

Impact Statement

3.1 iCRAG Centre's Vision for Economic and Social Impact

The principal economic impact objective of iCRAG is to unlock Ireland's natural resources, by developing improved technical knowledge and innovative techniques to increase the success rate of hydrocarbon, mineral and groundwater exploration. This will, in turn, stimulate and incentivise greater exploration activity in Ireland, thereby creating direct jobs and skills, and will provide a commensurate improvement in Ireland's potential to discover and develop offshore oil and gas resources, and onshore mineral wealth and groundwater supplies, to the benefit of the Irish economy and people.

The overarching societal impact objectives of the Centre are: (i) helping to ensure a plentiful supply of clean groundwater, by monitoring and minimising the environmental impact of industrial activity, (ii) securing Ireland's energy supply by developing Ireland's offshore gas and oil, and improving renewable sources, and (iii) providing enhanced educational and training environments for geoscientists and improved geosciences information to decision makers and the general public.

3.2 Importance of the Geoscience Sector to Ireland's Economy

An independent economic study (Geosciences, Gaining Ground, DCENR, 2007) estimated that, in 2006, the geoscience sector in Ireland employed over 30,000 people, or 1.4% of total Irish employment but added €4.6 billion (3% of GNP) to the economy. The sector makes a valuable contribution to balanced regional development, providing attractively paid work in rurally-based enterprises. Furthermore the industry has the rare potential for high impact wealth and job creation with minimal input, in the event of a natural resources discovery.

The geosciences sector is of major importance to the Irish economy because there is an urgent need to discover and utilise its natural resources, to safeguard the supply of oil, gas and water, and to boost a recovering economy by attracting inward investment and the associated creation of jobs. All the industry spokes associated with iCRAG will contribute to this and provide resulting economic benefits, aims which are supported by iCRAG's 53 industry partners and its 3 agency partners.

Ireland imports 100% of its oil and more than 95% of its gas needs, more than most other EU countries, with the resultant high risk associated with interruptions of supply and volatility in cost. This has recently been highlighted by the unrest and potential gas supply threat arising from the Russia – Ukraine dispute. The Irish offshore contains a number of very large, lightly explored sedimentary basins with indications of working petroleum systems. However, to date only Kinsale Head, Ballycotton and Seven Heads (all now nearing the end of their producing lives) have been in commercial production, while the Corrib gasfield should come on stream in 2015. Although the oil and gas exploration industry

"Ensuring secure reliable and safe supplies of electricity, gas, and oil is critical to Ireland's ability to attract inward investment, promote domestic investment, retain and create jobs and promote societal interests." – Pat Rabbitte, Minister for Communications, Energy & Natural Resources

has invested more than €3 billion in exploration and appraisal in the Irish offshore since 1970, the pace of exploration has lagged behind that of our neighbouring competitor countries, principally because of the more challenging geological conditions. This combination of insecure supply, low exploration activity, and challenging geological conditions, highlights the need to **invest in geoscience research now** to increase exploration success in this environment and secure new energy sources.

The financial impact of oil and gas production can be immense. A recent report commissioned for the UK government (the Wood Review 2013), demonstrated that the

British oil sector is the biggest industrial investor in the country, having put in £317 billion (\$528 billion, €383 billion euros) since North Sea oil production started four decades ago. It accounted for 15 % of corporation tax collected in 2012-2013 and employs 450,000 people directly and indirectly. An indication of the financial benefits from a single commercial discovery in Ireland can be seen from the fact that more than 1000 people (more than 50% of them from Mayo) have been employed in the construction of the Corrib gas onshore facility. In the past couple of years, there has been a modest resurgence in international interest in Irish offshore exploration. iCRAG is designed to provide an improved understanding of the nature and geological evolution of offshore Ireland which will help stimulate drilling interest and increase the possibility of a commercial oil or gas discovery.

Ireland is Europe's largest producer of zinc, but with both active mines in Galmoy and Lisheen reaching end-of-life, there is an urgent need for iCRAG's applied research in Raw Materials (Spoke 1) to support and stimulate the efforts to discover new economic mineral deposits. In 2012 Irish sales turnover

in mining amounted to €426 million;

combined total expenditures by exploration and mining companies amounting to an estimated €313 million (Assessment of Economic Contribution of Mineral Exploration and Mining in Ireland, Indecon, 2013). The combined direct, indirect

and induced impact of these

expenditures is estimated at €810 million. iCRAG will play a direct role in aiding exploration companies find new viable mineral resources by providing the necessary data-based understanding and exploration models applicable to the Irish mineral province.

Security of supply of safe water is central to the requirements of 'water hungry' industries, ranging from the agri-food to the 'high-tech' pharmaceutical and IT sector, whilst minimising detrimental impacts to the environment. The rapidly increasing demands of industrial sectors, critical to Ireland's economic recovery and growth, require urgent investment in research defining improved methods for predicting groundwater resources, a requirement which will be met by iCRAG research in Spoke 3 (Groundwater).

3.3 The role of iCRAG in supporting the Geosciences Sector, and other sectors

The geoscience academic community has a very close relationship with enterprise and its contribution to associated successes is reflected in its major engagement with industry, with substantial industry funding for both research projects and academic lecturing staff at a level which, for its size, is well beyond other disciplines. For example, the UCD School of Geological Sciences is responsible for more than 36% of the industry funding for science research in UCD over the past 5 years. The high quality research of iCRAG members is

therefore strongly aligned to the requirements of industry. iCRAG will support companies investing in Ireland by providing improved exploration models and methods which will both promote exploration activity and improve associated success rates. These will also enhance

"As the target depth for finding new ore gets deeper, we are examining increasingly innovative and sophisticated exploration methods including new geophysical, geological and geochemical techniques" – Stefan Romedahl, General Manager of Boliden Tara Mines Ltd

"The work proposed supports the objective of reducing exploration risk and facilitating exploration activities offshore Ireland. The development of newly discovered hydrocarbon resources offshore Ireland will guarantee future tax revenue for Ireland, improve energy security of supply, increase turnover and remuneration to both capital and labour and generate employment" – Nick O'Neill, Secretary of PIPCo RSG Ltd

the international exploration programmes of the 12 Irish mineral companies and 11 Irish oil companies with significant overseas activities.

Risk is a primary concern in geoscience exploration projects and especially in offshore exploration for hydrocarbons in deep water. Scientific information which de-risks a project can have a major impact in attracting more companies, increasing activity and leading to more exploration wells and increasing the likelihood of a commercial discovery. A recent (May 2013) PWC report ‘Making the most of our natural resources’ estimates that five commercial oil/gas discoveries would yield €22.5 billion in corporation and PRRT (‘petroleum’) tax over the life of the fields, and would produce over 12,000 jobs. These benefits, combined with the security of supply, would have an enormous impact on the Irish economy.

Tullow Oil, (valued at c. €9 billion) established its global Geology and Geophysics Technical Centre in Dublin where it employs 400 people.

Tullow Oil sponsors four academic geoscience staff positions in UCD and has technical alliances with several research groups in UCD, funding research projects.

Spokes 2 and 4 of the research programme specifically target this enormous opportunity. The potential gains are so significant that the results of iCRAG need only make a very minor contribution to those gains to achieve the impact component of its mission and repay SFI’s investment many times over. The Irish offshore deep-water basins are centrally located in the Atlantic passive margin where recent discoveries have been made in other countries, and are ideally located for fundamental research into the nature and development of the hyperextended basins that characterise this margin. Providing exploration models and play concepts based on deep understanding of the nature and geological evolution of the basins will help to stimulate drilling interest and increase the likelihood of a commercial oil or gas discovery. The research outputs will be of value to Irish companies with increased activity abroad, either as explorers or as supporting service companies. Most nations that export raw materials have already established Centres of Excellence in Mineral Exploration which support industry by providing high quality technical backdrop to their exploration efforts. For example, the Australian Research Council funded CODES (Centre of Excellence in Ore Deposits) is a global leader in mineral exploration research and has activities far beyond the Australian continent, demonstrating that applied research itself is a commodity, with the centre providing analytical and technological services as well as training to a global array of collaborators and industry partners. Therefore if Ireland is to achieve similar success in exploration SFI must invest in iCRAG as the national centre of excellence in mineral exploration. A first small

“Teck Ireland believes that this proposed research centre would add significant value to the mineral exploration industry in Ireland and would increase the potential to make economic mineral discoveries in Ireland” – Chad Hewson, Exploration Manager Teck Ireland Ltd

step in this direction has been made by a group of mineral companies with Irish interests, through the funding of an associated lectureship at TCD. iCRAG will be Ireland’s first concerted attempt to capitalise on the unique national archive of decades of mineral exploration, by providing the essential backdrop to the investments in Ireland made by mineral exploration companies, as well as technically informing or underpinning the overseas exploration of Irish mineral companies abroad. The market for energy critical element (ECE) metals is valued at >€1 billion per year (dominated by rare earth elements, other elements valued at ca. €300 million per year; Skirrow et al., 2013). The iCRAG initiative could radically increase the value of Irish mineral resources by defining methods in which ECEs

can be sourced from ores. These metals are essential to the production of components used in the production of renewable energy (e.g., magnets and photovoltaics) and nanotechnology. The chief obstacle to more efficient extraction from base metal ores is a lack of knowledge of their distribution and the resulting inadvertent blending of high-ECE with low ECE ore. The currently untapped market for providing this expertise globally will be explored by iCrag, and will build on work by TCD researchers with the leading Chilean copper mining company CODELCO to understand the extraction of ECEs from leached Cu ore.

‘High-tech’ industry sectors attracting large multi-national companies, demand a secure and safe supply of water. In Ireland an increasing amount of this (18% and rising) comes from subsurface groundwater, while the remainder (from surface water sources) is intrinsically more vulnerable to short-term droughts and to unpredictable pollution events. In Spoke 3 ‘Groundwater’, iCrag will develop improved methods for sourcing the essential groundwater requirements of ‘water hungry’ industries, and at the same time define policy which minimises its environmental impact. It will also investigate the geothermal potential of deeper circulating groundwater flow systems as a renewable ‘always-on’ source of energy. The improved knowledge and associated technical advantage afforded by iCrag research

iCrag Track Record of Impact: Lead Applicant Group – 9 members

iCrag members have an extensive track record of working with industry to deliver real impact and these industrial relationships have only been strengthened in the development of this proposal. The companies supporting this proposal have helped to define the research plans associated with each of the spokes and their confidence in the team is evidenced by the large value of cash €3.5M and in kind €7M contributions from 53 companies. Together the 9 members of the lead applicant group have:

- Secured €3.9m in industry funding for research projects in the past 5 years
- Also secured nearly €3.0m of industry investment to create 4 academic staff positions in the past 2 years
- Generated > 25% of funding from industry
- Projects supported by more than 40 company sponsorships in the past 5 years
- Secured 1 innovation award from EI and the 2010 NovaUCD Award
- Signed 2 licences with the software industry
- Trained >150 PhD students and >70 post docs, the vast majority of which have gone on to industry.

will be advantageous not only to exploration companies but also to the associated service industry. The latter includes iCrag industry partners Geoscience Ireland, an alliance of 20 companies together employing 1100 staff, but will also involve potential startup companies implementing iCrag know-how in software for the hydrocarbon and mineral industries. iCrag members have significant experience in this area, having been associated with the development of leading software packages for the hydrocarbon industry; one of which has had revenues in excess of €0.5M in the past 5 years.

3.4 Economic Impact of Platform and Spoke Research

The iCrag research programme has been developed to address the principal technical requirements across application areas within the geoscience sector. iCrag researchers work with all the major petroleum and mineral exploration companies in Ireland, with many of the world’s leading geoscience industries, and with state agencies such as the two Geological Surveys in Ireland and the Environmental Protection Agency (EPA). This ensures that our research programme reflects the needs of industry, with our technical approach defined by

our team in collaboration with industry partners. The target for iCrag is to develop innovative ideas and models and to optimise techniques underpinning exploration and development of Ireland's natural resources including gas, oil, minerals, water and building materials. The main 'impact focus' of iCrag, is increased investment in exploration and a concomitant increase in the likelihood of commercial success (Table I1).

Table I1: Expected benefits of iCrag to stakeholders.

Who	How will stakeholder benefit from research	How & SFI Objectives
Ireland Inc	- De-risking of Irish hydrocarbon and mineral exploration will lead to increased foreign investment in exploration and enhanced probability of commercial discoveries with major economic benefits. - Improved technical expertise will improve performance of Irish companies in overseas exploration and in associated service industries. - Development of Irish software presence for hydrocarbon industry leading to spin-offs and associated licences. - Increased employment and tax revenue with the discovery of even a single offshore reservoir or mineral deposit, can be substantial: one oilfield of an anticipated scale of Bartyroe could employ 1200 for up to 20 years with revenues of €23billion and corporate tax and PRRT of €4.5billion. Measurable Impact Indicators: 1 Multi-national company partner to develop or expand corporate R&D lab in Ireland by 2020 2 High Potential Start-Ups by 2020	Transfer of technology and soft-knowledge to industry partners via presentations, reports and, in some cases, software. Transfer sometimes facilitated by industry placement of researchers and by university placement of industry staff. Software licencing and software spin-offs. Meets SFI Objectives: 1,2, 3, 4, 5, 6, 7, 8, 9
Wider Industry	- Security of supply of both energy and water are critical requirements for multi-national manufacturing industries. - The Corrib gas field will provide up to 60% of Ireland's gas needs during peak supply and is estimated to have a field life of 15-20 years. More discoveries are therefore required to meet Ireland's needs. - Concerns regarding security of affordable energy supply may result in fewer companies relocating to Ireland and, in the case of interruption of energy supply, could have a devastating effect on Irish industry and the economy in general. Measurable Impact Indicators: 70% graduates with industry as first destination 2 Industry Open Days p.a.	Transfer of technology and soft-knowledge to industry partners via presentations, reports and, in some cases, software. Transfer sometimes facilitated by industry placement of researchers and by university placement of industry staff. Meets SFI Objectives: 2, 5, 6, 7, 8, 9.
Society in General	- Policy guidelines on groundwater exploitation, flood risk mitigation and protection of groundwater-related ecosystems. - Increased likelihood of security of supply of energy and water. - Improved human health by reducing risk to populations currently exposed to metal, metalloid, nitrate and microbial ingestion via untreated groundwater. - Measurable Impact Indicators: 5 technical/policy papers to Government by 2020	Publish policy guidelines through Environmental Protection Agency. Meets SFI Objectives: 1, 2, 6,
Company Partners	- Industry partners will adopt research results and methods which de-risk exploration and provide the essential backdrop to the efforts of industry to discover, develop and produce natural resources for their and Ireland's benefit. - Irish service industry and exploration companies can use the improved know-how to benefit their overseas operations. - Industry will also benefit from the availability of methodologies embodied in software and provide a test bed for new methods. - iCrag will also provide a cohort of highly qualified and skilled graduates for Irish industry. Measurable Impact Indicators: 20 commercial licence agreements (including NERF licences) 5 licenced technologies by 2020 10 joint research programmes with industry by 2020 5 new partners beyond existing p.a. 11 industry placements per year	Transfer of technology and soft-knowledge to industry partners via presentations, reports and, in some cases, software. Transfer sometimes facilitated by industry placement of researchers and by university placement of industry staff. Meets SFI Objectives: 1, 2, 3, 5, 6, 7, 8, 9

Associated critical contributions to Ireland's economic growth involve the security of supply of energy, water and building materials, with shortages of any of these resources potentially having a devastating impact on many industry sectors within our economy. Our ambitious and innovative research programme reflects not only the brief of the SFI call 'Geoscience underpinning sustainable economic development', but also extends the reach of geosciences across the economic spectrum. The breadth of research is a strength, with multiple synergies between different application areas, sometimes with geological and subsurface databases common to several spokes. In addition, there are cross-linking geological processes, such as sedimentary architecture and fluid flow, that will yield benefits in the cross-fertilisation, development and application of ideas and models. iCRAG will also deliver more conventional impacts, in the form of licences and start-ups, together with a broad range of societal and educational impacts.

Platform and Spoke research will together deliver impacts, with three of the 4 platform projects providing the essential geophysical and geochemical innovations and support, together with datasets which will underpin research in the spokes. Each platform project supports multiple spokes, increasing centre cohesion and leading to innovations which straddle application areas and are multi-disciplinary in nature. Individual targeted projects will utilise state-of-the-art methods and technologies, some of which will be developed in the platform, to address the requirements of industry. The main impacts are highlighted in Table I1 and the Tables below which also show how they deliver on the SFI objectives.

Spoke 1: Raw Materials

Our raw materials research will address the imminent domestic ore reserve issues by providing the first 3D model of the Irish Pb-Zn mineralisation system and by spatially defining the pathways of geofluids (Table I2). We will also perform research on other types of mineral deposit in an attempt to broaden the scope of Irish mineral studies and related exploration. Identifying the importance of energy critical elements (ECE) underpinning the renewable energy revolution, we will perform world class research linked to this large emerging market. Finally, we will address the nation's need for sustainable building materials with a combination of approaches, including novel analytical innovation for fingerprinting quarry products and exploring non-traditional sources for high-quality building materials. Specific impacts linked to Targeted projects are provided in the table below.

Spoke 1. Raw Materials	SFI Objectives
Project: TP1.1: Extending the life of the Zn-Pb Minerals Industry in Ireland	1,2,3,6,7,8,9
Partners: Boliden, Geoscience Ireland, GNS, Lundin, PIPCO, SRK, Teck, Trevali Mining De-risk mineral exploration, attract greater foreign investment and increased likelihood of the discovery of Irish Zn-Pb mineral deposits through improved models for their origin, geometry and evolution and better geological, geochemical and geophysical methods for their discovery.	
Project: TP1.2: Broadening the scope of mineral exploration in Ireland	1,2,3,6,7,8,9
Partners: Geoscience Ireland, GNS, International Lithium, Lundin, SRK De-risk mineral exploration, and increase foreign investment and likelihood of economic discovery via better models for unexploited Irish mineral deposit types, and new methods for their discovery.	
Project: TP1.3: Energy critical metals (ECEs)	1,2,3,6,7,8,9
Partners: Trevali Mining, Lundin, Teck Ireland, SRK. Centre of excellence in ECE metals, essential to the manufacture of renewable energy industry components, will provide new models for their presence and distribution in host minerals and will lead to their potential exploitation from mineral deposits in Ireland and overseas.	
Project: TP1.4: Sustainable building materials	1,2,3,6,7,8,9
Partners: Eurostone, Geoscience Ireland, Homebond	

Ensuring the supply of high quality and safe aggregates for the building industry through new multi-disciplinary approaches to characterising aggregate sources, including chemical fingerprinting of pyrite-bearing quarry products, and improved characterisation of sea bed aggregates.

Spoke 2: Marine Geoscience

This spoke will generate a database and regional stratigraphic models of the shallow subsurface seabed which is applicable to a range of industrial activities in Irish water and extends national seabed mapping coverage to depth. The ability to monitor and identify surface slicks via remote sensing will provide valuable information of economic importance for a variety of end users from a diverse range of maritime industries. Research on the identification of hydrocarbons by fluorescence in the Irish Marine environment directly feeds into the establishment of Good Environmental Status for chemical pollutants in the context of the Marine Strategy Framework Directive. Specific impacts linked to Targeted projects are provided in the table below.

Spoke 2. Marine	SFI Objectives
Partners: PIPCO - Atlantic Petroleum, Cairn Energy, Chevron, ENI, Europa Oil and Gas, ExxonMobil, Husky Energy, Kosmos Energy, Maersk Oil, Providence Resources, Repsol Exploration, San Leon Energy, Serica Energy, Shell, Sosina and Woodside Energy.	
Project: TP2.1: Enhancing knowledge and understanding of Ireland's seabed	1,2,3,6,7,8,9
Strategic evaluations of Ireland's seabed pertinent to industry's needs and to evaluate seabed geohazards, including landslides, which could negatively impact sea bed installations and pipelines.	
Project: TP2.2: Marine remote sensing applications	1,2,3,5,6,7,8,9
New remote sensing tools for industry to aid in the economic development of Ireland's offshore regions and provide baselines for assessing GES, with development of a suite of decision making software tools customized to Ireland's offshore regions for industry and policy makers.	

Spoke 3: Groundwater

Our groundwater research will enhance knowledge of hydrogeological controls on groundwater flow leading to the development of policy guidelines on (a) groundwater exploitation and management, (b) flood risk mitigation, and (c) protection of groundwater dependent terrestrial ecosystems. We will generate improved understanding of the geological, geotechnical and geochemical processes that control contaminant mobilisation, migration, retardation and immobilisation relating to (a) the operation of unregulated private wells and group water schemes that currently supply almost 200,000 households in Ireland, (b) the subsurface behaviour of nutrient-related and 'emerging pollutants' in rural areas, (c) the impact of submarine freshwater discharges on coastal ecosystems and (d) the flow characteristics of selected deep (c.1,300m) low-enthalpy geothermal systems. Specific impacts linked to Targeted projects are provided in the table below.

Spoke 3. Groundwater	SFI Objectives
Project: TP3.1: Geological & Climate Change Impacts on Groundwater Quantity	1,2,3,6,7,8,9
Partners: David Ball Assoc., Geoserv, Geoscience Ireland, PIPCO, Lundin, NRA, Tobin Consulting Evidence-based criteria for the sustainable development and siting of 'water hungry' industries, (e.g. 'high-tech' pharmaceutical and IT sectors), whilst minimising detrimental impacts to the environment. Improved methods for discovery and appraisal of low-enthalpy geothermal systems.	
Project: TP3.2: Land-use & Climate Change Impacts on Groundwater Quality	1,2,3,6,7,8,9
Partners: David Ball Assoc., Geoserv, Geoscience Ireland, Lundin, NRA, Tobin Consulting Reduction of the risk to populations currently exposed to metal, metalloid, nitrate and microbial ingestion via untreated groundwater, improved efficiency in the mari-culture industry by counteracting the detrimental effects of submarine freshwater outflows.	

Spoke 4: Hydrocarbons

Our hydrocarbons research will (a) help de-risk and stimulate Irish offshore exploration, improving the likelihood of oil and gas development, production and increased revenues, (b) support Irish companies exploring overseas (c) advise government in optimising exploration and development strategies by provision of independent scientific information and exploration models, (d) lead to new spinout companies, commercial industry software and expertise that will generate employment, (e) enhance Irish research reputation, improving the skills base and making Ireland a more attractive place to locate specialist geoscience service companies and research offices, (f) develop a global subsurface training and information centre, that will provide training for the international oil and gas exploration industry, act an interface with Irish schools and the local community, be a source of scientific information to inform public opinion on geoscience topics, and serve to attract high-impact international visitors to the Atlantic coast region. Specific impacts are provided in table below.

Spoke 4. Hydrocarbons		SFI Objectives
Partners: PIPCO (Atlantic Petroleum, Cairn Energy, Chevron, ENI, Europa Oil and Gas, ExxonMobil, Husky Energy, Kosmos Energy, Maersk Oil, Providence Resources, Repsol, San Leon Energy, Serica Energy, Shell, Sosina, Woodside Energy) & GNS.		
Project: TP4.1: Sediment tracking		1,2,3,6,7,8,9
Development of sediment tracking techniques for the oil and gas exploration industry and associated predictive tools for reservoir sandstone distribution and quality, issues which help define the exploration potential of sedimentary basins, including offshore Ireland.		
Project: TP4.2: Basin evolution and petroleum systems		1,2,3,6,7,8,9
Improved understanding of the evolution of reservoir and trap architecture in sedimentary basins from early rift to hyperextended passive margins, providing better predictive capability for prospectivity, thereby de-risking and helping to attract foreign exploration investment to Ireland.		
Project: TP4.3: Reservoir modelling and software development		1,2,3,4,5,6,7,8,9
Production of new workable models of sedimentological and structural reservoir heterogeneity that will assist in maximising oil and gas recovery in complex reservoirs and the associated development of new reservoir modelling software techniques for the hydrocarbon industry.		
Project: TP4.4: Unconventional hydrocarbons		1,2,3,6,7,8,9
Assessment of unconventional hydrocarbon potential in the Irish offshore and onshore, including natural gas hydrates and shale gas, identification of potential exploration and production techniques and their associated geoscientific risks.		
Project: TP4.5: Global Subsurface Training Centre		1,2,3,6,7,8,9
To develop a global subsurface training and information centre combining behind-outcrop cores and associated outcrop and borehole data from the Clare Basin, western Ireland, a centre which will provide unique training and outreach capabilities, as well as attracting high-impact international visitors to the Irish Atlantic coast and providing a sustainable economic benefit to the region.		

Spoke 5: Opidat – Big Data

This spoke is designed to address issues related to large hydrocarbon seismic datasets and the performance of file system and format changes, together with common operations, both routinely and efficiently on existing and future hardware.

Spoke 5: Opidat		SFI Objectives
Project: TP.1: Sediment tracking		1,2,3,6,7,8,9.
Partners: DataDirect Networks, Tullow Oil		
(1) Virtual file system (VFS) to alleviate conflicts between geophysics file formats, to consolidate and reduce data, reduce management overheads and leverage available technology transparently. (2) Optimised parallel I/O library (PIOL) to perform efficient operations on industry standard files.		

3.5 Wider Impact

1. Security of energy supply is an increasing risk for all industrial countries, especially Ireland, where we have an energy import dependency of over 90%. iCRAG research will help de-risk Irish offshore exploration and play an important role in improving Ireland's security of energy supply. In addition non-conventional on-shore gas has revolutionised the energy market in the US and may ultimately play an important role in securing affordable and secure gas supplies for Ireland. Our Platform research includes baseline research on geological risks and societal perceptions and concerns in this area.
2. Improved basis for sustainable development and siting of 'water hungry industries' which underpin much of Ireland's economic recovery, and policy guidelines on large scale groundwater exploitation and management, flood risk mitigation and protection of groundwater dependent ecosystems.
3. Improved human health by reducing the risk to populations currently exposed to metal, metalloid, nitrate and microbial ingestion via untreated groundwater, improved efficiency in the mari-culture industry by counteracting the detrimental effects of submarine freshwater outflows and economic benefits offered by geothermal systems close to population centres.
4. Geoscience can provide an added niche to tourism in Atlantic coastal regions, linking with the recently launched Fáilte Ireland Wild Atlantic Way tourist route initiative. In excess of 200 geoscientists visit the area on international courses each year providing a high-impact tourist spend and with the advent of our Global Subsurface Training Centre the better provision of tailored core training facilities will lead to an associated increase in visitors.

3.6 Impact Structures and Supports

iCRAG is an innovative concept that will achieve the scientific, economic and societal impacts by building a network of excellent researchers from key areas of the geosciences sector across the country, together with international academic colleagues and supported by industry collaborators. In order to assure its planned impact the Centre's integrated and multi-faceted approach has developed (a) the appropriate academic/industry research mix, (b) a system to ensure the integration of access to appropriate world class analytical equipment in the constituent institutions, (c) a multidisciplinary knowledge dissemination methodology between research spokes and with the platform, (d) management of technology transfer and commercialisation across all its constituent institutions, (e) an effective public outreach and communications environment and (f) a governance and management system that is cognisant of the dynamic nature of interdisciplinary science and the mutual objectives of top quality geoscience research and of industry. iCRAG involves all the geoscience research institutions in Ireland and has partnerships with all the major geoscience industry companies in Ireland. Together with these, and in combination with our international partners, our research is tailored to industry, and benefits from their financial and technical support. This close linkage ensures that our research results will be used to achieve our intended impacts.

3.7 Training, Education, Entrepreneurship and Outreach

Training and Education: There will be 68 PhD and 48 Postdoctoral positions in iCRAG. In combination with the generic transferable, research and innovation skills outlined below, the PhD researchers will receive a comprehensive training through research. The geoscience research community in Ireland has, for the past several years, been operating the Irish Geoscience Graduate Programme (IGGP). This delivers tailored training into structured postgraduate degrees across the island of Ireland. iCRAG researchers will benefit from the existing delivery of these modules through IGGP (<http://www.iggp.ie/>), while the additional industry-focussed iCRAG researchers will allow expansion of the breadth and scale of the IGGP programme. A major focus of the training of PhD researchers will be to prepare them

to move seamlessly into industry upon completion of their research. iCRAG is very confident of exceeding the SFI target of 50% of PhD graduates developing careers in industry. iCRAG will operate an internship scheme where PhD students will spend a period of time working directly with industry partners. PhD students will also have an advisory panel, involving industry experts, whom they will meet regularly to provide and receive feedback and advice. As an example of the research training and education support schemes developed by our institutions, UCD has a researcher career structure for PhD and post-doctoral researchers. UCD also implements the Research Careers Framework (RCF), with a structured early career development model for Postdoctoral researchers. This is underpinned by a formal training and development structure which provides early stage researchers with access to training and development opportunities in transferable skills. Researchers recruited to iCRAG will use these supports and will receive training in:

- Research and Research Management (e.g., project management, protocol & study design).
- Personal and Professional Excellence (e.g., communication skills, creative thinking etc.).
- Teaching, Learning and Mentoring (e.g., engaging students, sessions plans and modules).
- Innovation and Transferable Skills (e.g., IP management, commercialisation strategies).

These will have a significant impact in fostering creativity, imagination and confidence in that are necessary skills for industry careers and entrepreneurship.

Entrepreneurship: iCRAG will foster a spirit of entrepreneurship within all activities. This is central to the success of our impact agenda as we strive to ‘translate discoveries into benefits for business and society’ (Agenda 2020) and will build upon the innovation-focussed training support outlined in the Training and Education section above. Each of the partnering institutions is already resourced with Technology Transfer units as supported by Enterprise Ireland. As an example Nova UCD provides incubation and other related facilities for entrepreneurs, campus companies, and spin-in companies and is resources with a team of Technology Transfer Case Managers. Because of the nature of our research, it underpins many societal issues directly relevant to Ireland and elsewhere, but without the development of a manufacturing base or specific product, or the creation of start-ups or patents. Nonetheless, we have already identified a number of potential spin-out components in the areas of specialist technology and software development as outlined in the application.

Outreach: iCRAG is committed to communicating the importance and discoveries of geosciences to industry, decision makers, schoolchildren and the general public. We see the dissemination of science, in an exciting and understandable manner, as a key societal role that we will continue to develop. Our outreach activities will involve interaction with local and national communities, and in fostering industry-community dialogue on geoscience matters of common interest, concern and benefit. For example, our Global Subsurface Training Centre in Co. Clare will involve a major outreach facility and will be a unique testbed for industry, community and educational collaboration.

In pursuing our outreach objectives we will leverage the existing outreach supports of the host institutions as well as the SFI Discover programme. The recent investment in UCD’s Science District will be pivotal in supporting the Education and Outreach objectives of the Centre. A key element of the new District is the Education and Outreach programme with its focus on external partnership. The new infrastructure includes demonstration labs, the innovation academy, exhibition space and meeting rooms to accommodate the full range of outreach activities taking place including Secondary School Visits, Seminars, Workshops and special exhibition installations.