for young people and can be an important mechanism for attracting students into science.

Summary

If Ireland is to join an astronomy IRO, then ESO presents the best combination of options. It is a major international technological organisation presenting major and unique opportunities for research and new technologies, it is by far the preferred choice of the ~50 PIs who are active in the field, and it has by far the greatest range of facilities and services to offer to Irish researchers and industry. Although astronomy is not directly one of the priority topics identified among the 14 National Priorities, and the cohort of researchers is relatively small, the skills generated include data analysis and management, which is a priority area of RTD activity.

Regarding procurement (for which the current ESO annual budget is €120m), ESO does not offer a formal *juste retour* system. However, it provides promotional and support services for industry in countries whose are not achieving contracts in line with their contribution. Membership is relatively

expensive at €3.26m per year for the first 10 years (presuming payment of entrance fees over 10 years). However it is very likely, based on ESA experience, that income to Irish companies would offset this total. However, it should be noted that there would be necessary support costs to ensure that this was realised. The existing support structure for ESA could be expanded to also support ESO participation.

European Synchrotron Radiation Facility -ESRF

Background

The European Synchrotron Radiation Facility ESRF is the most powerful synchrotron radiation facility in Europe. It enables researchers from Europe and worldwide to conduct cutting-edge scientific experiments. ESRF provides more than 40 specialised experimental stations on its beam lines which are used by the international scientific communities in various disciplines such as engineering, physics, chemistry, crystallography, earth science, biology and medicine, surface and materials science. In addition to beamlines arranged by ESRF, collaborating research groups construct and operate beamlines with independent funding. The establishment of ESRF dates back to 1975, the first experiments took place in 1994. In 1998, 40 beamlines were operational.

Main research areas/programmes

The current Science and Technology Programme 2008-2017 (the "Purple Book") describes ESRF's scientific plan including the scientific Upgrade Programme. This latter is a ten year project devoted to new facilities and the associated scientific environment. ESRF's development strategy identified nanoscience and nanotechnology, pump-and-probe experiments and time-resolved science, science at extreme conditions, structural and functional biology and soft matter, and X-ray imaging as key areas for future scientific engagement of synchrotron light. The upgrade focuses on extending ESRF's capabilities in these areas. Key objectives are:

- 18 new and upgraded beamlines/ experimental stations with a strong emphasis on nanoscience
- Delivering enabling technologies: nanocompatible engineering and optics, extended range of extreme environments, vastly improved X-ray detectors, data analysis tools
- Developing collaborations and partnerships with academia, industry and other synchrotrons.

The facility uses and operates different technologies; the Accelerator and Source division is responsible for the operation, development and maintenance of the accelerator complex. Scientific activities at ESRF are made possible by specific instrumentation and enabling technologies. These include X-ray optics, sample handling and sample environment, detectors and electronics, and software development. ESRF cooperates with other light sources and synchrotrons in Europe and worldwide.

ESRF maintains a Business Development Office and offers access for industrial companies to beamlines and expertise. ESRF industrial users are mainly active in the following sectors: pharmaceuticals, chemistry, catalysis, cosmetics, food, batteries, nanotechnologies, medicine, advanced and structural materials and non-destructive testing.

Structure and Membership Fees

ESRF is located at the European Photon and Neutron Campus in Grenoble (EPN), together with the Institute Laue-Langevin (ILL), and the European Molecular Biology Laboratory (EMBL). There is much collaboration between these institutes, as well as with further university and non-university research groups in Grenoble.

ESRF budget is mainly shared between nine member states or member states groups (France, Germany, Italy, UK, Russia, Spain, Switzerland, Belgium/ Netherlands, and Denmark/Finland/Norway/Sweden). Of these, France (27.5%) and Germany (24.0%) are the largest contributors. There are also additional smaller contributors (Israel, Austria, Poland, Portugal, Czech Republic/Hungary/Slovakia, and South Africa). In 2014, the total budget amounted to €102.2m of which €86.9m was covered by member contributions.

In order to conduct experiments at ESRF, scientists submit their proposals for evaluation by one of 11 review committees, made up of specialists from Europe, Israel and South Africa. Successful proposals enable scientists from member states to perform experiments at ESRF; in this case, the use of ESRF facilities, and service support as well as costs related to travel and stay in Grenoble are covered by ESRF (for a defined number of persons; additional persons can join at own expense).

Cost for constructing and operating the synchrotron radiation facility are assessed, and the contributions of members are defined. The Convention concerning the construction and operation of ESRF defines a budgetary ceiling of expected costs, as well as the contributions of the member states. Members' contributions should be at least 4% of the overall budget. ESRF strives for balancing members' contributions and their use of ESRF facilities. Member Countries are represented by specific institutions (contracting parties).

Given the total contributions of ESRF members in 2014 (€86.9m), Ireland's contribution for full membership could be estimated at about €3.6m. However, as the examples of Belgium/ the Netherlands and Denmark/Finland/Norway/Sweden show, shared contributions seem possible. These calculations should consider that beamtime allocations are matched with contributions, thus the higher the contribution the higher the beamtime shifts that are made available to Irish researchers. Two kinds of Scientific Association with ESRF are also possible:

- Long term Scientific Association (minimum 5 years). Total costs ~ €1.13m p.a.
- Medium term Scientific Association (minimum 3 years). Total costs ~€227k p.a.

Irish Research at ESRF includes:

There are about 19 active Irish research groups (involving ~ 21 tenured academic researchers) in the related areas of Synchrotron Research (SR), Free Electron Laser (FEL), and Neutron Beam (NB) research. Due to Ireland's non-membership, Irish scientists can only use ESRF facilities through research collaborators in member countries. This has the disadvantage of not benefitting from ESRF to pay for travel and accommodation.

In the past, Irish researchers have benefitted from the Trans National Access (TNA) opportunity of the European Commission. This was made possible through the Instrument of Integrating Activities (IA) in the European Union 7th Framework Programme. The community of Irish scientific researchers who utilise synchrotron radiation and free electronic laser light sources as well as neutron beam facilities

are concerned about a changed philosophy of the European Commission in the new framework programme of Horizon2020, since the latter foresees a focus on seven societal challenges ("spotlight approach"). While parts of Irish scientific research fit into these focal fields (e.g. photon science which also matches one of the platform sciences in Irish national research priorities), other parts of Irish research interests might not, and consequently may be excluded through the new supporting mechanisms. The TNA instrument used in the past is highly appreciated by the Irish scientific research community due to the benefits for Irish research and due to its opportunity to enable access to different sources.

Further information at: http://www.esrf.eu/

Table 4.8: ESRF Assessment Criteria

Science questions	***Comments***
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	No. Use of ESRF facilities is possible through collaboration with other research groups. However Irish research groups have to pay their own travel and accommodation costs.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but the Irish research group in the areas of Synchrotron, FEL and NB research would prefer an alternative approach to ESRF membership (see text)
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, but the Irish SR, FEL, and NB research groups would prefer an alternative approach.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes. But as above an alternative approach is preferred.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, but as above an alternative approach is preferred.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, but an alternative approach is preferred.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but an alternative approach is preferred.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Most of the time spent by Irish research groups at International Synchrotron facilities is research time. This involves some "on the job" training and development. ESRF allocates 35 PhD grants that are strictly reserved for member countries' students. In addition, some 25 to 30 PhD grants are financed by external sources directly linked with member countries. As a result there is a permanent PhD community of some 60 PhD students from member countries at ESRF.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	In the medium and longer term some applications of this research may be possible with advanced industries based in Ireland – e.g. Intel or the pharma industries. It is not likely to be relevant to Irish industry in the short term.

10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	ESRF does operate a "juste retour" policy for member countries.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	No.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	In general ESRF's industrial policy is to make the facilities available to industry on a fee-paying basis. However for member states it does operate a "juste retour" policy.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, but in the long term. It is not likely that there will be short term industrial impact.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes -To a limited extent.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Only to a limited extent. This area of science is not as readily accessible to the wider public as e.g. Astronomy.

Summary

There is a small but active community of Irish researchers involved in the related areas of Synchrotron Research (SR), Free Electron Laser (FEL) research and Neutron Beam (NB) research. This is advanced materials science research, which requires specialist facilities. This research may be of medium/long term interest to a small group of advanced industries in Ireland. But it is unlikely to be of short term relevance to most industrial companies in Ireland, including SMEs and start-ups.

Membership of ESRF, ILL, and ESS is not a priority for the Irish SR research groups. Their priority is to safeguard the existing mechanisms of Trans National Access (TNA) funding via H2020.

Note:

The entire European light source research community has now come together under the leadership of the ESUO (European Synchrotron Users Organisation) to propose a specific text to be included in the next H2020 Research Infrastructures Work Programme Call to serve the whole of the pan-European user community. A similar emphasis on an inclusive text for neutron beam facilities is also clearly desirable from the pan- European neutron user community.

The title of this topic suggested by ISUO/ESUO is "A user-driven approach towards consolidating the pan-European accelerator-based light source user community".

This new user-driven bottom-up approach envisages the most appropriate combination of floodlights and spotlights (i.e. broad based and narrow based research themes) through strong **Trans National Access** and Networking activities as well as appropriate Joint Research Activities to enable the most

efficient future utilisation of these facilities by all users across Europe. It is recommended that relevant Irish H2020 delegates should support this initiative at Commission level.

Institut Laue-Langevin - ILL

Background

The Institut Max von Laue-Paul Langevin (ILL) is an international research centre with a focus on neutron science and technology, located in Grenoble. ILL operates about forty instruments; its High-Flux Reactor (HFR) provides the strongest neutron source worldwide. Constant further development and upgrade contributes to ILL's standing as a flagship for neutron science. As with ESRF, ILL is a service institute that places its instruments and facilities at the disposal of scientists who visit the institute. Experiments are conducted in fundamental science and also in industrial research and development.

Main research areas/programmes

Eight instrument groups (Diffraction, Large scale structures, Time of flight, Triple axis, Nuclear and particle physics) operate ILL instruments and focus on specific scientific fields. Three further groups support scientists in sample simulation (C-Lab and Virtual Experiments group), neutrons and their interactions (Theory group), and macromolecular systems (Life Sciences group). ILL and ESRF maintain a partnership for research on neural cell adhesion.

The ILL launched its Millennium Programme in 2001 to modernise its infrastructure and instruments. Total investments for this Programme are €91m. The Endurance (2016-2022) programme is targeting ILL's development until 2030. Endurance has three main components: guides, instruments and infrastructure; a further important part being data acquisition, processing and analysis.

ILL has cooperation agreements with the European Spallation Source (ESS), the future world-leading neutron source.

Neutrons are used as powerful tools in various scientific fields such as biology, chemistry and crystallography, liquids and glasses, magnetism, materials science and engineering, nuclear and particle physics, and soft condensed matter. In addition to fundamental research, neutron science is also used in fields related to Grand Challenges of present societies including cultural heritage, earth and environment, information and communication technology, energy and health.

ILL cooperates with industry through making its neutron instrumentation and know-how of its staff available for industrial users. Technology transfer is performed through (1) direct purchase of solutions, (2) collaboration on a customised product (ILL brings in its specific expertise), (3) joint developments, and (4) assigning licences to access ILL technology.

Structure and Membership Fees

ILL was founded in 1967, based on an agreement between the French and German governments. ILL was founded as a service institute, an innovative status. This status was related to the institute's mission to provide the scientific community with leading facilities in neutron science and technology, In 2010, ILL received responsibilities for environmental monitoring from the French Commissariat à

l'énergie atomique et aux énergies alternatives (CEA). In the same year, the European Photon and Neutron science campus (EPN) was launched in Grenoble.

About 1,500 scientists from more than 40 countries visit ILL every year to perform experiments. Scientists submit their proposals for conducting experiments at ILL; these proposals are reviewed by a scientific committee that selects more than 800 experiments per year. The founding countries of France and Germany as well the United Kingdom, which joined the consortium in 1974, govern ILL in association with eleven scientific members (Spain, Switzerland, Austria, Italy, the Czech Republic, Sweden, Hungary, Belgium, Slovakia, Poland, and Denmark).

At the end of 2014, ILL reported 473 staff members (of these 36 thesis students and 66 scientific experimentalists). The institute had a net budget of €90.9m; main income sources are ILL associates (€61.5m), and scientific members (€20.3m). Further sources are own income, local authorities and transfers from preceding year. Based on experiments carried out at ILL, about 600 papers are published every year, of which about 140 papers are published in high-impact journals.

Three associated members (France, Germany and United Kingdom) pay the highest share of ILL's budget (about 68% of the total 2014 budget). Its eleven scientific members bring in a total of €20.270m (about 22%), thus on average €1.84m. Ireland could join initially as an "Interim scientific member" at a cost of €854k per annum for 2 years. After two years this would have to be converted into "full scientific membership" which involved also a contribution to investment. This size of this depends on joining a consortium of other scientific members, and sharing a flat fee of ~ €1.4m. Thus Irish membership might involve an additional fee of ~ €300k - €400k per annum after the first 2 years.

In 2013, ILL purchased nearly 60% of its goods and services in France, about 17% in Germany, 7% in the UK, and about 5% in scientific member countries. 11% is purchased in other countries. Total purchases in 2013 amounted to €24.25m.

In 2013, 1,269 users visited ILL to conduct their experiments. Of these were 290 from France, 226 from Germany and 216 from the UK. 4,184 days (in terms of beamtime allocation) were provided to ILL users, and 220 days were used by ILL scientists for their own scientific research.

Irish Research at ILL includes:

Within the last three years, two Irish researcher groups used ILL facilities. Access was possible through lead partners from member countries. Further and as in the case of ESRF, Irish researchers benefitted from the Trans National Access (TNA) opportunity granted by the European Commission to access ILL as well as other scientific facilities. However, the Irish scientific community using these facilities is concerned about a new philosophy of the European Commission, as perceived for Horizon2020. This philosophy is connected to focusing on selected societal challenges, in which some of the Irish researchers' main topics fit, while others do not. The latter would then be excluded from using service institutes through the TNA/ Horizon 2020 channel. The Irish research community opts for the maintenance of such a support rather than an Irish membership of individual selected IROs.

Further information at: https://www.ill.eu/

Table 4.9: ILL Assessment Criteria	
Science questions	***Comments***
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	No. Use of ILL facilities is possible through collaboration with other research groups. However Irish research groups have to pay their own travel and accommodation costs.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but the Irish research group in the areas of Synchrotron, FEL and NB research would prefer an alternative approach to ILL membership.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, but the Irish SR, FEL, and NB research groups would prefer an alternative approach.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes. But as above an alternative approach is preferred.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, but as above an alternative approach is preferred.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, but an alternative approach is preferred.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but an alternative approach is preferred.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Most of the time spent by Irish research groups at International Synchrotron facilities is research time. This involves some "on the job" training and development. Stays at ILL are of high importance for students; typical stays are for 2 years. Doctoral students: There are joint programmes between universities and ILL (financed by ILL). Training and qualification of doctoral students is of high importance for ILL. There are also training programmes in Grenoble (to introduce equipment).
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	In the medium and longer term some applications of this research may be possible with advanced industries based in Ireland – e.g. Intel or the pharma industries. It is not likely to be relevant to Irish industry in the short term.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	ILL does operate a formal "juste retour" policy for member countries. ILL purchases goods and services in Grenoble and the region, but also in member states.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	No.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	In general ILL industrial policy is to make the facilities available to industry on a fee-paying basis. However it

	does purchase some goods and services in member states. In 2014 about 5% of ILL purchasing budget of €24.3m was spent in 11 scientific members countries (i.e. ~ €1.2m)
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, but in the long term. It is not likely that there will be short term industrial impact.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes -To a limited extent.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Only to a limited extent. This area of science is not as readily accessible to the wider public as e.g. Astronomy.

Summary

As noted for ESRF above, there is a small but active community of Irish researchers involved in the related areas of Synchrotron Research (SR), Free Electron Laser (FEL) research and Neutron Beam (NB) research. This is advanced materials science research, which requires specialist facilities. It may be of medium/long term interest to a small group of advanced industries in Ireland. But it is unlikely to be of short term relevance to most industrial companies in Ireland, including SMEs and start-ups. Membership of ESRF, ILL, and ESS is not a priority for the Irish SR research groups. Their priority is to safeguard the existing mechanisms of Trans National Access (TNA) funding via H2020.

The European Life-Science Infrastructure for Biological Information - ELIXIR

Background

In 2014, the "*European Life-Science Infrastructure for Biological Information*" (**ELIXIR**) was established to build a sustainable distributed network of infrastructures for biological information, supporting life science research and its translation to medicine, agriculture, bio-industries and society. ELIXIR will be an infrastructure that brings together and coordinates many of Europe's leading bioinformatics resources. It is being built on a 'hub and spokes' model with a management hub associated with the European Bioinformatics Institute in UK, and spokes to be developed in each member country. The spokes, or nodes, will provide relevant services to Elixir members and will be backed by a national funding commitment to Elixir. It will provide a mechanism through which Irish organisations can showcase their competences in this field.

Main research themes

It is envisaged that ELIXIR Nodes will provide and/or coordinate services in bio-data capture, storage, distribution, and bioinformatics analysis for life science and biomedical research in Europe.

ELIXIR is also likely to become the main authority in setting unified standards for activities in these areas in the future.

Structure

The legal framework of ELIXIR is based on the ELIXIR Consortium Agreement (ECA), which has been agreed by the Member States and EMBL. The ECA covers ELIXIR's mission, membership, obligations of the Members and the ELIXIR Hub, the governance structure between the ELIXIR Hub and the ELIXIR Nodes and the internal governance structure of the ELIXIR Hub itself.

The organisational structure of ELIXIR will consist of the following bodies:

- The ELIXIR Board
- The ELIXIR Directorate
- The Scientific Advisory Board
- Heads of Nodes Committee
- Other Committees established by the ELIXIR Board

ELIXIR's physical structure is based on a hub and nodes model. The ELIXIR Hub, located in EMBL-EBI, provides an administrative governance structure, which carries out scientific, technical and administrative coordination tasks in addition to the delivery of core services. The ELIXIR Nodes, national or international research institutes from ELIXIR Members that enter into a collaboration agreement with the ELIXIR Hub, play a leading role in the provision of technical services.

Membership Fees

ELIXIR is funded by the ELIXIR Member States. The Member State contributions are defined in accordance with a scale that is fixed every three years by the ELIXIR Board. The scale is based on the average Net National Income at factor cost (NNI) of each State for the three latest preceding calendar years in accordance with OECD statistics. Ireland's membership fee for the next 5 years would be within the range €50,000 - €80,000.

Further information: ***www.elixir-europe.org***

Table 4.10: ELIXIR Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Membership is a condition for access to the services of Elixir, which will enhance our research capacity and efficiency; and also for promoting Irish services in this field to the Elixir network.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes. Ireland already has a large investment in data analytics involving >800 people/researchers. Membership allows the further development and exploitation of this expertise. Data analytics is a national R&D priority.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes. Enhanced capacity in data management will enhance research capabilities and impact. It will contribute to establishing a sound biological data infrastructure which will help to ensure that the benefit from investments in research are realised.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes. Pilot actions within Elixir will facilitate such collaboration. In addition, ELIXIR is actively involved in

	Horizon 2020 applications and the return on investment from H2020 grants to institutes in member countries has already outstripped their contribution to the ELIXIR Hub.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by membership?	Yes, participation will be seen as a commitment to enhance national and European data management capability, including sharing of data between countries. This is expected to have a significant impact on EU RTD effectiveness.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes. Elixir will provide access to data management courses, expertise and other forms of capability development.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	The organisation will provide all forms of support for management, storage, analysis etc. of bio-data.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	Yes. It will be relevant to Irish companies as a source of data, and as a source of expertise, training and services in data deposit and management.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	There may be some minor possibilities
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	Enhancement of data management capability in research and enterprise is a priority activity and Elixir will contribute to this goal, with consequent socio-economic impacts
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Yes
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, through enhancement of national capacity to create, analyse, store and use data.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	To some indirect extent
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Not directly.

Summary

The case for Irish membership of ELIXIR is very straightforward. Its services are directly in line with a national priority to develop data management capacity, it will provide Irish companies and researchers with access to the best EU expertise and facilities, and will also allow Irish organisations to make their services and expertise available to other network members. It will also facilitate access to high-quality consortia which can successfully compete for funding in the H2020 programme. In the light of these benefits, the membership fee of €50-80k is very good value.

European Spallation Source - ESS

Background

The ESS is a materials science research/Neutron Beam facility planned to start operation in 2019. So far, at least 17 European countries are expected to sponsor ESS. Over five years a competitive site selection process led to the choice of Lund (Sweden).

More than 50 universities, research institutes and laboratories from all over the world take part in the ESS collaboration. The future research at ESS is being planned in cooperation with European researchers and partners. Each year an estimated two to three thousand visiting scientists will come to ESS to perform experiments. Most users will be based at European universities and institutes, others within industry. According to its designers ESS will provide Neutron Beams up to 30 times brighter than any current neutron source.

Main research areas/programmes

The ESS will use spallation, a process in which spalls (fragments of material) are ejected from a body due to impact or stress. The future facility is composed of a linear accelerator in which protons are accelerated and collide with a tungsten target. By this process, intense pulses of neutrons are emitted and led through beamlines to experimental stations, where research is done on different materials.

Neutron scattering enables study the structure and dynamics of atoms and molecules over an enormous range of distances and times: from micrometres to one-hundred-thousandth of a micrometre, and from milliseconds to ten-million-millionths of a millisecond. While other techniques can provide information either within the same spatial range or the same temporal range as neutrons, neutron scattering provides a unique combination of structural and dynamic information.

A total of 22 instruments will be built at the ESS to serve the neutron user community, with the aim of having the initial seven instruments online with the first neutrons by the end of the decade. A detailed list of the planned instruments and support facilities can be found at:

http://europeanspallationsource.se/instruments-and-support-facilities

Structure and Membership Fees

As of 2013 the estimated cost of the facility will be about €1.843bn. Host nations Sweden and Denmark plan to give about half of the sum. However the negotiations about the exact contributions from every partner seem to be still in progress. At present, 17 partner countries are represented in the ESS Steering Committee. We can only estimate that membership costs for Ireland would probably be somewhat more than in the case of ILL**.** For this exercise we estimate Ireland's annual membership costs may be ~ €1m. There is no precise figure available at this early stage, to this must be regarded as a best estimate.

Further information at: http://europeanspallationsource.se/

Table 4.11: ESS Assessment Criteria	
Science questions	***Comments***
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes but alternative neutron beam sources are available. It is too early to say if ESS will become indispensable for Irish researchers.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but the Irish research group in the areas of Synchrotron, FEL and NB research would prefer an alternative approach to ESS membership.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, but the Irish SR, FEL, and NB research groups would prefer an alternative approach.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes. But as above an alternative approach is preferred.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, but as above an alternative approach is preferred.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, but an alternative approach is preferred.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but an alternative approach is preferred.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	Most of the time spent by Irish research groups at Neutron Beam facilities is research time. This involves some "on the job" training and development. It is too early to comment on the possible training benefits that might arise for Irish researchers.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	In the medium and longer term some applications of this research may be possible with advanced industries based in Ireland – e.g. Intel or the pharma industries. It is not likely to be relevant to Irish industry in the short term.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	Too early to say if Irish companies may be able to find opportunities for contracts from ESS.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	No.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	It is foreseen that ~ 50% of ESS project contributions will be in "in kind" contributions from Shareholders and partners. ESS does have a procurement process, and procurement tenders are currently advertised on its website. ESS also supports a network of Industrial Liaison Officers in each member country. Although there

	may be procurement potential for Irish industry in the event of membership, it is unlikely to be very significant.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	Yes, but in the long term. It is not likely that there will be short- term industrial impact.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	Yes -To a limited extent.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Only to a limited extent. This area of science is not as readily accessible to the wider public as e.g. Astronomy.

Summary

ESS is intended to be a futuristic, advanced version of ILL – a neutron source of greater power and intensity. It will not be operational before 2019 at the earliest.

During our information gathering processes we received very little comment about ESS. That in itself indicates that membership of this IRO is a low priority in the eyes of the Irish research community. Similarly our industrial survey revealed little or no knowledge or awareness of ESS, and no indication of any interest in Irish membership of ESS.

There is no doubt that membership of ESS for Ireland is not a priority now, and will not be for at least the next 5 years. This issue should be reviewed again ~ 2019.

Square Kilometre Array - SKA

Background

SKA – the Square Kilometre Array - is a €1.5 billion multi-national project which plans to create a collection of thousands of radio receivers and dishes spread across two sites in South Africa and Western Australia. By combining the signals from thousands of small antennas spread over a distance of more than 3000 km, it will simulate a single giant radio telescope capable of extremely high sensitivity. When the first phase is completed in 2023, the SKA will be the world's largest radio telescope and a highly powerful tool for astrophysics research. In addition to the potential for enhancement of our understanding of the universe, SKA will be a major user of 'big data' analytical and management expertise. The dishes and antennae that will make up the telescope will produce 20 times the current global traffic of the internet. This array will deliver massive volumes of data, and will, in the words of one Irish researcher "push data-analytics software and hardware systems to their limit".

It will be built in two phases, with Phase 1 (2018-2023) representing about 10% of the capability of the whole telescope. Construction is scheduled to begin in 2018 for initial observations by 2020.

The second phase is due to be completed in the late 2020s. The SKA facility will be built in the southern hemisphere, to avail of the low radio interference. It is expected to particularly contribute to study of pulsars, cosmic magnetism, the early stages of the Universe and the search for life in the Universe.

There will be industrial opportunities through procurement of components and services, and involvement in research.

Main research areas/programmes

SKA will address a wide range of questions in astrophysics, fundamental physics, cosmology and particle astrophysics and will also greatly extend the range of the observable universe.

Structure and Membership Fees[8]

In summary, if Ireland were to join SKA in 2016, it would pay €1m in up-front fee, and a €400k annual membership fee thereafter. The details are below.

The SKA Organisation was established as a UK Limited Company in Dec 2011; and SKA will be managed by the Jodrell Bank Observatory in England. The membership agreement requires each Full Member to pay a membership contribution in cash of €1M, by way of four equal instalments (2012 – 2015) of €250K.It currently has 11 member countries – Australia, Canada, China, Germany, India, Italy, New Zealand, South Africa, Sweden, the Netherlands and the United Kingdom. Full Members have been asked to sign a non-binding 'Letter of Intent' to demonstrate a commitment to establish the SKA Observatory as a permanent international organisation through construction of SKA Phase-1. A cost cap of €650M has been set for construction of SKA-1 but the contribution levels by member countries remains subject to negotiation.

The same level of membership contribution has been charged to all Full Members to date but in 2016-17, 'smaller' countries will pay a membership contribution of €400k per annum whilst 'larger' countries will pay €500k per annum. Ireland would fall within the category of 'smaller' country for this purpose.

During the pre-construction phase of SKA development, an 'entity of national scale' may initially apply for Associate Member status if (i) it is able to co-ordinate SKA activities in its country, and (ii) it intends to ultimately become a Full Member. An Associate member does not pay a membership contribution but has the right to appoint a representative to attend (but not vote at) SKA Board meetings and SKA Members' general meetings.

A new Full Member is expected to pay an amount equal to the aggregate of the Members' contributions they would have paid had they been a Full Member from the date of incorporation. For a 'smaller' country joining as a new Full Member in 2016, this would be €1M (to cover contribution instalments for 2012-15) plus €400 k for the 2016 instalment. There is effectively no provision for in-kind payments or for staging of the fees over a longer period.

[8]Information from Colin Greenwood, Company Secretary; and Dr Simon Berry, Director of Policy Development, SKA Organisation.

Regarding procurement rights, the process is still in development, but the principles that are expected to apply are:

"1 – Contributors to the project should benefit, broadly in proportion to their contribution to the project (so not strict *juste-retour* a la ESA, but more ESO-like where efforts are made, and over time generally balance)

2 – There should be a mix of high IP and low IP activities for contributors

3 – To get access to the opportunities (contracts/IP generation etc.) you have to be an Organisation member"[9]

It should be noted that the SKA model allows for participation of a wide range of institutes in the design of SKA facilities, but this involvement does not represent membership. According to Dr Simon Berry, Director of Policy Development "*Our model at present is one of where the central organisation acts as the coordinating design authority, and operates the core project management function. The design effort itself is undertaken by institutes, laboratories and universities globally, funded locally by their own processes (internal or government). In principle, individual groups could take a role in the design activities*". SKA is open to discussion as to how Irish researchers might become involved in this process.

Irish Research at SKA:

As SKA is still in development, there is no current Irish involvement in research.

Further information at: www.skatelescope.org

Table 4.12: SKA Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes. It is a small base (approximately 50 PIs) but the facilities offered are of limited relevance to this cohort. Of 37 astronomy researchers surveyed by CIRCA, only 1 indicated this IRO as the preferred option for membership.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, but in a limited area as noted above.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, but in a limited area as noted above.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, it would offer the possibility of some involvement of Irish researchers in one of the grand international scientific challenges, which is fundamental research on the origins of the universe. .
Education, Skills, Training questions	

[9] Information from Dr Simon Berry, Director of Policy Development, SKA Organisation.

6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, but in a limited way as noted above. SKA will create 'big-data' and require support in data analysis. This will provide real problem-solving opportunities for students and be an excellent training opportunity in a field of foreseen skill needs.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but in a limited way as noted above.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	There will be opportunities but the extent and nature is not clear as yet. It should be noted that the observatory facilities will be based in Australia and South Africa.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	There is no reason to believe that Irish companies could not take some advantage, but the extent of the opportunity is not yet clear.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	There will be opportunities, but the extent is not yet clear. The planned budget for phase 1 of the facilities is €650m but note that these will be in Australia and S. Africa which will limit some forms of participation by Irish industry.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	There is likely to be impact, but the extent is not yet clear.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	The organisation is in development, but procurement and industrial participation programmes are part of their plans.
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	This is likely, but it is not possible to say at this early stage.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	This is likely, but it is not possible to say at this early stage.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Astronomy and astrophysics are areas of significant interest for the public and for young people and can be an important mechanism for attracting students into science. At the moment, there are no plans for outreach activities such as are available from ESO or LOFAR.

Summary

There are few clear benefits to Irish membership of SKA. Regarding research support, it is only of benefit to a small cohort of the 50 PIs which are active in astronomy and is of very low priority within

this cohort. There will be opportunities for industrial involvement in development programmes and in procurement (budget for the first phase of development is €650m) but the details are not yet clear. The annual membership fee of €1m is poor value in the light of this.

Cherenkov Telescope Array - CTA

Background

The **Cherenkov Telescope Array** (CTA) is a unique instrument to explore the cosmos at the highest photon energies. It will serve as an open observatory to the astrophysics community and offer a deep insight into the non-thermal high-energy universe. It will provide an order-of-magnitude jump in sensitivity over current instruments. CTA began as a collaboration of 1000 scientists and engineers from 170 research institutes in 28 countries. In 2012, funding agencies in 13 countries signed a 'Declaration of Interest' to participate in construction and operation of CTA. Construction, which is expected to begin in 2015, will consist of over 100 Cherenkov telescopes of 23-m, 12-m and 4-m dish size located at 1 southern and 1 smaller northern hemisphere sites. Scientific exploitation of the CTA observatories could start by 2016, with a partial array, while the construction is still in progress. CTA capacity will be used (~ 50/50) for Key Science Programmes (below) and Guest Observer Programmes which will be proposed by member consortia. The headquarters of CTA is in Heidelberg, Germany.

There will be industrial opportunities through procurement of components and services, and in the construction and operational phases. It plans to interact with SMEs across Europe for tenders and purchasing.

Main research areas/programmes

CTA's Key Science Programmes can be grouped into three main themes:

- Understanding the origin of cosmic rays and their role in the Universe
- Understanding the nature and variety of particle acceleration around black holes
- Searching for the ultimate nature of matter and physics beyond the Standard Model.

In addition, member countries and their institutions can propose additional programmes of research (see below under 'Structure and Membership Fees').

Irish Research at CTA

Although CTA has not formally started, Irish researchers have had significant involvement in the underlying field of Very High Energy (VHE) gamma-ray astronomy. The Whipple Collaboration, which featured strong Irish involvement, developed the Cherenkov-imaging technique, and the first Cherenkov imaging camera was developed at UCD by Professor David Fegan and his team in the early 1980s. Research in this field continues in UCD and at NUI Galway and Irish researchers are members of the VERITAS Collaboration which is the major international network in this field. It is expected that VERITAS will be run down when CTA is up and running. The involvement of Irish scientists in the field will most likely cease at that point unless Ireland is formally a member of CTA.

Structure and Membership Fees

The costs of participation in CTA are based on the model below. As this is a new institution, there is no 'catch-up' fee as is required in joining some other long established organisations. There are 2 forms of activity within CTA and members can opt to participate in one or both. The extent of participation in these activities will determine the total annual fee. For reference, the annual operating costs are estimated to €15M, and the construction costs will be about €200M. The two areas of activity are:

1. Key Science Programmes (KSPs) are core projects carried out by CTA to advance the main science topics of CTA, and will mainly consist of surveys of sky regions and object classes. KSPs are expected to account for 40-50% of the CTA observation time during the first decade. A minimum threshold involvement of each member country would be at a level around 2% of the construction costs (of about €200M) or €4m.

2. The **Guest Observer (GO)** Programme will support projects proposed by member country institutions, typically in consortia. Proposals for allocation of CTA time to GOs will be independently evaluated and projects accepted through this process will receive all of the required technical and data analysis support from CTA. In these projects, sharing of operating costs is planned on the basis of a country's anticipated use, and will be calculated using a weighting based on GDP, the number of members of the International Astronomical Union, and the number of CTA Consortium members. The details remain to be negotiated, and it is not possible in advance to calculate the costs to Ireland. It will entirely depend on the extent of Irish involvement in GO consortia.

It should be noted that CTA interaction is primarily through research institutions. There are currently about 1,000 institutions from member countries involved in CTA.

Further information at: https://portal.cta-observatory.org/Pages/Home.aspx

Table 4.13: CTA Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes. UCD researchers were involved in the design and construction of the first Cherenkov imaging camera and Irish researchers have been involvement in development of this form of observation. Without membership, Irish involvement is likely to cease. Cost of membership would be ~€4m plus an additional fee for participation in collaborative research programmes.
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but CTA only provides access to one form of astronomic observation and the cohort of researchers who would benefit from membership is therefore small. Of 37 astronomy researchers surveyed by CIRCA, only 5 indicated this IRO as the preferred option for membership; a further 5 indicated it as their second preference after ESO.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes, but in a limited area as noted above.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, but in a limited area as noted above.

5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, it would offer the possibility of some involvement of Irish researchers in one of the grand international scientific challenges, which is fundamental research on the origins of the universe. .
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes, but in a limited way as noted above. CTA will create 'big-data' and require support in data analysis. This will provide real problem-solving opportunities for students and be an excellent training opportunity in a field of foreseen skill needs.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes, but in a limited way as noted above.
8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	There will be opportunities but the extent and nature is not clear as yet.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	There is no reason to believe that Irish companies could not take some advantage, but the extent of the opportunity is not yet clear. Membership is relatively expensive at €4m per year.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	There will be opportunities, but the extent is not yet clear.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	There is likely to be impact, but the extent is not yet clear.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	The organisation plans to interact with SMEs across Europe for tenders and purchasing
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	This is likely, but it is not possible to say at this early stage.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	This is likely, but it is not possible to say at this early stage.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Astronomy and astrophysics are areas of significant interest for the public and for young people and can be an important mechanism for attracting students into science. At the moment, there are no plans for outreach activities such as are available from ESO or LOFAR.

Summary

As with SKA, there are few clear benefits to Irish membership of CTA. Regarding research support, it is only of benefit to a small cohort of the 50 PIs which are active in astronomy and is of low priority within this cohort. There will be opportunities for industrial involvement in development programmes and in procurement but the details are not yet clear. The annual membership fee of €4m is very poor value in the light of this.

The Low Frequency Array - LOFAR

Background

The LOw Frequency ARray (LOFAR) is a distributed radio telescope which uses a large array of low-cost sensors (antennas, geophones and more) to achieve its sensitivity rather than a small number of big dishes. It will consist of 5,000 separate antennas all over Europe and relies on broad-band datalinks and advanced digital signal processing to achieve its functionality. Radio astronomy is the only branch of ground-based observational astronomy that can realistically be conducted in Europe. It plans to survey the Universe at frequencies of ~10-240 MHz. LOFAR was initiated by ASTRON, the Netherlands Institute for Radio Astronomy which is working with Dutch universities and with many international institutes. If funding can be obtained, an Irish LOFAR station will be built in Birr and will link with the other planned European LOFAR stations. The Irish station will support Irish researchers, and provide public and educational outreach. The site is already a visitor destination and a further specific visitor centre is planned. Industrial opportunities will include some contracting of production and services, but the major LOFAR sensor arrays will be centrally supplied from the Netherlands. There is also a Bureau of Technology Transfer (BTT) to manage commercialisation of LOFAR technologies.

In Ireland, The I-LOFAR project will require cooperation with industrial partners with experience in networks, data storage, and high-speed processing, and commitments to such interaction have already been made.

Main research areas/programmes

LOFAR will conduct studies into transient stars and galaxies; conduct the first studies into the early Universe after the Big Bang, complete the most extensive surveys of galaxies at low frequencies; and provide a new insight into the Sun-Earth connection. These studies will address a wide range of questions in astrophysics, fundamental physics, cosmology and particle astrophysics and will also greatly extend the range of the observable universe. The outputs of LOFAR research will have applications in geophysics, meteorology, and agriculture.

Irish Research at LOFAR

As LOFAR is still in development, there is no active Irish involvement in research. However, preparatory work on the design of LOFAR programmes and equipment, and on software requirements, has begun.

Structure and Membership Fees

The cost elements are:

(a) The cost of building an Irish LOFAR radio telescope in Birr, Co. Offaly, which is €1.5 million. The project promoter Dr Peter Gallagher of TCD has raised 50% of this from a range of academic, industrial and other sources. They will shortly make an application to the Strategic Partnership programme of Science Foundation seeking the remaining 50% of the construction costs.

(b) On-going membership fees for the International LOFAR Telescope network of approximately €80k per annum.

Further information at: ***www.lofar.org and www.lofar.ie/***

Table 4.14: LOFAR Assessment Criteria

Science questions	
1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?	Yes. This organisation is based on establishment of local observation facilities distributed around Europe. If there is no local node, there is no participation. For a relatively low investment, LOFAR will connect Ireland to a €150M network of European radio telescopes
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?	Yes, but LOFAR only provides access to one form of astronomic observation and the cohort of researchers who would benefit is therefore small. Of 37 astronomy researchers surveyed by CIRCA, only 3 indicated this IRO as the preferred option for membership; a further 3 indicated it as their second preference after ESO. Nevertheless, Irish LOFAR (I-LOFAR) consortium is in place with 16 HE institutions and centres (3 of them overseas). The majority of these have committed financially to I-LOFAR.
3. Would/does membership add value to the impact of Ireland's research output/quality?	Yes. Although in a limited area as noted above, an observational facility located in Ireland will be a benefit for training and education. The 50% contribution to membership cost by non-State organisations (including universities) is an indicator of the perceived value.
4. Would/does membership enhance international collaboration of Irish researchers?	Yes, Irish researchers will be part of a wide network of researcher in LOFAR nodes all over Europe.
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by continuing membership?	Yes, it will allow involvement of Irish researchers in the grand international scientific challenges of researching the origins of the universe. Also, as the LOFAR array effectiveness is related to its span, a node in Ireland will be particularly valued by other EU researchers as it will enhance the entire network.
Education, Skills, Training questions	
6. Would/does membership have positive benefits for education in Irish HEIs?	Yes. The presence of an observational facility in Ireland will be a benefit for training and education. LOFAR will also be a major creator of 'big-data' and will require significant support in data analytics, which is a priority area for capacity development. LOFAR projects will provide real problem-solving opportunities for students and represent an excellent training opportunity in a field of foreseen skill needs. This data will also be locally captured by the Irish facility, and further data will be available from other nodes.
7. Would/does membership enhance the profile of human capital output from Irish HEIs?	Yes. Although in a limited area, the presence of an observational facility in Ireland will be a benefit for training and education.

8. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?	There will be some opportunities for staffing, and the location of a facility in Ireland will also create opportunity for training and fellowships.
Industry questions	
9. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?	LOFAR will also be a major creator of 'big-data'. One major Irish company noted the availability of this data and the analytical processes and skills which will be developed to manage it will be a major advantage for Ireland. Collaboration is most likely in this area.
10. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?	There will be limited opportunities for such contracts. The major observation equipment is centrally supplied from ASTRON in Netherlands. However, there are potential spin-off benefits from data analysis activities.
11. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?	There is likely to be limited opportunity for product or service supply. There will be some tourism benefit due to the establishment of the observatory and visitor centre in Birr, Co. Offaly.
12. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?	Limited opportunities as noted above
13. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?	This is particularly likely in the area of data analysis and management.
14. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?	This is particularly likely in the area of data analysis and management.
STEM	
15. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?	Astronomy and astrophysics are areas of significant interest for the public and for young people and can be an important mechanism for attracting students into science. The presence of an observatory facility in Ireland (and a planned visitor centre) has the potential to engage further students in science.

Summary

As with SKA and CTA, LOFAR is only of benefit to a small cohort of the 50 PIs which are active in astronomy and is of low priority within this cohort. There are few opportunities for industrial involvement in procurement due to the central supply of equipment for each of the LOFAR nodes. The major benefits of LOFAR are (a) its low cost (€80k/annum and the fact that 50% of the immediate capital costs of establishment have been raised through contributions from industry sponsors, HE research groups and other supporters; (b) it will have an Irish location and operation which has benefits for education and training, for industrial involvement in data management, and also for outreach to schools and the public.

Chapter 5: Cost-Benefit Analysis of IRO Membership

In this chapter we combine the various strands of our analysis and derive a ranking of IROs that takes account of the benefits each can deliver for Ireland and the direct cost that membership entails.

The primary task for this chapter is to provide an answer to the following question: given the current annual budget available to pay the direct costs of IRO membership, what is the set of IRO memberships that will yield greatest benefit for the country?

To answer this question we must compare benefits delivered to the direct costs of membership for each IRO. For this purpose we use a cost-benefit approach that is designed to rank IROs along a scale according to the size of the ratio of benefit to cost. When combined with a given budget this enables choice on membership to be made in a fashion that maximises the benefit to Ireland per euro of expenditure.

The presentation in the chapter is organised into a series of iterative steps leading to the ultimate benefit/cost ranking. Using the methodology described in chapter 2 and the data and assessments in chapters 3 and 4 we calculate benefits that can be derived from membership of each IRO. We will report these in total and by the sub category areas in the assessment criteria: science, education & skills & training, industry, and STEM/outreach.

IROs are then compared with respect to the cost of membership. Finally we bring the measures of benefit and cost together in order to derive a value for money ranking of IRO membership.

Rankings of IROs by Science Benefits derived from Membership

The five science questions addressed were as follows.

1. Is membership a necessary condition for Irish-based researchers to participate in research in the organisation or use its facilities?
2. Is the Irish research base in relevant fields capable of taking advantage of Ireland's membership of the organisation and participation in international collaboration groups engaging with the organisation's facilities?
3. Would/does membership add value to the impact of Ireland's research output/quality?
4. Would/does membership enhance international collaboration of Irish researchers?
5. Is there reputational merit in Ireland committing to contributing to European and global human development endeavours and knowledge accumulation by becoming a member?

We used the five data sources - bibliometric analysis, surveys of the opinions of the R&D community based in research performing organisations (RPOs) and industry, Interviews with scientific leadership in the RPOs and the scientific learned societies, consultation with research leaders in countries actively engaged with the IROs, and desk research on the IROs supported by consultation industry – in addressing these questions. For every data source where there is evidence sufficient to warrant a positive answer to any of the questions a score of 1 is recorded when assessing any particular IRO. A score of zero is awarded if such evidence does not exist. The total potential science benefit mark for any IRO is therefore 25. In Table 5.1 we rank the IROs under consideration according to the total science benefit score. Three of the IROs – ESA, CERN and ELIXIR – are jointly ranked in first place with a score of 18 each.

Table 5.1: Ranking of IROs by Science Benefits (Maximum potential score = 25)

IRO	*Science Benefit Score*
ELIXIR	18
CERN	18
ESA	18
EMBC	17
ESO	16
COST	12
EUREKA	12
EMBL	11
LOFAR	5
CTA	2
ILL	2
SKA	1
ESS	1
ESRF	1

We have been asked to take cognisance of national research prioritisation in assessing the benefits of IRO membership for Ireland. In particular we have been asked to assess the extent to which membership might deliver benefits in the 14 priority areas. In order to do so we weight the science benefits. Where an IRO can deliver scientific benefits that are a direct match with some or all of the 14 priority areas the science benefit is given a weight of 1. Where there is a partial match there is a weighting of .5. Where the science benefit does not match with the priority areas but makes a contribution to the underpinning science there is a weighting of .1. This follows the recommendations in the Report of the National Research Prioritisation Exercise which advocated that the majority of funding be directed at the priority areas with the remainder going to support underpinning science and policy research.

In Table 5.2 we rank the IROs according to their weighted science benefits. ESA and CERN drop down the list as their weighting is for contribution to underpinning science. It is arguable that COST and EUREKA should be weighted at 1 given that activity can be in the priority areas. However, there is no requirement for the science activity for COST and EUREKA to be in the priority areas only. For this reason these IROs are given a weighting of .5 for their science benefits. A similar argument could be made with respect to EMBC and EMBL. On balance, however the work of these entities span so much of the scientific subject matter in the priority areas that it would be inappropriate to undervalue their contribution with a weighting other than 1.

Table 5.2: Ranking of IROs by Science Benefits weighted for National Research Prioritisation (Maximum potential score = 25)

IRO	*Unweighted Benefit Score*	*Weighting*	*Weighted Science Benefit Score*
ELIXIR	18	1	18
EMBC	17	1	17
EMBL	11	1	11
COST	12	0.5	6
EUREKA	12	0.5	6
CERN	18	0.1	1.8
ESA	18	0.1	1.8
ESO	16	0.1	1.6
LOFAR	5	0.1	0.5
CTA	2	0.1	0.2
ILL	2	0.1	0.2
SKA	1	0.1	0.1
ESS	1	0.1	0.1
ESRF	1	0.1	0.1

Rankings of IROs by Education and Outreach Benefits

The education and outreach questions address were as follows.

1. Would/does membership have positive benefits for education in Irish HEIs?
2. Would/does membership enhance the profile of human capital output from Irish HEIs?
3. Is there significant value to be derived from scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements?
4. Would/does membership of the organisation enhance public engagement with science/promote increased take-up of STEM subjects?

The last question is concerned with outreach and the other three deal with education, skills and training. The bibliometric analysis is not used in addressing these questions. Hence the total potential score for education is 12 and 4 for outreach. Table 5.3 records the benefit scores for education and outreach separately but the ranking of IROs is done on the basis of the total benefits arising in these areas.

ESA scores full marks on the education criteria and 3 of the 4 available marks for outreach. While ESO scores ahead of CERN it must be recognised that this assessment is a judgement on potential whereas there is an established track record for CERN informing the scores.

The network benefits of COST to emerging researchers were emphasised repeatedly to us during interviews. As a consequence there may be some surprise at its failure to score in this category. The reason is that we measured these networking benefits as arising in science as opposed to human capital development.

Table 5.3: Ranking of IROs by Total of Education & Outreach/STEM Benefits (Maximum potential score = 16)

IRO	Education, Skills & Training Benefits	Outreach/STEM	Total of Education, Skills, Training, Outreach/STEM
ESA	12	3	15
ESO	9	3	12
CERN	7	2	9
ELIXIR	7	0	7
EUREKA	6	0	6
LOFAR	4	2	6
EMBC	5	0	5
EMBL	5	0	5
CTA	1	1	2
SKA	1	0	1
ILL	1	0	1
ESS	1	0	1
COST	0	0	0
ESRF	0	0	0

The poor scoring of EMBL is this category is noteworthy. Less than 50% of the available points were awarded under the education, skills and training heading where it would have been expected that EMBL would have strength. Given earlier assessments of EMBL that showed surprisingly little usage/awareness among the scientific community the issue of EMBL's contribution was probed during interviews. In this context the poor scoring is particularly striking.

Ranking of IROs by Industry Benefits

The industry questions addressed were as follows.

1. Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhancing its participation in international collaboration?
2. Are there opportunities for Irish companies to acquire contracts from the organisation through recurrent supplies and services, and/or new technologies required for new projects and developments?
3. Is it anticipated that socio-economic impact will be enhanced in relevant sectors associated with the organisation through membership of the relevant organisation?
4. Does the Organisation have an industrial policy suitable for engagement by SMEs and start-ups?
5. Would/does membership of the relevant organisation provide access to capabilities which will enhance the translation of innovative scientific research into commercial opportunities by Irish based researchers?
6. Would/does membership of the organisation support and promotes collaboration between individual companies and between companies and 3rd level research?

As with the education and outreach benefits the bibliometric data source was not used in scoring against the industry criteria. As a consequence the total score that an IRO can achieve for industry benefits is 24.

Table 5.4: Ranking of IROs by Industry Benefits (Maximum potential score = 24)

IRO	*Industry Benefit Score*
ESA	21
COST	12
CERN	12
EUREKA	11
ESO	10
LOFAR	9
ELIXIR	6
EMBL	2
CTA	1
SKA	1
ILL	1
EMBC	0
ESS	0
ESRF	0

The ranking by industry benefits in Table 5.4 demonstrates that ESA comes out ahead by a considerable margin. EMBL again scores poorly achieving only 2 out of a possible 24 points.

Ranking of IROs by Total Benefits

Table 5.5: Ranking of IROs by Total Benefits (Maximum potential score = 65)

IRO	*Total Benefit Score*
ESA	37.8
ELIXIR	31
ESO	23.6
EUREKA	23
CERN	22.8
EMBC	22
COST	18
EMBL	18
LOFAR	15.5
CTA	3.2
ILL	2.2
SKA	2.1
ESS	1.1
ESRF	0.1

Table 5.5 sums the data from the previous four tables to get an overall benefit ranking. ESA comes out ahead with a benefit score for Ireland that is more than 50% larger than the scores achieved by each of CERN and ESO. The results for ELIXIR are particularly noteworthy.

A number of the IROs have performed badly in each on the assessment categories. No matter what the cost it is hard to see any benefit to Ireland from involvement with CTA, ESRF, ESS, ILL or SKA.

Rankings of IROs by Cost of Membership

The costs of membership are expressed as an annual recurring cost. The actual membership fee levied will generally bear some relationship to the size of country, as measured by GDP/GNP, and may also involves some element of negotiation. Upfront one time charges may be levied on joining an IRO. Where this occurs we incorporate this amount into the annual fee by amortising the upfront charge over a decade. Our enquiries have established that, in general, a country can negotiate such an arrangement for upfront charges.

In table 5.6 we rank IROs by cost of membership from the most to the least expensive. We record the annualised membership fee described above as a percentage of €18.65 million which is the latest available information that we have on the size of the Irish IRO budget.

Table 5.6: Ranking of IROs by Cost of Membership (Most expensive to least expensive)

IRO	*Fee as a percentage of Irish Budget*
ESA	94.89
CERN	53.61
CTA	21.44
SKA	21.44
ESRF	18.23
ESO	17.48
ILL	9.86
EMBL	6.17
ESS	5.36
EMBC	1.13
LOFAR	0.43
ELIXIR	0.27
EUREKA	0.18
COST	0.01

Virtually 95% of the budget is accounted for by the fee payable to ESA. This is almost double the cost of being a member of CERN. It is notable that the cost of membership for ELIXIR, EUREKA and COST is very low.

Table 5.7: Ranking of IROs by Cost of Membership with Adjustment for Cost Recovery (Most expensive to least expensive)

IRO	*Adjustment Factor*	*Fee as a percentage of Irish Budget*
ESRF	1	18.23
CERN	5	10.72
ESA	10	9.49
ILL	1.05	9.39
CTA	2.5	8.58
SKA	2.5	8.58
ESO	2.5	6.99
EMBL	1	6.17
ESS	1	5.36
EMBC	1	1.13
LOFAR	1	0.43
ELIXIR	1	0.27
EUREKA	1	0.18
COST	1	0.01

There is an ability to recover some of the national expenditure on membership from areas outside of industry based R&D interaction that is captured in the benefit assessment. This could occur, for example, through the award of procurement contracts to Irish firms for equipment and services. In order to take account of this cost recovery we use available evidence on outcomes and potential to assign a cost adjustment factor.

Table 5.7 contains the results of the cost ranking after making this adjustment. Where there is evidence of significant cost recovery the membership fee is adjusted downwards. The strongest evidence of actual or potential cost recovery exists for ESA. It is assigned an adjustment factor of 10 so that its adjusted cost is a tenth of its actual cost. All other cost recovery is weighted against the performance of ESA. In the case of most of the IROs there is little or no reason to expect cost recovery. There are assigned an adjustment factor of 1 so that their actual and adjusted costs are the same. It is estimated that CERN membership has 50% of the potential as ESA for cost recovery and ESO has 25%. This weighting takes account of the build-up time that would be required to achieve these cost recovery outcomes.

Once account is taken of cost recovery the relative costs of CERN and ESA to Ireland is almost identical whereas the raw cost expense has ESA being almost double the cost of CERN.

Table 5.8: Ranking of IROs by Cost of Membership with a negotiated CERN Fee and with Adjustment for Cost Recovery (Most expensive to least expensive)

IRO	*Adjustment Factor*	*Fee as a percentage of Irish Budget*
ESRF	1	18.23
ESA	10	9.49
ILL	1.05	9.39
CTA	2.5	8.58
SKA	2.5	8.58
ESO	2.5	6.99
EMBL	1	6.17
ESS	1	5.36
EMBC	1	1.13
CERN	5	1.07
LOFAR	1	0.43
ELIXIR	1	0.27
EUREKA	1	0.18
COST	1	0.01

In the case of CERN there are two membership levels, full and associate, with the latter being 10% of the former. As officially advertised the associate membership is either for associated countries outside Europe or it is a temporary category during transition to full membership. Given the current state of maturity of CERN capital investment and taking account of the practical realities that membership organisations have to confront in periods of economic uncertainty it is not unreasonable to suppose that there is scope for achieving a negotiated membership fee from CERN. What we do, therefore, is to examine the position with CERN where such a negotiated fee is set equal to the associate fee and benefits, such as the opportunity to achieve cost recovery, are associated with this membership. The results of the ranking with this adjustment are contained in Table 5.8.

Rankings of IROs by Benefit-Cost Ratio

We now combine the benefits with the costs in order to achieve a value for money ranking of the IROs. ESA, as we have seen, delivers benefits well in excess of any other of the IROs. ELIXIR is the only one that comes close to matching ESA benefits. However, we also saw that ESA consumes almost 95% of the Irish IRO budget. Therefore benefits from membership need to be high to justify the cost.

Our approach, as described in chapter 2, is to divide the benefit score for an IRO by an index of cost derived from the Irish budget share of the annualised membership fee for the particular IRO. This gives us a benefit cost ratio. While interpretations of this ratio in terms of benefits per euro can be derived it is best to first focus of the ranking of IROs and how many memberships can be afforded given the Irish budget for IRO membership.

Table 5.9: Ranking of IROs by Ratio of Benefits to Costs calculated with Adjustment for Cost Recovery

IRO	*% of Irish IRO Budget*	*Cumulative % of Irish IRO Budget*
COST	0.01	0.01
EUREKA	0.18	0.19
ELIXIR	0.27	0.45
LOFAR	0.43	0.88
EMBC	1.13	2.01
ESA	94.89	96.90
ESO	17.48	114.38
EMBL	6.17	120.54
CERN	53.61	174.15
CTA	21.44	195.60
SKA	21.44	217.04
ILL	9.86	226.91
ESS	5.36	232.27
ESRF	18.23	250.49

Table 5.9 ranks IROs according to the ratio of benefits to costs from highest to lowest. When doing this ranking we use the measure of cost that takes account of cost recovery in the fashion described in the previous section.

The second column in the table is the actual percentage of the IRO budget associated with membership of each IRO. The final column measures the cumulative share of budget required as you progressively join IROs starting from COST as the one with the highest benefit-cost ratio.

This analysis suggests that it is desirable and affordable to join 6 IROs, i.e. to go down the rankings as far as ESA. To go beyond this and join ESO would add almost 15% to the budget. A significant result is that EMBL is ranked below ESO. CERN membership is ranked lower again. Our analysis suggests that it becomes a desirable IRO to join at full membership rates only if the Irish IRO budget were to be increased by 75%. Therefore CERN membership at full rates is effectively ruled out by the analysis.

The remaining IROs performed poorly on the benefits analysis and the comparison to cost suggests that they rank at the lower end of the table. There is no case for considering membership of CTA, ESRF, ESS, ILL or SKA.

Chapter 6: Recommendations

This chapter brings together the strands of our review – taking account of our comparative assessment of the costs and socio-economic benefits of membership of each organisation - to make specific recommendations IRO membership options for Ireland.

Options Analysis

What courses of action ought to be considered? In all cases the analysis is unambiguous in guiding that Ireland retain membership in COST, EUREKA, EMBC and ESA. Options discussed below consider the various combinations of the remaining IROs in which membership might be desirable and affordable for Ireland.

One option would be to follow the logic of the ranking in Table 5.9. This would involve reducing the budget by just over 3%, joining ELIXIR and LOFAR and leaving EMBL.

A second option would be to join ELIXIR, LOFAR and ESO and leave EMBL. This would involve increasing the Irish IRO budget by over 14%. Such a cost which is in excess of two million euro would have to be found elsewhere in the science, technology and innovation budget. The opportunity cost of doing this would be the lost benefit from not having an entity such as an SFI centre of significant scale. On science grounds alone – where such an entity would contribute circa 50 peer reviewed publications annually as well as training significant numbers of research students – it is hard to see the weighted ESO science benefits of 1.6 in Table 5.2 as matching this opportunity cost. Therefore we cannot recommend that Ireland join ESO.

Table 6.1 Ranking of IROs by Ratio of Benefits to Costs calculated with a negotiated CERN Fee and with Adjustment for Cost recovery

IRO	*% of Irish IRO Budget*	*Cumulative % of Irish IRO Budget*
COST	0.01	0.01
EUREKA	0.18	0.19
ELIXIR	0.27	0.45
LOFAR	0.43	0.88
CERN	5.36	6.24
EMBC	1.13	7.37
ESA	94.89	102.26
ESO	17.48	119.74
EMBL	6.17	125.90
CTA	21.44	147.35
SKA	21.44	168.79
ILL	9.86	178.66
ESS	5.36	184.02
ESRF	18.23	202.25

A third option is to consider if there is a potential for achieving a negotiated rate from CERN and if the benefit-cost of taking up such an option is worthwhile. In table 6.1 we consider such a possibility. We use the cost adjustments described in Table 5.8 when measuring the benefit cost ratio. As a consequence CERN membership of the negotiated variety discussed above jumps up the rankings.

Following the logic of Table 6.1 an outcome that could be achieved would be to join ELIXIR, LOFAR and CERN on a negotiated rate that does not exceed €1 million per annum and leave EMBL. We must caution, however, that this is speculative in that in depends on an ability to negotiate a membership rate of CERN that delivers the type of benefits that we have identified in our analysis while not being part of the CERN council. We noted in the previous section that membership of CERN on full rates would not deliver sufficient benefit – taking account of scientific, educational, industrial and STEM benefits – to justify the cost. The only circumstance in which it is worthwhile considering joining CERN is the case in which a negotiated membership of the type discussed is on offer.

We have devised option three in order to fully explore all options for CERN membership given the extent of debate in Ireland on CERN membership and the strength of feeling associated with advocacy of membership. What we find is that CERN membership is only desirable for Ireland at a tenth of the current full membership fee. Could such a rate be negotiated? Would it allow access to opportunities for cost offset through industrial contracts? Answers to these questions can only be found if there is an actual negotiation process.

Finally it could be decided to maintain EMBL membership while joining ELIXIR and LOFAR. This could be achieved with a budget increase of 0.7%. The justification for this course of action might be a desire to avoid any potential reputational damage that a decision to leave EMBL might involve.

Table 6.2: Options Summary

Options	*Budget relative to Status Quo Budget (%)*	*Net change in Benefit Points compared to SQ (%)*	*Total Benefit Points*
Status Quo (SQ)	100	-	118.8
SQ + ELIXIR + LOFAR - EMBL	96.9	24	147.3
SQ + ELIXIR + LOFAR – EMBL + CERN negotiated	102.26	43	170.1
SQ + ELIXIR	100.27	26	149.8
SQ + ELIXIR + LOFAR	100.7	39	165.3

Table 6.2 summarises the set of options that ought to be considered. We have excluded the option that involved joining ESO for the reasons discussed above. The table compares the consequence of change in terms of benefit and cost to the status quo.

At the very least Ireland ought to join ELIXIR. This change would yield a 26% increase in benefits for an additional cost of less than 1% of the current IRO budget.

A 24% increase in benefits could be achieved by joining ELIXIR and LOFAR and leaving EMBL. This would also reduce the size of the budget by 3.1% which could be re-allocated elsewhere in the science, technology and innovation budget. We are confident that the benefits currently gained through EMBL membership could be replicated by direct subvention to researchers at lower cost overall. However, there is the potential of reputational damage if Ireland is seen as disengaging from EMBL. While it is hard to justify remaining in EMBL on benefit cost grounds there will be public relations issues to be managed if EMBL membership is cancelled.

The highest benefit could be achieved through adding ELIXIR, LOFAR and a negotiated membership of CERN while leaving EMBL. This would increase total benefits by 43% at an additional cost of 2.26% of budget. This is compelling in terms of the percentage improvement in benefit that it brings. However, it depends on the capacity to achieve a negotiated fee. Success here will depend on the mandate given to those doing the negotiation. If it is one where Ireland approaches discussions where payment of the full fee is not an option – that is, the hands of the negotiators are tied – then CERN might see the value of engaging on a negotiated fee. There would be a positive reputational impact of joining CERN would likely outweigh the negative one associated with leaving EMBL.

Recommendations

1. Retain membership in ESA, COST, EUREKA, and EMBC.

2. Join ELIXIR. This will be an important organisation for the collection and dissemination of life sciences data and in related training and standards development. It will be crucial to the future efficiency and effectiveness of life sciences research, and its activities will support several areas of national RTD priority. It also opens the possibility of securing H2020 funds from an otherwise restricted programme.

3. Join LOFAR. This is a special case in that it is the only IRO which will have a physical presence in Ireland. This will have benefits for education and outreach, and for industry collaboration. Astronomy is a high profile area of science among young people and is responsible for encouraging many to pursue careers in STEM. The vast majority of the relatively small Irish astronomy research community agree that their first choice (among the 4 astronomy-related IROs reviewed) for membership is ESO, as it would provide access to the greatest range of expertise, equipment and opportunities for their various research and training activities. However, the value for money ranking of ESO does not place it within the set of IRO memberships that would make it desirable and affordable. The opportunity cost of diverting resources from elsewhere in the STI budget to fund ESO membership would not be justified. LOFAR membership on the other hand is a very low-cost opportunity if there is sufficient non-state funding to support capital costs. An appropriate capital funding programme within SFI has been identified, and the sponsors have already complied with the SFI requirement that half of the capital requirement be available from private sources. It is acknowledged that this funding is not guaranteed, and an evaluation and approval process must be undertaken. However, if it is judged fundable within this programme, this would be a useful investment.

4. Engage in negotiations with CERN to determine if membership on associate terms is a steady state option. Membership would be beneficial only if the linkage results in excellent science

and procurement contracts that recoup most of Ireland's expenditure. There is a relatively low base of researchers which can take direct advantage of CERN facilities and full membership is therefore not justified in our view. Membership would have benefits for STEM training and research, and also for Irish industry (through procurement and technology development).

5. Retain membership of EMBL for now but review in the light of the outcome of negotiations with CERN. The membership fee to EMBL effectively contributes to the running costs of a very high quality and prestigious research institute in molecular biology. This institute has been an effective agent for enhancement of European skills in this field and is a flagship for European life sciences. However, the returns to Ireland are minimal. A small number of researchers and students have the opportunity to work at EMBL, and/or to receive training on specialised equipment. Irish researchers also benefit from facilities which EMBL has been instrumental in establishing. However, as Ireland and other EU countries develop similar high-quality institutes, EMBL's relevance is diminishing. Furthermore, several studies, including this review, have identified a low level of awareness of EMBL among Irish researchers. SFI was tasked to promote EMBL and despite its best efforts, interest in EMBL is still low. This is unlikely to change in the future. If the criteria defined for this review are applied to EMBL, in our view it does not justify the cost of membership. However, Irish prestige and reputation could be badly affected by any attempt by Ireland to withdraw from membership. Due to the elite nature of EMBL researchers, their alumni are highly placed internationally in research and other organisations and Irish withdrawal would invite negative comment, which might affect national ambitions to attract life sciences R&D to locate in Ireland.
    a. In retaining membership of EMBL Ireland should seek, as a member of the governing body, explore EMBL's future development and seek to expand the benefits which accrue to Ireland.
    b. In the event that a negotiated fee can be agreed with CERN on the terms discussed here leave EMBL and join CERN on those terms.

Volume 2 Appendices

The following appendices are contained in Volume 2 of the report.