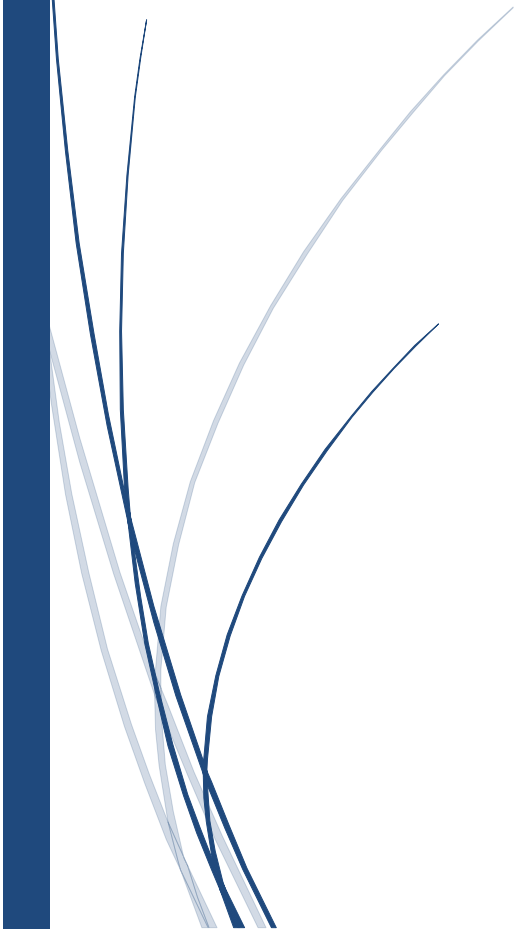
July 2015



CIRCA Group &Fraunhofer ISI

APPENDICES

Appendix 1: Project Terms of Reference

In Table A1 below we summarise the 14 IRO's that are the subject of this review. They are divided into 3 lists:

- List A consists of those five IROs of which Ireland is currently a member.
- List B consists of four IROs, which are currently operational, and of which Ireland is not a member.
- List C consists of a further five IROs which are currently at various stages of development, and membership of which may be of interest to Ireland over the next few years.

Table A1: The 14 IROs reviewed in this study.

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).
European Space Agency **(ESA)** HQ in Paris. Multiple sites.	European Organisation for Nuclear Research. (**CERN)** HQ in Geneva, Switzerland	The Square Kilometre Array (**SKA)** Large radio telescope system. HQ in Manchester, England. Operational sites in Australia, South Africa.
European Molecular Biology Laboratory. (**EMBL)** HQ in Heidelberg, Germany. Four other sites.	European Southern Observatory. **(ESO)** HQ near Munich, Germany. Operational sites in Chile.	European Spallation Source (**ESS)** HQ in Lund, Sweden. Another site in Denmark. A high power neutron facility for materials research.
European Molecular Biology Conference **(EMBC)** HQ in Heidelberg, Germany.	European Synchrotron Radiation Facility (**ESRF)** HQ in Grenoble, France	Low Frequency Array (**LOFAR)** 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.	Institut Laue-Langevin **(ILL)** A high flux neutron source for materials research. HQ in Grenoble, France	**ELIXIR** A European network of bioinformatics 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.

Issues to be addressed in this study

For each of the above categories, this study is expected to address the issues specified below:

- ✓ To clarify the costs of membership, including annual subscription charges (optional and mandatory)and annual administrative costs arising from membership as well as identification of any further measures appropriate to support Irish membership, such as funding schemes, resources, training and development of national competence
- ✓ To ascertain the extent of the research base in Ireland which does or would benefit from membership of such organisations
- ✓ To ascertain how the enterprise base in Ireland does or would benefit from membership of each organisation
- ✓ To identify any other benefits which does or would follow from membership of each organisation, including any "juste retour" policy
- ✓ To summarise the extent of the support membership of the organisation provides to achievement of Ireland's research and innovation priorities.
- ✓ To provide a comparative assessment of the costs and socio-economic benefits of membership of organisations, taking into account the 12 criteria described below.
- ✓ To propose a ranking of membership options having regard to national research and innovation priorities, areas of emerging opportunity and funding constraints, and taking into account any specificities of the organisation concerned and the sectors involved.

Criteria to be used in assessing the 14 IROs in this review

Science Issues:

1. Does research enabled through the organisation's facilities support national research goals? Any process by which Irish-based researchers can participate in research in the organisation or use its facilities without the need for Irish membership should be identified and distinguished from processes enabled solely through membership.
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 issues:

6. Would/does membership have positive benefits for education in universities?
7. Would/does membership change the profile of human capital output in a positive or negative way – e.g. result in an imbalance in particular skills areas or correct an imbalance in particular skills areas?
8. Value of scientific and engineering training and development opportunities at the organisation through staffing, fellowships and other arrangements

Industry issues:

9. Irish Industrial capability to engage:

- Is the Irish industrial base in relevant fields capable of taking advantage of Ireland's membership of the organisation and enhance its participation in international collaboration;
- Are there opportunities for Irish companies to acquire contracts from the organisation:
    - Recurrent supplies and services
    - New technologies required for new projects and developments.
- The extent of growth anticipated in relevant sectors associated with the organisation and the socio-economic impact likely through membership of the relevant organisation.

10. Organisation's policy towards industry:
    - Does the Organisation have an industrial policy and if so to what extent does it apply to SMEs and start-ups?
    - The extent to which membership of the relevant organisation provides and facilitates translation of innovative scientific research into commercial opportunities leading to company formation, employment, sales and exports.
    - Extent to which membership of the organisation supports and promotes collaboration between individual companies and between companies and 3rd level research.

Outreach

11. Would membership of the organisation enhance public engagement with science, promote increased take-up of STEM subjects and support education in STEM subjects?

Financial issues - Estimated costs of membership:

- Membership options and annual subscription fees (optional and mandatory)
- Administrative costs of servicing membership
- Any costs required to support researcher and industry engagement (e.g. funding programmes, awareness raising, and expert advice).

Table A2: Other issues of relevance to this Review

The European Space Agency (ESA)	At the beginning of this project in December 2014, it was stated by DJEI that a parallel review of ESA was already being carried out by a separate team of consultants. A report from this ESA was expected around March /April 2015. It was agreed that the CIRCA/Frauhofer project team would await the report on the ESA review before deciding whether or not any additional work needed to be done with respect to ESA. The current view of the CIRCA/Fraunhofer team is that the ESA review is comprehensive, and that further detailed studies of Ireland's membership of ESA are not necessary. However we have included ESA in our Benefit/Cost studies for completeness.
Other IROs of possible interest	It was agreed that, in the course of this study, the project team would also gather information about other IROs – whether operational or under development – which are not included in Table 1 above, but which may be of interest to DJEI.
Consultation paper for successor to SSTI	During the course of this study we became aware of an inter-departmental Government initiative to develop a successor to the Strategy for Science, Technology and Innovation (2006 – 2013). This initiative is still in progress as we come toward the end of our study. We understand and accept that our objectives and terms of reference as a project team remain unchanged by the parallel exercise in updating the SSTI.

Appendix 2: Persons and Organisations Consulted

Table A3: Persons consulted

Organisation	Person(s) Consulted	Position
Waterford Institute of Technology	Dr Willie Donnelly	VP Research
NUI Maynooth	Prof Bernard Mahon	VP Research
Institute of Physics (IOP)	Dr Sheila Gilheany Alex Connor Dr Mark Lang	IOP Ireland; Policy advisor IOP UK; Senior policy manager NUI Galway; Vice-Chair IOPI
Royal Irish Academy (RIA)	Prof Eugene Kennedy Dr John Maguire Prof Paul Callanan Prof M. Jones Prof M. O'Droma Prof Gerry McKinney	Senior Programme Manager
Dublin Institute for Advanced Studies (DIAS)	Prof Luke Drury Prof Werner Nahm Cecil Keaveney	School of Cosmic Physics School of Theoretical Physics Registrar
NUI Galway	Prof Lokesh Joshi	VP Research
University College Cork (UCC)	Prof Anita Maguire	VP Research
Cork Institute of Technology	Orla Flynn Dr Niall Smith	VP External Relations Head of Research
Dublin City University (DCU)	Prof Alan Harvey	VP Research
Enterprise Ireland(EI)	Gearoid Mooney	Head /Research & Innovation
University College Dublin (UCD)	Prof Orla Feely Prof Padraig Dunne	VP Research Physics Dept
Trinity College Dublin(TCD)	Prof Vincent Cahill Dr Cormac McGuinness	Director / Research Chair, Irish Synchrotron Users
Dublin Institute of Technology(DIT)	Dr Brian O'Neill Dr John Donovan	Head of Research
Teagasc	Dr Frank O'Mara	Head of Research
Marine Institute	Dr John Evans	
Health Research Board	Graham Love	Chief Executive (by phone)
Science Foundation Ireland(SFI)	Prof Mark Ferguson	Chief Executive Science policy advisor to Irish Government
Irish Research Council	Dr Eucharia Meehan	Director IRC
Irish Business & Employers' Confederation (IBEC)	Claire McGee Aidan Sweeney	IBEC Executives
Irish Pharmaceutical & Healthcare Association (IPHA)	Rebecca Cramp	Scientific & Regulatory Affairs
Industry R&D Group (IRDG)	Denis Hayes	Managing Director
Irish Centre for High End Computing (ICHEC)	Dr Michael Browne	Technical Manager

Name	Institution
FRANCE	
AUTIERO Dario	INPL
BACHUREL José	ESRF
BEAULIEU Jean-Philippe	IAP
BOTTI Thierry	ESO
HERAUD Jean-Alain	Université de Strasbourg
LEDOUX Marc	CNRS
MASQUIDA Benoît	Université de Strasbourg
THIERRY Jean-Claude	IGBMC
GERMANY	
JORDAN, Rafael	Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM
Zeitnitz, Christian	BergischeUniversität Wuppertal
Wagner, Wolfgang	BergischeUniversität Wuppertal
Reygers, Klaus	Universität Heidelberg
Eisenhauer, Frank	Max-Planck-Institut für extraterrestrische Physik
Pössel, Markus	Haus der Astronomie
Severing, Andrea	Universitätzu Köln
Magnussen, Olaf	Christian-Albrechts-Universität zu Kiel
Kuhs, Werner	UniversitätGöttingen
Magerl, Andreas	Universität Erlangen

Appendix 3: International members of IROs

There are 9 IROs in this review of which Ireland is not currently a member. For 7 out of these 9 IROs data has been collected on the membership status of 33 international countries. See below.

Table A4: International members of various IROs.

	ELIXIR	ESO	ESRF	ESS	CERN	ILL	SKA
Australia							**M**
Austria		**M**	**A**		**M**	**M**	
Belgium		**M**	**M**		**M**	**M**	
Brazil		**M**					
Canada							**M**
Czech Republic	**M**	**M**	**A**	**M**	**M**	**M**	**M**
Denmark	**M**	**M**	**M**	**M**	**M**	**M**	
Estonia	**M**			**M**			
Finland	**M**	**M**	**M**		**M**		
France		**M**	**M**	**M**	**M**	**G**	
Germany		**M**	**M**	**M**	**M**	**G**	**1**
Greece					**M**		
Hungary			**A**	**M**	**M**	**M**	
Iceland				**M**			
India						**M**	**M**
Israel	**M**		**A**		**M**		**M**
Italy	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Latvia				**M**			
Lithuania				**M**			
Netherlands	**M**	**M**	**M**	**M**	**M**		
New Zealand							**M**
Norway	**M**		**M**	**M**	**M**		
Poland		**M**	**A**	**M**	**M**	**M**	
Portugal	**M**	**M**	**A**		**M**		
Romania					**C**		
Russia			**M**				
Serbia					**A**		
Slovakia			**A**		**M**	**M**	
South Africa			**A**				**M**
Spain		**M**	**M**	**M**	**M**	**M**	
Sweden	**M**	**M**		**M**	**M**	**M**	**M**
Switzerland	**M**	**M**	**M**	**M**	**M**	**M**	
United Kingdom	**M**	**M**	**M**	**M**	**M**	**G**	**M**

M = Member; G = Governing Member; A = Associate member; C = Candidate Member

Source: Institute of Physics (IOP); also derived by CIRCA from IRO websites.

1. Germany has recently withdrawn from membership of SKA
2. Deduced from membership of ESS Steering Committee, ESS Activity Report 2012.
3. LOFAR is being developed by a consortium of knowledge institutes, Universities and industrial partners, led by ASTRON (The Netherlands Institute for Radio Astronomy).
4. CTA is a consortium of ~ 200 institutes in 29 countries. It is funded by FP7/Horizon 2020 and by a variety of Agencies, Ministries, and Organisations from ~ 16 countries.

Appendix 4: Bibliometric Analysis

The following note describes the proceeding of the bibliometric analysis and presents the related results. From a general point of view, the bibliometric analysis relied on the number of publications in Thomson Reuter's bibliometric database "Web of Science" (WoS) issued by researchers affiliated to the analysed IROs, before these figures were matched with publications of researchers affiliated to Irish institutions. Assigning the IRO and Irish publications to research fields then allows matching of Irish research capacity with research foci of the considered IROs and thus allows us to assess the benefit for an Irish membership with regard to scientific publications.

In a first step, publications of the relevant IROs were selected. This first part of the analysis relies on publications of researchers who are affiliated to the analysed IROs

Table A5: International research organisations (IROs) subject to bibliometric analysis

IROs of which Ireland is currently a member	**IROs of which Ireland is not a member**	**International research organizations/ projects under development**
European Space Agency (ESA)	European Organization for Nuclear Research (CERN)	Square Kilometre Array (SKA)
European Molecular Biology Laboratory (EMBL)	European Southern Observatory (ESO)	European Spallation Source (ESS)
European Molecular Biology Conference (EMBC)	European Synchrotron Radiation Facility (ESRF)	*Low Frequency Array (LOFAR)*[2]
EUREKA[1]	Institut Laue-Langevin (ILL)	*Infrastructure for Life-Science Information (ELIXIR)*[2]
COST[1]		*Cherenkov Telescope Array (CTA)*[2]

Notes:

1. EUREKA and COST are EU programmes without physical location. Therefore publications cannot be searched according to author affiliations as in the other cases. Cooperating researchers in Ireland were identified based on the programme websites, see below.
2. For these infrastructures under development, the Web of Science database did not list any publications.

The bibliometric analysis selects relevant publications according to author affiliations, as these were declared by the authors when submitting the paper. The main preparatory work of the analysis consisted in defining the range of publications to be included, in order to select the "correct" publications in a best possible way.[1] In order to avoid double counting due to different spellings or to different locations of one IRO by two co-authors of the same paper (e.g. ESA Nordwijk/ ESA Paris), the different names/locations of each IRO were assigned to one ID, after deciding which affiliations should

[1]E.g. to exclude publications emanating from institutions with similar acronym, private companies with similar names, etc.

be considered (see below). Different searching methods allowed us to identify almost all variations of the names and/or locations of each IRO and their publications.

As indicated above, preparing the bibliometric analysis required a clear definition of which IROs and which IRO affiliations should be included into the analysis. Due to the highly networked character of some IROs,[2] this was not always straightforward and required some preparatory work on the definitions. We investigated the organizational and locational structure of each IRO separately and included all their core facilities (mainly based on their online presentations and annual reports).[3] To ensure that all automatically searched IRO affiliations in the Web of Science database were matched, a manual check of affiliations was performed. This test showed a good coverage of affiliations in the automatic procedure. Further plausibility tests have proven a good hit rate of the automatic search which means that the chosen procedure displayed a high rate of relevant publications.

Table A6: Core facilities of IROs included in the bibliometric analysis

IROs of which Ireland is currently a member	IROs of which Ireland is not a member	International research organizations/ projects under development
European Space Agency (ESA) Headquarters: Paris, France European Space Research and Technology Centre (ESTEC), Noordwijk, South Holland European Space Operations Centre (ESOC), Darmstadt, Germany European Space Research Institute (ESRIN), Frascati, Italy EuropeanAstronaut Centre (EAC), Cologne, Germany EuropeanSpaceAstronomy Centre (ESAC), Villanueva de la Cañada, close to Madrid, Spain GuianaSpace Centre / Centre spatial guyanais (CSG), Kourou, French Guiana Redu Centre (Belgium) European Centre for Space Applications and	European Organization for Nuclear Research (CERN) Genf / Genève / Geneva	Square Kilometre Array (SKA) Headquarters: Jodrell Bank Observatory, near Manchester, UK Construction: SKA South Africa, National Research Foundation The Park, Pinelands, South Africa SKA Australia, Canberra, Australia

[2]This was particularly the case for ESA with its high degree of connections and interlinkages to related infrastructures and national space programmes.

[3]This means that parts of the bibliometric analysis related to ESA does not refer to publications of researchers affiliated to ESTRACK tracking stations or national space programmes.

Telecommunications (ECSAT), Harwell, Oxfordshire, UK		
European Molecular Biology Laboratory (EMBL) European Bioinformatics Institute (EMBL-EBI), Hinxton, Cambridgeshire, UK European Molecular Biology Laboratory (EMBL), Grenoble, France European Molecular Biology Laboratory (EMBL), Heidelberg, Germany European Molecular Biology Laboratory (EMBL), Hamburg, Germany European Molecular Biology Laboratory (EMBL) Monterotondo, Italy	European Southern Observatory (ESO) Headquarters: Garching (near Munich), Germany La Silla Observatory, 600 km north of Santiago de Chile, Chile. Administrative Office: ESO La Serena Office, La Serena, Chile Very Large Telescope array (VLT), Cerro Paranal, Chile. Administration: ESO Antofagasta Office, Antofagasta, Chile Cerro Chajnantor Atacama Telescope (CCAT), Chile (under development) Chile Headquarters: Vitacura Alonso de Córdova, Santiago, Chile	European Spallation Source (ESS) Main facility: Lund, Sweden Data Management and Software Centre (DMSC): Copenhagen, Denmark
European Molecular Biology Conference (EMBC) Heidelberg, Germany Also: European Molecular Biology Organisation (EMBO)	European Synchrotron Radiation Facility (ESRF) Grenoble, France	
	Institut Laue-Langevin (ILL) Grenoble, France	

This first step resulted in a list of all publications for each IRO. Those lists were then evaluated. For this purpose, the total number of publications of each IRO in the time period from 2010 to 2013 was counted and broken down into research fields. The research fields are related to academic journals in which the authors with IRO affiliation have published .The resulting research fields per IRO were cross-checked for plausibility based on the IROs' online presentations. Since one journal can be assigned to several research fields, the corresponding publication is counted multiple times, once in each research field.

In parallel, Irish publications (i.e. publications which are published by authors affiliated to Irish organisations) were selected from the Web of Science database in order to compare the number of publications related to each surveyed IRO and of researchers affiliated to Irish institutions.

Table A7: Number of publications originating from Irish research organisations and from analysed IROs (2010-2013)

Publications (2010-2013)	Irish membership			No Irish membership				Under development		Ireland
	ESA	EMBL	EMBC	CERN	ESO	ESRF	ILL	SKA	ESS	
Sum of counts in all research fields	2,300	1,818	15	5,519	655	4,055	2,420	2	102	61,150
Absolute number	1,562	1,362	15	4,260	589	2,651	1,681	2	56	45,212
Multiple classification[1]	1.5	1.3	1.0	1.3	1.1	1.5	1.4	1.0	1.8	1.4

1 This indicator (quotient of counts and absolute number of publications per IRO) points to the number of research fields in which the publications are counted. It enables us to assess the degree of interdisciplinary of the journals and their publications: 1.0 means that every publication is assigned to one research field while higher figures show that publications are on average counted in more than one research field. The research fields used for this analysis are listed below.

Table A7shows the counts of publications for the analysed IROs and for authors affiliated to Irish research institutes in different fields. This table enables us to match the most important research fields of the analysed IROs with research in Ireland.

Table A8: Results of the bibliometric analysis in research fields (absolute figures)

Publications in research fields (2010-2013)	Irish membership			No Irish membership				Under development		Publications with Irish affiliation
	ESA	EMBL	EMBC	CERN	ESO	ESRF	ILL	SKA	ESS	
Basic chemistry	13	50		9	2	622	534		10	2,837
Biology	32	229		12		85	8			3,240
Biotechnology	5	785	5			149	69			3,669
Chemical engineering	1			2		22	3			347
Computers	42	26		104	12	8				1,983
Ecology, climate	124	5		22	1	39	9			1,804
Electrical engineering	277			328	7	34	8		4	2,121
Food, nutrition	1	1				5	1			1,501
Geosciences	206			4	1	103	16			826
Humanities	1			3		18				2,167
Materials research	36	131		29		756	481		16	2,174
Mathematics	3	33		18		4				1,092

Measuring, control	169	11		654	17	202	63		18	626
Mechanical engineering	210			21	5	39	13			1,011
Medical engineering	6	13		64		68	9			1,306
Medicine	11	256	7	20		69	7		1	19,446
Multidisciplinary	23	194	3	37	7	110	30		1	837
Nuclear technology	41	1		457		70	46		14	79
Optics	135	14		30	48	141	21			1,020
Organic chemistry		8				11	9			429
Other	3					16	2			1,208
Pharmacy		35				11	6			1,131
Physics	914	21		3,642	555	1,346	964	2	36	4,096
Polymers	2	1		2		81	102		1	203
Social Sciences, Economics	1			3						1,075
Social Sciences, Other	14	4		24		2				3,846
Specific engineering	30			34		44	19		1	1,076
Sum of counts	**2,300**	**1,818**	**15**	**5,519**	**655**	**4,055**	**2,420**	**2**	**102**	**61,150**
Absolute number	**1,562**	**1,362**	**15**	**4,260**	**589**	**2,651**	**1,681**	**2**	**56**	**45,212**

Table A9 lists the relative shares of publications of the analysed IROs and of Irish publications according to their publication output. The number of publications is related to the absolute number of publications per IRO/ Ireland and thus includes multidisciplinary. Therefore, the sum of shares exceeds 100% in most cases.

Table A9: Relative importance of research fields in analysed IROs and in Irish publications according to their numbers of publications in scientific journals (shares in %)

Publications (2010-2013)	Irish membership			No Irish membership				Under development		IRL	Total WoS
	ESA	EMBL	EMBC	CERN	ESO	ESRF	ILL	SKA	ESS		
Basic chemistry	0.83	3.67	0.00	0.21	0.34	23.46	31.77	0.00	17.86	6.27	8.24
Biology	2.05	16.81	0.00	0.28	0.00	3.21	0.48	0.00	0.00	7.17	7.11
Biotechnology	0.32	57.64	33.33	0.00	0.00	5.62	4.10	0.00	0.00	8.12	7.57
Chem engineering	0.06	0.00	0.00	0.05	0.00	0.83	0.18	0.00	0.00	0.77	1.57
Computers	2.69	1.91	0.00	2.44	2.04	0.30	0.00	0.00	0.00	4.39	4.74
Ecology, climate	7.94	0.37	0.00	0.52	0.17	1.47	0.54	0.00	0.00	3.99	4.15
Electrical eng.	17.73	0.00	0.00	7.70	1.19	1.28	0.48	0.00	7.14	4.69	6.15
Food, nutrition	0.06	0.07	0.00	0.00	0.00	0.19	0.06	0.00	0.00	3.32	1.59
Geosciences	13.19	0.00	0.00	0.09	0.17	3.89	0.95	0.00	0.00	1.83	2.09
Humanities	0.06	0.00	0.00	0.07	0.00	0.68	0.00	0.00	0.00	4.79	5.98
Materials res.	2.30	9.62	0.00	0.68	0.00	28.52	28.61	0.00	28.57	4.81	7.45
Mathematics	0.19	2.42	0.00	0.42	0.00	0.15	0.00	0.00	0.00	2.42	3.39
Measuring, control	10.82	0.81	0.00	15.35	2.89	7.62	3.75	0.00	32.14	1.38	2.61
Mechanical eng.	13.44	0.00	0.00	0.49	0.85	1.47	0.77	0.00	0.00	2.24	4.66
Medical eng.	0.38	0.95	0.00	1.50	0.00	2.57	0.54	0.00	0.00	2.89	2.59
Medicine	0.70	18.80	46.67	0.47	0.00	2.60	0.42	0.00	1.79	43.01	32.92
Multidisciplinary	1.47	14.24	20.00	0.87	1.19	4.15	1.78	0.00	1.79	1.85	2.02
Nuclear technol.	2.62	0.07	0.00	10.73	0.00	2.64	2.74	0.00	25.00	0.17	0.51
Optics	8.64	1.03	0.00	0.70	8.15	5.32	1.25	0.00	0.00	2.26	2.42
Organic chemistry	0.00	0.59	0.00	0.00	0.00	0.41	0.54	0.00	0.00	0.95	1.04
Other	0.19	0.00	0.00	0.00	0.00	0.60	0.12	0.00	0.00	2.67	2.55
Pharmacy	0.00	2.57	0.00	0.00	0.00	0.41	0.36	0.00	0.00	2.50	2.93
Physics	58.51	1.54	0.00	85.49	94.23	50.77	57.35	100.00	64.29	9.06	9.87
Polymers	0.13	0.07	0.00	0.05	0.00	3.06	6.07	0.00	1.79	0.45	0.90
Social Sciences, Economics	0.06	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	2.38	2.24

Social Sciences, Other	0.90	0.29	0.00	0.56	0.00	0.08	0.00	0.00	0.00	8.51	7.73
Specific engineering	1.92	0.00	0.00	0.80	0.00	1.66	1.13	0.00	1.79	2.38	3.54
Sum	146.4	129.8	100.0	129.3	110.9	129.5	112.2	100.0	164.3	129.0	138.6

This allows us to identify the research fields in which the surveyed IROs are engaged and, at the same time, the research specialisations of scientists affiliated to Irish institutions. This approach enables us to detect research fields of mutual interest to Irish researchers and to researchers from European IROs. Researchers in Irish institutions for instance have strong publication activities in medicine. This focus matches the publication focus of EMBL and EMBC, which leads to the conclusion that this scientific interest is well met through the Irish membership in these two IROs. At the same time, Ireland also displays a publication focus in physics which is congruent to ESA (Irish membership), but also to the other IROs without current Irish membership. This could indicate a potential for Irish research which could possibly be exploited in the future. These first assessments should be further investigated by interviews with Irish research representatives to validate the bibliometric results, and to gather insights for in-depth assessments. Further, different "publication cultures" and database effects in the different disciplines should be kept in mind when interpreting the data. This might be one reason for a possible bias related to the field of medicine.

Based on this analysis and according to the targets of this study, the following research fields were selected for the next step of the analysis (the online survey): Basic chemistry, biology, biotechnology, computers, ecology/ climate, electrical engineering, materials research, mathematics, mechanical engineering, medicine, optics, pharmacy, and physics. Due to the high importance of physics disciplines for the IROs included, we attempted to sub-divide this research field into astronomy and astrophysics, atomic/ molecular/ chemical, and particles/ fields. In the next step, the top Irish researchers per research field were identified through bibliometric analyses. These researchers were then included into the online survey realised by CIRCA. Fraunhofer ISI extracted the top 100 researchers, CIRCA checked and adjusted this list (sorted out multiple entries or foreign researchers who cooperate with Irish scientists) and searched the corresponding e-mail addresses.

This procedure worked quite well for the selected research fields except physics. In the field of physics, many publications have various authors,[4] so that the top researcher list through bibliometric search generated a high share of names not affiliated to Irish research institutes.[5] After several tests for new search strategies, we could generate an adjusted list of researchers in physics, working in Irish institutions.

This described procedure led to the final list of Irish researchers who were included in the online survey (Table A10).

[4]For comparison: Publications in physics have an average of 64.4 co-authors compared to 4.2 in electrical engineering.

[5]Direct links between author and affiliation are not possible.

Since there are some overlaps between those research fields (leading to the fact that some authors work in more than one of the listed fields), the sample slightly decreased after elimination of these duplicates. In total, 695 e-mails were sent to Irish researchers.

Finally, an analysis of already existing cooperation between Irish researchers and the analysed IROs was carried out. In accordance with the above-described bibliometric analysis, the search selected publications in the period 2010-2013. Though the number of cooperations - measured as co-publications between authors in Irish research institutes and authors at the analysed IROs - is limited, it gives an overview of joint activities that can be measured by means of co-publications.

Table A10: Number of Irish Scientists included in the online survey

Field	No. scientists
Basic chemistry	54
Biology	59
Biotechnology	41
Computers	58
Ecology & Climate	20
Electrical engineering	49
Materials research	33
Mathematics	45
Mechanical engineering	37
Medicine	42
Optics	24
Pharmacy	34
Physics	5
Astronomy etc	109
Atomic Chemistry etc.	24
Particles & Fields	54
Total	688

Table A11: Cooperations between researchers at Irish institutes and analysed IROs

Publications in research fields (2010-2013)	Irish membership			No Irish membership				Under development		Sum
	ESA	EMBL	EMBC	CERN	ESO	ESRF	ILL	SKA	ESS	
Basic Chemistry	1					2	2			5
Biology		8				1				9
Biotechnology		17				2				19
Chemical engineering										

Computers		2								2
Ecology, climate		1								1
Electrical engineering	1									1
Food, nutrition										
Geosciences										
Humanities				1						1
Materials research	1	1				4	4			10
Mathematics		2								2
Measuring, control	1			25						26
Mechanical engineering										
Medical engineering										
Medicine		3								3
Multidisciplinary	1	4								5
Nuclear technology	1			1						2
Optics		1								1
Organic chemistry										
Other										
Pharmacy										
Physics	49			188	13	6	2			258
Polymers										
Social Sciences, Economics				1						1
Social Sciences, Other				1						1
Specific engineering										
Sum of counts	**55**	**39**		**217**	**13**	**15**	**8**			**347**
Absolute number	**53**	**29**		**214**	**13**	**9**	**6**			**324**
Multiple classification	**1.0**	**1.3**		**1.0**	**1.0**	**1.7**	**1.3**			**1.1**

It becomes obvious that co-publications are concentrated in research fields and also with some of the analysed IROs. By far the highest part of co-publications was realized in physics and with CERN, followed by ESA and EMBL. In the case of CERN, this shows that researchers at Irish institutes

published papers in co-operation with one or more authors affiliated at CERN. However, it has to be verified if this is an effect of the 'publication culture' in physics (see above), or if "real cooperation" has taken place.[6]

[6] This analysis takes into account that scientists publish in specific organisations, but cannot detail the exact relationship of scientists and research organizations (full researcher, visiting scientist, etc.).

EUREKA and COST

Both EUREKA and COST are European programmes that foster cooperation activities across Europe: While EUREKA targets European businesses, COST supports transnational cooperation of researchers, engineers and scholars. Since both acronyms represent programmes and not (physical) organisations, bibliometric analysis does not yield the desired results. In addition, particularly in the case of EUREKA, we did not expect to identify a large number of publications since this programme is rather directed towards technological development in private businesses.

Due to these reasons, the methodology in the case of these programmes differs from the approach described above. In order to gain insight into the research structure of EUREKA and COST projects with Irish participation and to identify Irish researchers engaged in these programmes, online searches were realized in both cases:

- The website http://www.eurekanetwork.org/ provides information about the programme, the EUREKA initiatives and projects and also allows searching for individual projects. The projects with Irish participation were selected and a table with the following information was compiled: EUREKA project acronym and name, outline of the project, status (finished/ running/ approved), start and end date, duration, cost, technological area (rarely filled), main contact, Eurostars project (yes/no), participating countries, participating organisation in Ireland, contact person in Ireland, e-mail address of Irish contact person, and source of information. This table showed that Irish companies have participated in about 60 EUREKA project from 1996 to date.
- The website http://www.cost.eu/ provides information on the COST programme and the various projects performed in different action areas. COST project chaired by researchers located in Ireland as well as projects with Irish participation were selected and a table with the following information was compiled: COST action, title, duration, chair, organization, e-mail and source for 20 projects chaired in Ireland. Concerning Irish researchers participating in COST actions, information on the name and organisation as well as e-mail of the researcher and the action involvement were selected. This table contains more than 800 names of researchers in Irish organisations who participated or currently participate in COST projects. These persons were included in an additional online survey performed by CIRCA.

Appendix 5: Outputs from Surveys

In this section we provide a summary of the outputs of the surveys and interviews. The following surveys were carried out using web based "SurveyMonkey" questionnaires.

Survey of Irish Researchers

The concept was to survey a cohort of active Irish researchers who have an interest in one or more of the areas of research that are relevant to the 14 IRO organisations. To establish the relevant areas of research, Fraunhofer ISI conducted a bibliometric analysis of publications with one or more authors affiliated to one of the IROs. Using the Web of Science database (http://thomsonreuters.com/thomson-reuters-web-of-science/) a core set of 16 broad research fields was identified as being the major 'Web of Science' fields with which the 14 IRO organisations were identified. These themes are indicated below. A detailed description of the bibliometric analysis process conducted by Fraunhofer ISI is in Appendix 4.

The themes identified represent the major publication fields in which international researchers have published scientific papers, which cite authors who are affiliated to one of these 14 IROs. Our presumption is that Irish researchers publishing in these fields should be interested in these IROs.

Table A12: Research Fields used for Bibliometric analysis

Basic Chemistry	Biology	Biotechnology	Computers
Ecology / Climate	Electrical Engineering	Materials Research	Mathematics
Mechanical Engineering	Medicine	Optics	Pharmacy
Physics	Astronomy	Atomic Chemistry	Particles & Fields

As a next step a bibliometric analysis was conducted to identify the Irish researchers who are the most active publishers in these 16 fields during the 4 year period 2010-2013. Approximately 50 Irish researchers in each of these fields were then identified, and included in the survey.

The 10 questions or variations thereof used in the Survey were:

1. Is the IRO of interest to you in your research or professional development?
   This was the 'by-pass' question. Respondents answering 'NO' were brought directly to the next organisation without being presented with the more specific questions below.
2. Awareness of the IRO services and programmes.
3. Awareness of Ireland's IRO member status.
4. Which of the IRO services or programmes have you (or members of your research group) availed of in the last 3 years?
5. Of the IRO services or programmes offered (or planned), which might you (or members of your research group) use if Ireland were to become a member?
6. Even though Ireland is not a member, have you used any of the facilities or services of this organisation?
7. How important is this organisation in developing your international research collaborations?
8. As a source of support for your research, how would you rate the IRO?
9. Do you receive information on the IRO activities or opportunities from any source?
10. Please give us your views on the value to your team, and/or to Irish science in general, of potential Irish membership of (IRO).

Following analysis of the database, it was decided that participants in Eureka would not be included in the survey because the individuals for whom names were available were not researchers.

The total number of researchers surveyed was 669. Reminders were sent to those who had not responded on two separate occasions, and the survey was closed on 27 February at which stage 282 responses (42% of the cohort) had been received.

Table A13: Number of Researchers interested in each specific IRO

Is the IRO below of interest to you in your research or professional development?		
	YES	**YES**
COST	238	88%
Eureka	116	41%
ESA	105	39%
EMBL	60	23%
EMBC/EMBO	54	21%
ESRF	54	21%
CERN	51	19%
Elixir	40	15%
ESO	30	12%
LOFAR	32	12%
SKa	27	10%
ILL	24	9%
ESS	24	9%
CTA	22	8%

General Comment

Generally speaking COST is clearly the organisation most widely chosen as being of interest to almost 90% of this cohort of these researchers, followed by EUREKA and ESA.

There is a further group of 7 IROs (EMBL, EMBO, CERN, ESRF, ESO, ELIXIER, 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. The responses to the individual IRO organisations are outlined below.

Eureka

Eureka is primarily directed at the support of industry projects, and thus has limited appeal to researchers. Nevertheless, it was regarded as of interest to 41% of the 283 respondents. There was also high awareness of the services offered (56% were very, or generally, aware) but 55% were not aware of Irish membership. Only 31 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.

COST

This programme showed by far the highest level of interest from researchers, with 88% indicating interest. Within the main researcher survey, only 6% indicated no awareness of the programme, and 92% were aware that Ireland is a member of 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 or extremely important in '*developing international research collaborations*' and only 2% regarded it as unimportant in this role.

ESA

ESA was of interest to 105 researchers, and there was a high level of awareness (93%) of the services offered within this cohort. There was also high awareness (89%) of Irish membership. A total of 62 researchers within the cohort had participated in one or more of the programmes or services offered, and particularly in the research programmes (42 researchers); usage of expertise or facilities (45); and attendance at workshops or conferences (44). It is also regarded as important in 'developing international research collaborations', with only 12% regarding it as unimportant in this role, and 47% regarding it as very or extremely important. Regarding sources of information on ESA, 56% indicated that they do not receive information on its services and, of those who do; the major source is ESA itself.

EMBL

EMBL was only of interest to 23% of the overall respondents, once again noting that this is a specialised organisation and the respondent base is of very wide sectoral nature. Even among those interested, only 36% regarded themselves as being very well aware of the services offered, and 27% were not aware that Ireland is a member. A total of 32 researchers had availed of EMBL services, and this was mainly through attendance at conferences or symposia; but also instrumentation training, Post grad or Post-doc programmes, and collaboration with EMBL researchers. It is regarded as of moderate importance in 'developing international research collaborations'. As an overall source of support, only a minority (37%) regarded it as being vital or important. This echoes the findings of an earlier report (Forfás, 2010) which found low levels of awareness of EMBL across the Irish research system.

EMBO/ EMBC

EMBO was of interest to 21% of respondents (50-60 researchers), and of these 87% were aware of its services, and 67% were aware that Ireland is a member. EMBO offers many services and all had been availed of, but only by 29 researchers in total. The most popular services were short-term fellowships, funding to run workshops and courses, and the EMBO publications. It was regarded as being of slight or moderate importance in developing collaboration networks. Most researchers (71%) do not receive information on EMBO.

CERN

CERN was of interest to only 19% of respondents (51 researchers), and of these 96% were generally or very aware of its services, and 94% were aware that Ireland is not a member. Within this cohort, 31% had used CERN services by other means. 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. CERN was highly valued as a mechanism to develop international research collaboration, with 50% regarding it as being very or extremely important. Similarly, 48% regarded CERN as being either vital or important as a source of support for their research. 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.

ILL

This very specialised organisation was only of interest to 24 researchers (9% of total). Of these 14 were aware of their services to a greater or lesser extent and about half were unaware that Ireland was not a member. 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.

ESRF

ESRF was of interest to 54 respondents (21%), and of these 81% were generally or very aware of its services, and 67% were aware that Ireland is not a member. Within this cohort of 54 researchers, 28% had used ESRF services by other means. If Ireland was to become a member, 52 indicate interest in the following services: 21 Irish researchers would be interested to partner with ESRF researchers; 47 (90%) would seek access to 'beam-time'; and 12 would attend ESRF conferences or workshops.

ESO

ESO provides what are widely regarded as the best observational telescope facilities in the world. ESO was of interest to only 12% of respondents, and of these 97% were generally or very aware of its services, and 90% were aware that Ireland is not a member. Within the cohort of 29 responding researchers, 48% had used ESO services by other means. If Ireland was to become a member of ESO, 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

SKA

This specialised astronomy organisation was of interest to 27 researchers (10% of total). Of these 96% were aware that this organisation was under development. Almost all of this cohort of researchers would use one or more of the services of SKA if Ireland was to become a member. As a source of support for their research, the majority (64%) regarded it as vital (20%) or important (44%). Some comments received on the value of SKA are in Appendix 1.

ELIXIR

Elixir was of interest to 40 researchers. As a new organisation, there was an understandably low awareness (28%) of the organisation within this cohort. If Ireland was to become a member of Elixir,

the services which would be of interest would be: 28 would seek training; 30 would attend conferences or workshops.

ESS

This specialised organisation, whose services are related to ILL above, was only of interest to 24 researchers (9% of total). Of these there was a low awareness of the planned services. All of this cohort of researchers would use one or more of the services of ESS if Ireland was to become a member. Of particular interest would be Access to neutron sources (83% of cohort interested); and access to expertise or facilities (79%).

CTA

CTA is a specialised astronomy organisation, and was of interest to only 8% of respondents, and of these 77% were generally or very aware that it was being planned and built. Within the cohort of 29 responding researchers, 48% had used CTA services by other means. 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.

LOFAR

This very specialised radio astronomy facility was of interest to 32 researchers (12% of total). Of these 88% were aware that this organisation's facilities were under development. Even though Ireland is not a member, 25% of this cohort had already engaged with LOFAR as research collaborators, or workshop attendees. Almost all of this cohort of 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.

Final comment

Despite lack of membership, Irish researchers have worked with IROs/IRO staff over recent years. Some Irish researchers achieved this while they were working/studying in a country that was a member or through collaborations with researchers whose country is a member. Others located in Ireland have accessed IROs though their citizenship of a country that is a member. But such links are unlikely to evolve into anything major or long lasting and tend not to generate national meaningful long term benefits.

Survey of participants in COST

The results of the survey of COST participants is detailed in a separate report. Generally Irish COST participants are very positive about their experiences with COST.

Survey of Irish Astronomy researchers

53 Irish Astronomy researchers were surveyed by email. They were asked for their preferences regarding potential Irish membership of one of the 4 Astronomy related IROs that are the subject of this review: - ESO, CTA, SKA, LOFAR.

A big majority of those who responded expressed a preference for membership of ESO.

Table A14: Preferences of astronomy researchers for IRO membership					
	ESO	**CTA**	**SKA**	**LOFAR**	**Total**
First Preference	23	5	1	3	32
Second Preference	5	5	5	6	21

Survey of IRDG members

To obtain industry views on membership of IROs, contact was made with the Industry R&D Group, which is an "*an industry-led representative group for manufacturing and services companies involved in Research, Development and Innovation*". The full services of the organisation can be seen at http://www.irdg.ie.

A survey questionnaire was developed (in liaison with IRDG Management) and circulated to ~ 4,000 companies on IRDG's mailing list. (Note this list of companies is much greater than the number of companies that are members of IRDG). A total of 89 responses were received, but some 6 of these failed to fully complete the survey. In addition to providing answers to the questions, it was possible to comment on many of the issues, almost no comments were received. The sectors of operation of the 89 respondents are indicated in Table 8

Table A15: In Which Sector Do You Operate		
Answer	**%**	**Numbers**
Chemicals	1.1	1
Construction	2.2	2
Consumer Products	2.2	2
Electronics	6.7	6
Engineering	10.1	9
Energy & Environment	3.4	3
Manufacturing & Supply Chain	19.1	17
Media & Communications		
Medical Devices	0.0	0
Pharmaceutical & Healthcare	12.4	11
Software & Technology	15.7	14
Other	13.5	12
		89

The survey was similar in structure to the Researcher survey. It included an initial question asking if a particular IRO was of interest, and specific information on those IROs in which interest was indicated. It contained information on the role and services of each IRO, including (where available) information on the procurement policy and budget. The 4 Astronomy-related IROs were put together within one question.

Table A 16: Is IRO of interest to your company research performance or competence, or your sales?				
	No. of respondents	**% Yes**	**% No**	**% Don't know**

Eureka	80	40	26	34
COST	76	32	38	30
EMBL	73	8	78	14
CERN	73	8	84	8
ILL	73	4	92	4
ESRF	73	4	90	6
ELIXIR	73	15	66	19
ESS	73	3	88	9
4 Astronomy	73	7	89	4

Table A 17: Were you previously aware of the services and programmes of IRO? (%)

	Very aware	Generally aware	Not aware
Eureka	13	24	63
COST	14	23	63
EMBL	0	17	83
CERN	17	50	33
ILL			100
ESRF			100
ELIXIR			100
ESS			100
4 Astronomy		60	40

In response to the question "*Is IRO of interest to your company research performance or competence, or your sales?*" almost all IROs were regarded as of very low interest (Table A16). The exceptions were EUREKA, COST and (to a lesser extent) ELIXIR. If the 'don't knows 'are excluded from this result, 60% and 45% of companies indicate an interest in EUREKA and COST respectively. A further finding is that there was a very low awareness of these IROs among the respondents. The data is in Table A17, but note that this only includes the views of the respondents who indicated 'Yes' to the question in Table 9

Summary of All Survey results

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). Among enterprises, there is a very different picture. Companies are mainly aware of CERN, COST and EUREKA, but there is no or little awareness of any of the other IROs. In terms of the relative importance of IROs to researchers, the highest level of cited importance are of the astronomy IROs (average 61% citing these are vital or important) while the lowest levels are of EUREKA (18%), ESS (29%) and EMBL (37%). This is very consistent with the issue of 'dependency' identified in Chapter 1 (Introduction) of our main report. In

the industry survey, the highest levels of interest were in EUREKA (40% indicating interest) and COST (38%) and ELIXIR. The other 9 IROs were only of interest to an average of ~6% of companies.

Awareness of Membership or non-membership

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.

Among enterprises, there is a very different picture. Companies are aware of CERN (67%), COST (37%), EUREKA (also 37%) and EMBL (17%), but there is no or little awareness of any of the other IROs.

The low level of researchers (36%) 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[7] of EMBL. This must also reflect a lower level of relevance of EMBL to this cohort of researchers. ELIXIR, whose services are also aimed at this cohort, but which is very new, was only known to 28% of researchers. Some of the IROs are highly specialised and these are understandably less known. ESS, ILL and ELIXIR all show relatively low levels of awareness among researchers.

Relevance and Importance

The relevance of an IRO is directly related to the scope of services offered. Bigger IROs with a broad range of services (CERN, ESA, ESO) will clearly be of wider interest than the smaller specialised IROs such as ESS, ESRF and ILL. While services can be of interest, their importance to the user can vary. Variations in the dependency of different disciplines on IROs are discussed later. Thus, while COST is of interest to 88% of researchers, within this cohort it is only regarded as important or vital to 48%.

Conversely, ESO is only of interest to 12% of researchers, but is regarded as important or vital to 67% of this cohort. Among enterprises, there is again a very different picture. The only IROs which companies indicated as being of interest to their 'company research performance, or sales were EUREKA (40%) and COST (32%). ELIXIR was of interest to 15% of companies, but other IROs were of interest to between 4 and 8% of companies.

The researcher survey validates the high level of dependency on IROs among astronomy researchers. All of the space-related IROs and CERN are rated as important or vital at a level above the average (44%). The lowest levels of importance are shown by EUREKA (18%); ESS (29%) and EMBL (37%).

[7] CIRCA Review…. 2008

Appendix 6: Interview Summaries

Interviews

A series of interviews was carried out with a variety of stakeholders in Ireland and with a sample of experienced researchers in France and Germany. The interviews were mostly face to face, and in some cases by telephone. The key outputs of these interviews are presented below in summarised form. It should be noted that some of these comments can be contradictory, as one would expect given the range of opinions and diversity of people interviewed.

General Comments from Research VPs in 10 HEI interviews
○ 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. ○ The views of the HEIs are not being heard by policy makers. There is a need for a mechanism such as existed in the past (e.g., ACTSI) and for a Chief Science Advisor (separate from any Agency) with a budget who consults and interacts with a HE advisory group. Bring in as decision makers those who will be involved in delivery of benefits from IRO memberships. ○ The costs of IRO memberships are set against the research budget, but the main benefits accrue to industry. ○ Research prioritisation is eroding the link between education and research; it is also de-motivating scientists in those areas not chosen for prioritisation. It has disadvantaged most those who are involved in very fundamental research. ○ Ph. D support and individual grants (e.g. IRC grants) are of primary importance – more important than IRO memberships. Membership of IROs is of little use if students cannot access funds that will facilitate access to these IROs. ○ There is a view that Ireland does not contribute its fair share to European scientific endeavour. ○ There is too much emphasis on excellence in knowledge creation, as opposed to excellence in knowledge diffusion. ○ US based IROs can be an alternative for Irish researchers. ○ A saturation point has been reached in terms of job openings for scientists in Ireland.

Interviews with other Research Groups.

The Institute of Physics and the Royal Irish Academy.
There were some similarities in the comments made by the representatives of these organisations. A summary of these comments follows: • Ireland's exploitation of international scientific infrastructures is too low. • Both CERN and ESO are important to groups of researchers in Ireland. Apart from their scientific benefits, they both have effective outreach programmes. • Membership of CERN and ESO would align Irish science strategy with that of our European partners, and provide Irish industry with opportunities to compete for contracts in a range of areas including imaging, detectors, computing, micro-electronics, big data issues. • They would also provide great opportunities for training for students, teachers, scientists, and engineers at every career stage.

- Research areas such as Astronomy, although not specifically mentioned in the 14 national research priority areas, develop important and relevant skills in areas such as data analytics, imaging, optics etc.
- ESRF, ESS, ILL , LOFAR, CTA are of lower priority.
- Currently it is difficult to acquire funds for research fields which are not explicitly mentioned in the 14 national priority areas. A holistic approach to research funding in Ireland is needed.

The Irish Synchrotron Users Organisation (ISUO)
The main priority for ISUO is to safeguard existing mechanisms of access to Synchrotron Radiation, Free Electron Laser, and Neutron Beam facilities, rather than consider membership of IROs such as ESRF and ILL. It is the issue of EU Trans National Access (TNA), to which the Irish government contributes as part of the overall EC Framework Programme/Horizon 2020 that is most important to the Synchrotron Users Organisation.

Interviews with representatives of Government Agencies

SFI, HRB, EI, IDA, Teagasc, Marine Institute
• The focus of SFI research funding is the 14 national priorities • Small countries are not "scaled down" versions of large countries. • Arguments based on reputational gains are less convincing than arguments based on cost and benefit (for example, membership of ESA brings measurable benefits) • Membership of certain IROs (e.g. ELIXIR) facilitates access to substantial H2020 Research Infrastructure funds • Membership of ELIXIR is attractive, as ELIXIR is part of the European Strategy Forum for Research Infrastructure (ESFRI). ELIXIR is also a good fit for Ireland's SFI funded INSIGHT research centre and is concerned with Data Analytics – one of the national research priorities. The ELIXIR membership fee (<€100k) is relatively small. • Membership of CERN is more difficult to justify. Costs are high and procurement opportunities have not always been realised by some small countries. Individual researchers can access CERN through collaborations with other researchers. • Surveys on public attitudes in relation to science indicate that although members of the public generally support the concept of Astronomy research, in practice most people are unwilling to spend money on it. • ESO could, perhaps, be justified on the basis of data analytics and procurement opportunities. However procurement opportunities for IROs on other continents (e.g., in South America) are more difficult to win than those in Europe. • SFI promotes both EMBL and EMBO, but the interest level among the research community seems to be low. • EUREKA supports international research partnerships – a valuable contribution to Irish SMEs • Teagasc accesses valuable data on agricultural production and land usage from ESA.

Interviews with international researchers

Telephone interviews were conducted with 17 researchers in France and Germany from both University and non-University research organisations whose activities are linked to CERN, ESO, ESRF, ILL. Both Germany and France are members of each of these IROs. These comments are summarised below.

CERN	• 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. Other particle accelerator facilities (Fermilab, DESY) do not compare with CERN. • Researchers with CERN experience (e.g. hardware development, computing skills) easily find jobs in industry, as the specific skills acquired at CERN cannot be gained elsewhere. • In Germany, CERN related experiments at Universities are funded through research programmes (additional costs). • CERN is an important influence in attracting young people to a science career (STEM). • Knowledge created at CERN is available through open source publications.
ESO	• Research in cosmology and galaxies requires experiments at ESO. • Contributing to the design and manufacture of new instruments creates an important indirect impact for the research communities of member states. • It is possible that part of the membership fees could take the form of contributions in kind. • It is advantageous when scientists use instruments that they themselves have helped to develop. • Priority is given to younger researchers from member countries in relation to grants and positions. • Graduates of ESO fellowship programmes are highly demanded by industry; they often have skills not covered by formal education. • Astronomy is to an increasing extent being integrated in the curricula of Universities. ESO participates in some graduate courses in Munich. • France is the second largest contributor to ESO and benefits from a more or less proportional return on investments with respect to the design and manufacture of instruments. • Astronomy cannot be bought "off the shelf". It is thus a driver of innovation in many fields.

ESRF	• ESRF is a very high quality facility, with highly motivated staff. • Over the past 3 years only approx. 15 Irish scientists got access to ESRF, while ~ 500 Israeli scientists used the facilities. • On average one can expect 1 publication per visit to ESRF. • Membership fees seem to be more flexible nowadays. Israel pays ~ 1% or €1m per annum. Czech Republic, Poland, Austria, and Slovakia will form a consortium contributing 4% to ESRF budget. UK's contribution is 14% for a much higher access time. • Priority given to young researchers. About 60 PhD D students at ESRF at any time. • ESRF communicates well with audiences beyond the scientific community. After the accession of South Africa as a member state, special efforts were made to publicise ESRF findings related to an ancient skull found in South Africa. • ESRF practices a strict "*juste retour*" policy in relation to industry contracts.
ILL	• Important research fields are energy, physics, and chemistry. • ILL is like a "beehive" with many researchers interaction with one another. There are also other research facilities on the Grenoble research campus. • ILL facilitates visits from school groups to the ILL campus. • Typically students stay at ILL a period of about 2 years. • Industries may perform "protected research". They pay for the use of the facilities and are owners of the results.

Interviews – Overall summary of views expressed.

- ✓ There is a need for a mechanism such as existed in the past (e.g. Advisory Council for Science, Technology and Innovation) and for a Chief Science Advisor (separate from any Agency) with a budget who consults and interacts with a HE advisory group.
- ✓ Research prioritisation is eroding the link between education and research; it is also de-motivating scientists in those areas not chosen for prioritisation. There is a need for a holistic approach to research funding in Ireland.
- ✓ PhD D support and individual grants (e.g. IRC grants) are of primary importance – more important than IRO memberships. Membership of IROs is of little use if students cannot access funds that will facilitate access to these IROs.
- ✓ There is a view that Ireland does not contribute its fair share to European scientific endeavour.
- ✓ There is strong support for membership of ESA, COST. Strong interest in, but also some mixed views, about EMBL, CERN, ESO, ELIXIR.
- ✓ Membership of certain IROs (e.g. ELIXIR) facilitates access to substantial H2020 Research Infrastructure funds through ESFRI.
    - There is a lower level of interest in ESRF, ILL, LOFAR, ESS, SKA, CTA.
    - EUREKA is valuable for Irish SMEs, of less interest to the HEI sector.
    - The priority for the Synchrotron researchers is not IRO membership, but support for Trans National Access (TNA) to a variety of IROs.
    - German and French researchers are all very positive about the benefits of membership of CERN, ESO, ESRF, ILL.

Appendix 7: Ireland's national research priorities

Priority Area A - Future Networks & Communications

Priority Area B - Data Analytics, Management, Security & Privacy

Priority Area C - Digital Platforms, Content & Applications

Priority Area D - Connected Health and Independent Living

Priority Area E - Medical Devices

Priority Area F – Diagnostics

Priority Area G – Therapeutics: Synthesis, Formulation, Processing and Drug Delivery

Priority Area H - Food for Health

Priority Area I - Sustainable Food Production and Processing

Priority Area J – Marine Renewable Energy

Priority Area K - Smart Grids & Smart Cities

Priority Area L - Manufacturing Competitiveness

Priority Area M - Processing Technologies and Novel Materials

Priority Area N - Innovation in Services and Business Processes

Platform Technologies which support the above Research Priorities.

Basic Biomedical science

Nanotechnology

Advanced Materials

Microelectronics

Photonics

Software Engineering.

Appendix 8: Other IROs of possible interest.

A few other IROs were brought to our attention during the course of this study that may be of interest now or in the future.

CECAM

CIRCA has carried out some limited desk studies and a limited number of telephone interviews with relevant experts in relation to the CECAM network, and its Irish node CECAM-IRL. We have not had the time to carry out the full range of data gathering – as we have done in relation to the 14 IROs originally specified in our terms of reference.

On the basis of this limited study of CECAM, we believe that it successfully meets many of the 15 assessment criteria - scientific, educational and industrial - that we have used to judge the other IROs. Moreover its annual membership costs are small (€30k).

We have no means of independently checking that some School or Institute within UCD genuinely cannot find the funds for this CECAM membership. Equally we don't know if it would be possible to work out some cost sharing agreement with the other Irish based institutions involved in CECAM-IRL for example TCD, QUB, NUI Maynooth, Tyndall/UCC, UL.

But (bearing in mind the limited desk and field work that we have done) our recommendation is that it is important for Irish science that the membership of CECAM should continue to be funded, because

- its work is of high quality and importance, and very relevant to national research priorities,
- it does not duplicate other publicly funded computer based research work
- it would score well on the benefit cost model that we have used in this IRO study,
- it has already demonstrated the capacity to earn significant funding from H2020, and has the potential to earn more in the future.
- It is attracting interest from some industrial companies.

CECAM is a pan-European network which supports joint research and collaboration in the field of computational simulation science. It is directly relevant to Priority Area C of the National Research Priorities – Digital Platforms, Content, and Applications. CECAM is headquartered in Switzerland and facilitates collaboration through 18 nationally-based nodes. There are industrial sponsors for specific meetings – BASF etc. CECAM's main objectives are to implement a research strategy in computational science that boosts the capability of the partner organisations to address emerging challenges in science and technology. The CECAM convention is the legal instrument establishing CECAM. Current cost of CECAM membership is €30k. This annual cost has until recently been borne by UCD Physics Dept (The IUA is the formal signatory to the convention.) We are told that it is increasingly difficult for the Physics Dept at UCD to continue to fund this.

Modelling and Simulation as an area of scientific expertise.

In past years modelling and simulation (M & S) were of limited effectiveness in linking science theory with practical experimental science. Today, with powerful computer programmes M&S has become much more effective in improving the efficiency of experimental trials by narrowing down the range of experiments to be done (for example in drug trials).

Nobel Prize

In 2013 Martin Karplus, Michael Levitt, and AriehWarshel were jointly awarded the Nobel prize for Chemistry "*for the development of multiscale models for complex chemical systems" - another indicator that this computer driven area of research expertise has come of age, and established itself.*

Other issues

Although CECAM researchers in Ireland would use ICHEC supercomputers from time to time, there is no overlap between ICHEC and CECAM – they are complementary.
UCD were recently successful in the e-infrastructures call EINFRA-5-2015 under Horizon 2020 (Topic: Centres of Excellence for computing applications), leading a consortium called "E-CAM". The proposal was for "An e-infrastructure for software, training and consultancy in simulation and modelling" and the project value seems to be over €4.8m. UCD will receive ~ €900k of these funds. About 15% of this (~ €130k) will be absorbed by UCD central administration as overhead costs. The rest of these project funds have to be used for project work.

Without membership of CECAM, UCD could not have participated in this H2020 call. In fact UCD are project coordinators because the Swiss central node of CECAM could not act as coordinators, and asked the UCD node to act in its place as project coordinators. There is likely to be more H2020 e-infrastructural funding that could be won by CECAM in the next few years. Hence there is already significant "cost recovery" in the case of CECAM.

Industrial interest.

The Kerry Group were involved in this H2020 bid - so it has relevance for food industry research. Also a UCD spin out company called APC (Pharma process engineering) were involved in the H2020 submission.

PRACE: Partnership for Advanced Computing in Europe

Ireland is a member of PRACE through the Irish Centre for Advanced Computing (ICHEC) which DIAS was instrumental in establishing. Access to supercomputing resources is an example of a field where the requirements, at the highest level (tier 0 in PRACE terminology) are of such a scale and complexity that it makes sense to provide them at continental level as a shared European infrastructure

supported by local national infrastructures (tier 1) of which ICHEC is one. Advanced computing is now a fundamental research tool underpinning vast areas of science, from cosmological simulations of the entire universe, through *in silico*biology, to lattice QCD simulations of the internal structure of sub-atomic particles. At the highest levels the technology is very expensive and rapidly evolving (a high performance computer typically has a useful life of about three years before it becomes obsolete) so that a coordinated European provision and roadmap makes a lot of sense. ICHEC has demonstrated at national level a remarkable level of technology transfer into local industry and enjoys strong support from DJEI and the IDA. Prof Luke Drury is currently a member of the Scientific Advisory Committee of PRACE. For more information on PRACE see http://www.prace-ri.eu and for ICHEC https://www.ichec.ie

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XFEL:

This facility is under construction in Hamburg, Germany. The European XFEL will open up areas of research that were previously inaccessible. Using ultra short X-ray flashes scientists will be able to map the atomic details of viruses, decipher the molecular composition of cells, take three-dimensional images of the nanoworld, film chemical reactions, and study processes such as those occurring deep inside planets.
