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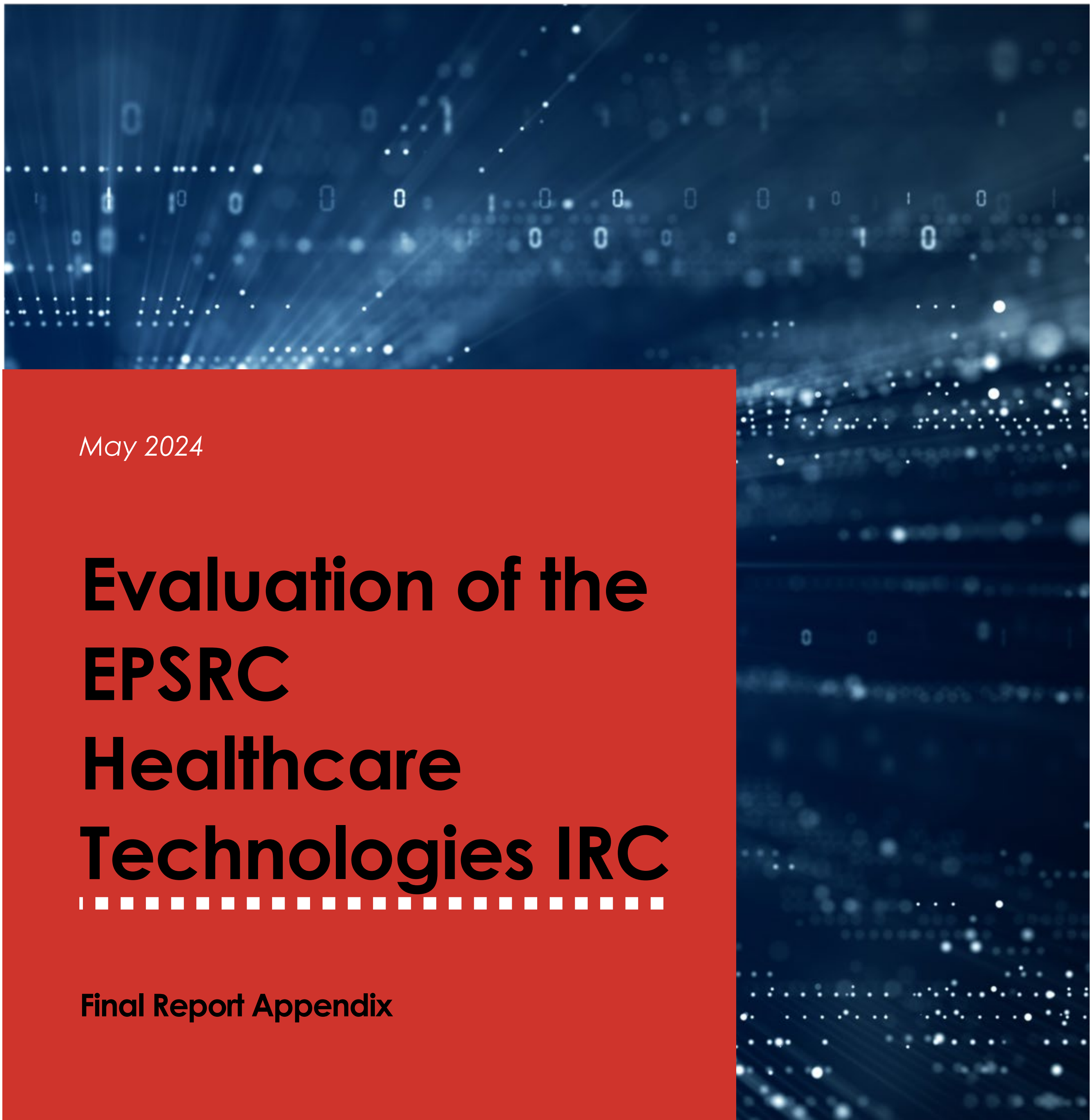

May 2024

Evaluation of the EPSRC Healthcare Technologies IRC

Final Report Appendix

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May 2024

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Final Report Appendix

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Appendix A Portfolio analysis: ResearchFish

An analysis of ResearchFish data was conducted for the portfolio analysis task of the evaluation of the EPSRC Healthcare Technologies IRC programme. ResearchFish submissions represent the most comprehensive and current self-reported secondary dataset available in terms of outputs and outcomes of projects funded through this programme. The data includes publications, spin-outs, dissemination activities, follow-on funding and several other types of outcomes.

A.1 Methodology

We conducted a quantitative analysis on the types and sub-types of outcomes based on the latest ResearchFish data available (March 2023). Our aim was to aggregate quantitative data according to the four IRCs (and their linked Next Step Plus projects), rather than individual grant reference numbers as reported in the ResearchFish data. In addition, we conducted a narrative summary of the qualitative data reported by researchers. We focused on specific data fields to contextualise the outcomes, namely the 'name', 'description' and 'impact' linked to the outcome. As such, the narrative summary provides an overview of notable findings. This activity also supported the identification of projects and outcomes relevant for case studies developed as part of the evaluation. The grant references analysed are shown in Table 1 below.

Table 1 IRC grant references

IRC Name	Grant references
IRC i-sense	EP/K031953/1, EP/R00529X/1, EP/R018391/1, EP/R018707/1
IRC Proteus	EP/K03197X/1, EP/R005257/1, EP/R018669/1
IRC SPHERE	EP/K031910/1, EP/R005273/1, EP/R018677/1
IRC TeDDy	EP/S009000/1

During our analysis, we noted that there have been duplications in the reported outcomes across different grant references (namely across the 2013 and 2018 IRC grants and/or the relevant Next Steps Plus projects) and hence automated data aggregation would have led to overestimation of IRC's quantitative outputs. Therefore, using a semi-automated process with the grant references, names and description of outcomes reported, we have removed duplicate outcomes reported as far as possible. However, some duplicate quantitative figures might have remained (if no description was available for quantitative figures to identify duplicates). For this reason, and due to the nature of possible under or overreporting by principal investigators, the total outcomes generated by the programme must be interpreted with caution.

A.2 Results

Table 2 below provides a quantitative summary of ResearchFish outcomes by IRCs and by outcome types.

Table 2 Researchfish outcomes data by outcome type and IRC

Outcome type	IRC SPHERE	IRC Proteus	IRC i-sense	IRC TeDDy	Total outcomes
Collaborations	19	15	71	8	**113**
Publications	321	142	158	62	**683**
Further funding	1	12	102	12	**127**
Awards and Recognition	4	60	89	20	**173**
Databases/Datasets	10	5	15	0	**30**
Research Tools/Methods	0	1	12	2	**15**
Software/Technical Products	1	0	10	0	**11**
Key Findings	3	3	4	1	**11**
Other	1	0	2	0	**3**
Facilities (use of)	0	0	1	0	**1**
Engagements	61	24	404	64	**553**
Policy	3	8	49	0	**60**
Artistic/Creative	0	2	10	0	**12**
Narrative Impact	3	3	4	1	**11**
Next Destinations	10	27	73	7	**117**
Secondments	3	3	22	4	**32**
Intellectual Property	0	7	4	0	**11**
Medical Products	0	5	0	0	**5**
Spinouts	1	1	0	1	**3**

Note: The colour heatmap scale is across rows for the four IRCs, and across the column for totals of outcome type

The data shows that since 2013, IRC investments have enabled over 100 research collaborations, suggesting the IRC programme has supported the creation of critical mass in healthcare technologies. Below, we provide a narrative summary to contextualise the quantitative outcomes in the above table.

Research outcomes

The IRC programme supported the production of nearly 700 publications spanning a range of disciplines, from computer science to chemistry. An analysis of a sample of publications shows that these include highly cited peer-reviewed articles in several high-impact journals. Examples of impactful research include semiconductors for imaging devices at Proteus[1], novel digital

[1] https://www.nature.com/articles/s41467-021-26837-0

epidemiology approaches at i-sense[2], smart devices for activity recognition at SPHERE[3] and biomedical engineering research on neurological medical devices at TeDDy[4]. A significant number of awards & recognition (over 170) was also reported across the four IRCs. These include included honorary degrees, research prizes and invitations to speak at international conferences.

In addition to publications, the IRC programme supported the development of many datasets, computer models and new research methods and tools. For example, new fluorescent reagents were developed by researchers from Proteus to improve the detection of bacteria and fungi in human tissue. At i-sense, several databases, mobile applications and new technology assays were developed. For example, novel biomarker discovery software platform (IDRIS) was developed to facilitate the analysis of genome sequence data from bacteria, to aid development of diagnostic sensors. Researchers from SPHERE also produced databases, in particular scripted datasets with robust annotation and curation, enabling further research into multi-sensor technologies. Examples of SPHERE datasets include:

- SPHERE House scripted dataset: a multi-sensor dataset with annotated activities of daily living recorded in a residential setting[5]. This dataset has been used in machine learning competitions, teaching, development and validation of activity recognition algorithms.
- SPHERE House multi-wearable, used for teaching[6].
- OPERAnet, a multimodal activity recognition dataset acquired from radio frequency and vision-based sensors (approximately 1 million annotated data points).

Another indicator of research excellence is the ability to raise further funding for new research. The data on research outcomes shows that a significant amount of further funding was obtained by researchers in the form of research grants, fellowships and studentships. These include small and large-scale funding to build on research conducted at the IRCs. Table 3 shows the total value of further funding obtained by type of funding and Table 4 shows the total value of further funding obtained by the funder's country or region.

Table 3 Total value of further funding obtained by type of funding

IRC	Public	Charity / Non-Profit	Private	Academic / University	Hospitals	Total
i-sense	£63,858,062	£13,408,344	£3,775,860	£3,848,921	£475	**£84,891,662**
Proteus	£20,497,253	£2,500,000		£250,000		**£23,247,253**
SPHERE	£878,055					**£878,055**

[2] https://www.nature.com/articles/s41598-018-32029-6

[3] https://www.mdpi.com/2227-9709/5/2/27

[4] https://www.frontiersin.org/articles/10.3389/fbioe.2021.622524/full

[5] https://doi.org/10.5523/bris.1dcxespcsafm02fba4bckx0ymt

[6] https://ieeexplore.ieee.org/document/9156257

TeDDy	£2,890,892	£334,596	£800,000			**£4,025,488**
Total	**£88,124,262**	**£16,242,940**	**£4,575,860**	**£4,098,921**	**£475**	**£113,042,458**

Source: Technopolis analysis of Researchfish data.

Table 4 Total value of further obtained by funder's country or region

Funder's country or region	i-sense	Proteus	SPHERE	TeDDy	Total
United Kingdom	£46,199,282	£19,522,270	£878,055	£1,707,327	**£68,306,934**
European Union	£23,518,035	£3,724,983		£2,183,260	**£29,426,278**
Switzerland	£8,600,699				**£8,600,699**
Germany	£5,093,718				**£5,093,718**
United States	£768,550				**£768,550**
France	£443,256				**£443,256**
Global	£268,122				**£268,122**
Belgium				£134,901	**£134,901**
Total	**£84,891,662**	**£23,247,253**	**£878,055**	**£4,025,488**	**£113,042,458**

Source: Technopolis analysis of Researchfish data.

Below we provide examples of some of the further funding obtained, as reported in Researchfish data:

- A new Digital Health Hub for Antimicrobial Resistance (£4.2 million - EPSRC)[7], obtained by researchers from IRC i-sense.
- Funding for pre-clinical development of diagnostics to reduce the impact of antimicrobial resistance (£0.9 million – CARBX)[8], obtained by researchers from IRC Proteus.
- Momentum Award to explore new research avenues for dementia research (£0.9 million – MRC)[9], obtained by researchers from IRC SPHERE.

As shown in Table 2, Researchfish outcomes also include five 'medical products'. These outcomes refer to four clinical trials for diagnostic tools developed at IRC Proteus. Two clinical trials were conducted between 2016 and 2018 to test the imaging parameters of fluorescent chemical probes for diagnosis of lung infections[10]. One clinical trial was conducted between

[7] https://gtr.ukri.org/projects?ref=EP%2FX031276%2F1

[8] https://www.proteus.ac.uk/stories/news-archive/proteus-awarded-prestigious-carb-x-grant

[9] https://www.bristol.ac.uk/news/2016/october/sphere-mrc-award.html

[10] https://clinicaltrials.gov/study/NCT02558062 and https://clinicaltrials.gov/study/NCT02491164

2016 and 2018 for testing the microendoscopy system developed at IRC Proteus[11]. A fourth study using chemical probes to detect bacterial infection in the eye is also mentioned, however, no clinical trial registration or study title was provided.

Outcomes with societal relevance

The IRC programme also enabled outcomes relevant for society in the form of policy influence and engagement activities with civil society, patients and others. Several outcomes were reported, such as researchers' contribution to national consultations, citation in policy documents and participation in advisory committees. Key examples of policy influence from i-sense are highlighted below.

Researchers at **i-sense** provided advice to the UK's Scientific Advisory Group for Emergencies, the Parliamentary Office of Science and Technology and the Council for Science and Technology advising the Prime Minister. Advice was also provided to the Chief Medical and Scientific Officers, NHS Digital and Africa CDC. In addition, researchers have helped to develop WHO guidelines on diagnostic tests and participated in several panels and forums at grant award organisations such as the National Institute for Health and Care Research (NIHR, UK).

i-sense researchers have also collaborated with Public Health England (now UK Health Security Agency) to develop machine learning models and tools using Google and Twitter data, to support early warning surveillance of influenza and COVID-19 outbreaks. This work has supported decisions around rolling out vaccination programmes and influenced national policy during the COVID-19 pandemic, providing one of the earliest indicators that the national lockdown was successfully reducing COVID-19 activity.

Other socially relevant outcomes include a large number of engagement activities (over 500 across the four IRCs) such as talks/presentations, workshops, media appearances and press releases. These outcomes helped to disseminate knowledge, recruit end-users, and change perceptions around different disciplines. Key examples from Proteus and SPHERE are highlighted below.

Researchers and programme managers at **Proteus** created several public engagement and outreach activities. A teaching tool named 'Embed Proteus Circuits!' was developed with co-funding from the Royal Academy of Engineering, to facilitate learnings around bioengineering and health. The tool has been embedded into the Scottish curriculum, to teach school pupils about bioengineering applications in health and inspire the next generation of bioengineers[12]. It has been showcased and used by school pupils in Rwanda[13].

SPHERE researchers and programme managers invited the public to SPHERE's Smart House at the 'We The Curious' regional science centre in Bristol. Over a 5-month period, over 4,700 people tested the demonstration, undertaking activities in the Smart House and generating data to the

[11] https://clinicaltrials.gov/study/NCT02604862

[12] https://www.proteus.ac.uk/stories/news-archive/proteus-selected-engineering-ingenious-award

[13] https://www.proteus.ac.uk/stories/news-archive/circuits-finishes-rwanda-schools-tour

research project. Participants were also given an opportunity to provide their opinions around data management topics such as data sharing.

People & Skills outcomes

In terms of people and skills, the IRC programme has led to outcomes relevant to career development, underpinned by several training activities for researchers. Workshops with cross-disciplinary themes were delivered to help researchers improve technical skills (for example, diagnostics development) and more general research skills (for example, presentation, communication).

Many postdoctoral researchers and associated PhD students also benefited from the interdisciplinary research environment created by the programme, which exposed researchers to different areas and to experts from industry and healthcare settings. These activities led to secondments of researchers to a wide range of organisations, as evidenced in the examples below.

The interdisciplinary collaborations taking place with clinicians, chemists and engineers at **TeDDy** enabled researchers to develop technical skills through industrial work experience via secondments at pharmaceutical companies.

Researchers and students at **i-sense** benefited from secondments to the Joint Biosecurity Centre, the World Health Organization, Uganda Virus Research Institute, Google and several other organisations.

In addition to secondments, researchers reported 'Next Destinations' outcomes to highlight how the IRC programme has supported researchers to secure new jobs. Several examples were provided of researchers receiving lectureships at universities and other roles in research institutes. Other researchers are now working in public health organisations, local authorities and industry, including the pharmaceutical and information technology sectors.

Economic outcomes

The economic outcomes reported via ResearchFish include 11 patents filed to protect intellectual property developed at the IRCs and at least three spin-out companies. These outcomes may enable future economic impact through the creation of jobs and commercialisation of technologies in the field of healthcare technologies.

Researchers from Proteus have generated at least seven patents on novel detectors and smart probes, semiconductors for imaging devices and fibre optical systems. At i-sense, four patents were reported in the areas of biomarker and antibody discovery, and in-vitro diagnostics assays. Below we provide examples of spin-out companies which are using the technologies behind these patents and other research findings supported by the IRC programme.

The spinout company Vector Bioscience has been created by **TeDDy** researchers to advance commercialisation of drug delivery vehicles for anti-cancer therapeutics[14]. The company translates research on nanomaterials, such as metal-organic frameworks, which can improve the efficacy of drugs for hard-to-treat cancers. Vector Bioscience has received £2.2 million investment from the European Innovation Council and £500,000 from Innovate UK[15] .

Spin-out company Singular Photonics is emerging from research conducted at Proteus on imaging sensors (complementary metal-oxide semiconductors compatible single-photo avalanche diode sensors). These sensors provide state-of-the-art performance to understand behaviours of fluorescent molecules in human tissues. The company will explore the use of the imaging sensors in different application areas.

[14] https://www.vectorbiocam.com/

[15] https://www.cam.ac.uk/news/cambridge-spin-out-receives-ps2-2-million-to-help-improve-cancer-treatments

Appendix B Portfolio analysis: Dimensions

An analysis of Dimensions data[16] was conducted to improve our understanding of IRC programme outputs and outcomes, as well as to complement the portfolio analysis task of the evaluation. The dataset provided by the EPSRC and Dimensions consists of publications, clinical trials, patents and policy documents linked to the EPSRC Healthcare Technologies IRC programme (from hereafter 'the dataset'). The analysis was conducted using Python. We outline below the methodology, observations and caveats, and results of our analysis.

B.1 Methodology

The dataset was created by matching all grant references from the EPSRC Interdisciplinary Research Collaboration (IRC) programme with academic publications in Dimensions database, as of September 2023. Grant references include all funding calls of the Healthcare Technologies IRC programme: the creation of the first three IRCs in sensing systems for healthcare (2013)[17] and their follow-on funding (2018/19)[18], Next Step Plus projects[19], and IRC TeDDy for targeted therapeutic delivery (2018)[20]. The IRCs and respective Next Step Plus projects are:

- **IRC Proteus (2013-2023)** - Multiplexed 'Touch and Tell' Optical Molecular Sensing and Imaging - Lifetime and Beyond
    - **PPT - Photonic Pathogen Theranostics (2018-2023)-** Point-of-care image guided photonic therapy of bacterial and fungal infection (Next Steps Plus project)
- **IRC SPHERE (2013-2023)**: A Sensor Platform for HEalthcare in a Residential Environment.
    - **OPERA (2019-2023)** – Opportunistic Passive Radar for Non-Cooperative Contextual Sensing (Next Steps Plus project)
- **IRC i-sense (2013-2024)** - EPSRC IRC in Agile Early Warning Sensing Systems for Infectious Diseases and Antimicrobial Resistance
    - **u-sense (2018-2024) -** Ultra-Sensitive Enhanced NanoSensing of Anti-Microbial Resistance (Next Steps Plus project)
    - **Smartphone Powered mRNA Sequence Detector (2018-2023)** (Next Steps Plus project)
- **IRC TeDDy (2018-2024)** - Targeted Delivery for Hard-to-Treat Cancers

Patent, clinical trials and policy documents were identified in two ways by Dimensions staff for data extract:

- Direct matching: the IRC programme grant references were used to directly match patents and clinical trials in the Dimensions database. Policy documents were not included in direct matching.

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[16] Dimensions is a linked research data source by Digital Science: https://www.dimensions.ai/

[17] Grant references EP/K031953/1, EP/K03197X/1 and EP/K031910/1

[18] Grant references EP/R00529X/1, EP/R005257/1, EP/R005273/1

[19] Grant references EP/R018391/1, EP/R018707/1, EP/R018669/1, EP/R018677/1

[20] Grant references EP/S009000/1

- Indirect matching: patents, clinical trials and policy documents were also identified if they cite one or more of the publications resulting from the IRC programme.

All documents identified in the dataset include attributes such as title, year, publication type authors' organisations, their type and country. Each type of document (publications, patents) contains specific attributes such as 'Field Citation Ratio (FCR)[21]' for publications, 'Start Year' for clinical trials and 'Family patent id' for patents. In addition to these attributes, all documents were automatically tagged by Dimensions according to three established research classification systems:

- UK Health Research Classification System (health category and research activity code)[22].
- ANZSRC Field of Research (FoR) categories[23].
- US NIH Research Condition and Disease Categorization (RCDC) system[24].

The document's attributes discussed above provide the basis for analysing research outputs of the IRC programme. The following section discusses observations and caveats.

B.2 Observation and caveats

The attribution of identified documents in the dataset should be interpreted with the following caveats. Direct matching provides strong indication of attribution of research outputs to the IRC programme, while indirect matching (through citation of publications produced by the IRC programme) provides a secondary 'one step removed' attribution of outputs, where knowledge created by the IRC programme informed the work of others. For this reason, we report direct and indirect matched documents separately in the case of patents and clinical trials. Further, the coverage of certain attributes in the dataset are not fully complete (for example, research categories were not allocated by the automated tagging process or the publications are less than two-year-old and FCR cannot be calculated), and therefore we also report on the completeness of the dataset, to contextualise findings. Further, note that the year 2023 is not complete and as such, the values calculated for this year are subject to change.

B.3 Publications

A total of 708 unique publications were identified in the dataset, which closely mirrors the number of publications reported through ResearchFish (n = 683). As ResearchFish relies on self-reported data and its submission deadline was March 2023, a small difference between the number of publications in the dataset and ResearchFish was expected. Thus, the number of publications identified in the dataset helps to validate our portfolio analysis.

Table 5 below provides a breakdown of the number of publications by IRC and publication type. Although most publications are academic peer-reviewed articles, many proceeding publications were also identified for SPHERE. This highlights different publication practices

[21] Top 10% field-normalised citation (FCR) metric per year considered 'highly cited'. FCR is calculated on publications that are at least two years old, therefore any publication less than two years old will have blank values. For more information, see: https://support-funder.dimensions.ai/support/solutions/articles/13000043941-what-is-the-fcr-how-is-it-calculated-

[22] https://hrcsonline.net/research-activities/

[23] https://www.abs.gov.au/statistics/classifications/australian-and-new-zealand-standard-research-classification-anzsrc/latest-release

[24] https://report.nih.gov/funding/categorical-spending/rcdc-process

across the IRC programme, which are expected due to the different disciplines involved in each IRC. For example, researchers in electrical engineering and computer science (key disciplines for SPHERE), traditionally present their work at conferences and publish in conference proceedings[25]. We note that each IRC has different objectives, and in the case of TeDDy also a different timeline. The analysis is therefore not meant to compare and contrast research outputs of individual IRCs, but to provide a transparent analysis of the IRC programme as a whole.

Table 5 Number of publications by IRC and publication type

IRC	Article	Book	Chapter	Preprint	Proceeding	Total number of publications
Proteus	120		3	2	22	147
SPHERE	151	4	20	6	132	313
i-sense	154		1	8	14	177
TeDDy	69			2		71
IRC programme	**494**	**4**	**24**	**18**	**168**	**708**

Source: Technopolis analysis based on Dimensions data. Note 1: TeDDy is a relatively recent collaboration (2018-2024), compared to Proteus, SPHERE and i-sense (2013-2023/24).

B.3.1 Overview of publications and their attributes

Table 6 below provides an overview of the number and share of publications tagged with different attributes. This information provides an indication of the completeness of the dataset in relation to analysis of the publications' attributes. The number of tagged publications also provides the denominators for further analysis of each attribute.

Table 6 Number and share of tagged publications

IRC	Organisation types	Organisation countries	Field citation ratio[26]	FoR first level[27]	FoR second level[28]	RCDC[29]	HRCS-HC[30]	HRCS-RAC[31]
Proteus	122 (83%)	122 (83%)	116 (79%)	146 (99%)	132 (90%)	84 (57%)	40 (27%)	34 (23%)
SPHERE	291 (93%)	291 (93%)	246 (78%)	306 (98%)	284 (91%)	129 (41%)	86 (27%)	54 (17%)
i-sense	172 (97%)	172 (97%)	136 (77%)	175 (99%)	155 (87%)	137 (77%)	96 (54%)	73 (41%)

[25] https://onlinelibrary.wiley.com/doi/abs/10.1087/20130307

[26] Publications less than two years old are not expected to have FCR tags and these publications account for the majority of missing FCR values.

[27] ANZSRC Field of Research (FoR) categories

[28] ANZSRC Field of Research (FoR) categories

[29] US NIH Research Condition and Disease Categorization (RCDC) system

[30] UK Health Research Classification System (health category)

[31] UK Health Research Classification System (research activity code)

TeDDy	71 (100%)	71 (100%)	44 (62%)	71 (100%)	63 (89%)	53 (74%)	39 (55%)	33 (46%)
IRC programme	**656 (93%)**	**656 (93%)**	**542 (77%)**	**698 (98%)**	**634 (90%)**	**403 (57%)**	**261 (37%)**	**194 (27%)**

Source: Technopolis analysis based on Dimensions data

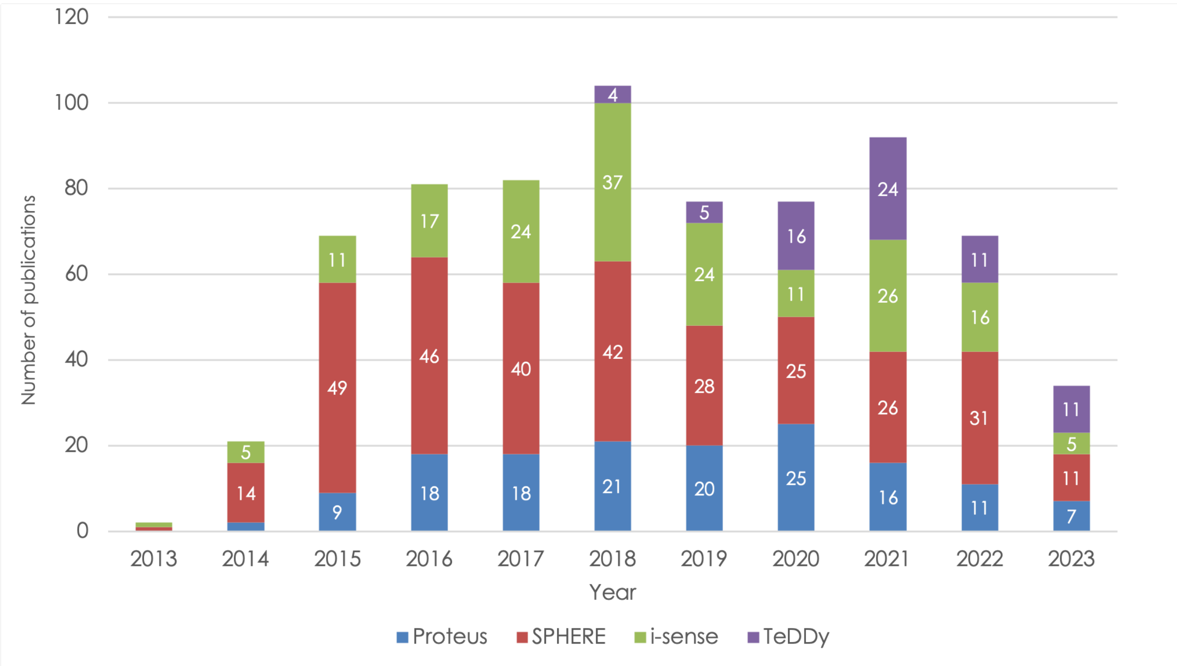
In some cases (for example, organisation types, organisation countries or Field of Research categorisation), publication attributes are complete in the dataset to over 90% of all publications. However, in other cases (for example, Health Research Activity Codes (HRCS-RAC)), coverage is poor at less than 30% of all publications. For this reason, analysis of certain attributes can provide limited insight.

B.3.2 Number of publications per publication year

The number of publications per publication year is shown in Figure 1. It provides a starting point to understand how the IRC programme has enabled research outputs emerging during its initial five-year period (2013) and subsequent funding phase (2018 onwards).

A notable upward trend is evident during the initial five years, reaching its peak in 2018 with more than 100 publications per year. From 2018, there is a downward trend observable in the number of publications per year, which may indicate a change of focus at IRCs in the second funding phase (for example, from publishing research papers to developing and patenting technologies). There are differences across publication practices across IRCs. For example, SPHERE publishes more and earlier than other IRCs and i-sense's work on COVID-19 response[32] is observable in an increase of its publication trend in 2021.

Figure 1 Number of publications per publication year



[32] https://www.i-sense.org.uk/covid-19/covid-19-response

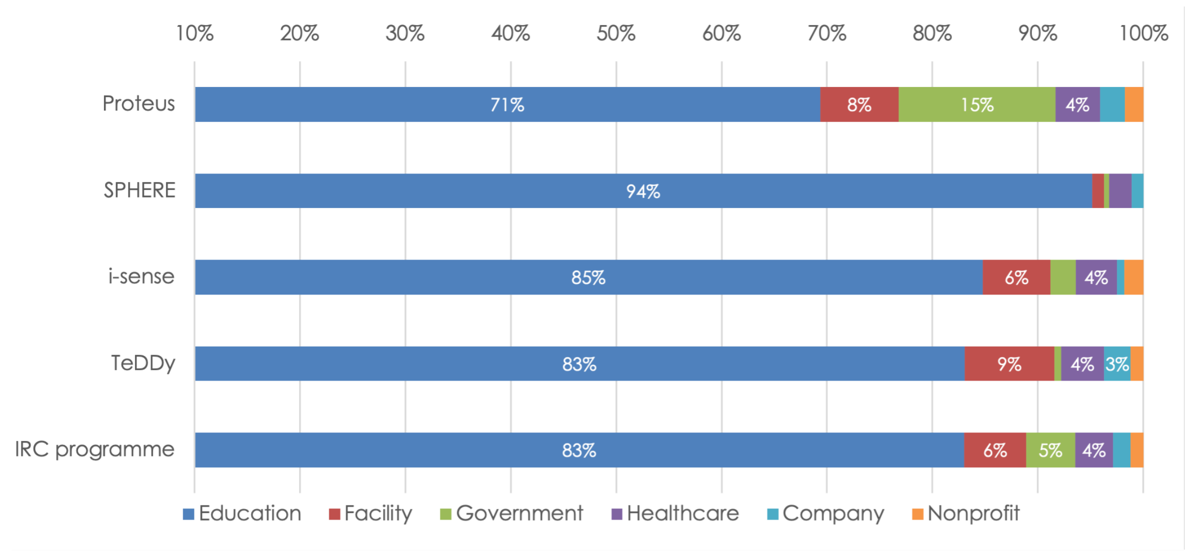
Source: Technopolis analysis based on Dimensions data. Note: no complete data is available in the dataset for year 2023.

B.3.3 Share of authors' organisations by organisation type

The organisation type attribute of publications in the dataset provides the number and the type of organisations associated with the authors of a publication. We use fractional count of contributions of these organisations (summing organisations contributions to a publication adds up to 1), providing a proportionate measure of contribution by each publication. We report this analysis as a share of organisation types for all publications across all years (where relevant data available in the dataset). This is used as a proxy for the contribution of academic co-investigators and non-academic partners to research outputs throughout the IRC programme.

Over 80% of the IRC authors' organisations are of 'Education' type (universities), see Figure 2 below. A total of 11% of organisation type of authors are attributed to 'Facility' (6%) and 'Government' (5%). Some examples of organisations tagged as 'facilities' are the Africa Health Research Institute, Fraunhofer Institute for Solar Energy Systems and Leibniz Institute for Interactive Materials. Government organisations include the UK Health Security Agency and Public Health England. Note that some manual checking of results shows that some organisation types may be incorrectly tagged as 'Government' in the dataset (for example, the Queen's Medical Research Institute, a clinical research facility, is tagged as government). Another caveat is that in the case of Proteus, the coverage of organisation type was lower than other IRCs and thus 17% of Proteus publications could not be included in this analysis. Nevertheless, difference in co-authors' organisational types for Proteus publications is visible: relatively lower share of academic co-authors and more from government agencies.

Figure 2 Share of authors' organisations by organisation type, over all years



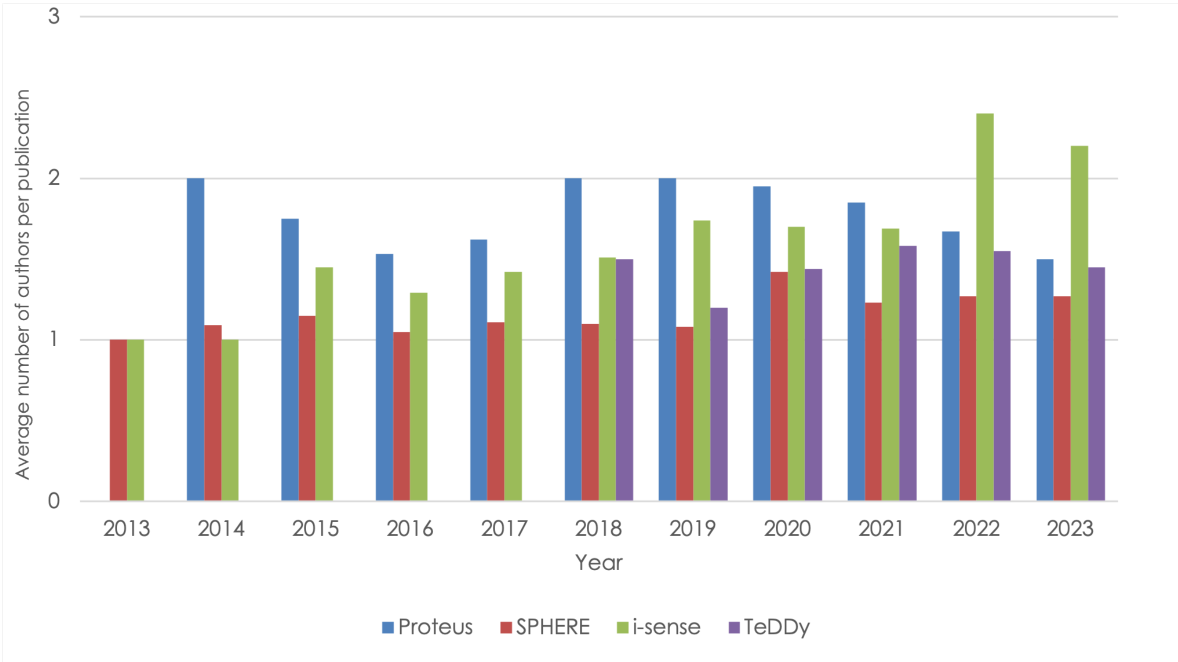
Source: Technopolis analysis based on Dimensions data

Overall, healthcare organisations, companies and non-profit organisations represent a relatively low level of co-authorship of publications by the IRC programme. It is possible that the focus on basic research and low technology readiness level (TRL) technology development may have constrained collaborative opportunities outside universities and research institutes. In addition, it is likely that healthcare organisations, industry and non-profit organisations provided advisory inputs during their collaborations, rather than actively contributing to implementation of research.

B.3.4 *Average number of distinct organisation types per publication per year*

Figure 3 shows the average number of different organisation types involved in a publication in each publication year. We use this measure as an indication of the extent to which the IRC programme has resulted in collaborations with different organisation types over the years. A small positive trend is observable since the start of the IRC programme for all individual IRCs. While at the start of the programme the average number is close to 1 (academic only publications), it rises to 1.5, indicating other organisation types regularly co-author papers with academic researchers. This may be due to the effective utilisation of the IRC programme's partnership resource fund, which allocates 10% of the overall IRC funding to exploring new collaborations. In the case of i-sense, the increasing trend is clearly observable over the years.

Figure 3 Average number of distinct organisation types per publication year



Source: Technopolis analysis based on Dimensions data

B.3.5 *Total publications over all years which includes organisation type Company & Education (academic-industry co-publication)*

There was a relatively low number of publications indicating academic-industry co-publication in the IRC programme (n = 26 out of 656 publications where organisation types were provided in the dataset). This measure provides another indication of modest industry involvement in research implementation and thus publication co-authorship, as discussed in the previous sections. In Table 7 we provide the company names involved in co-authorship of publications, including a column to contextualise the company's involvement (namely, if they were listed as key company partners in the stakeholder mapping conducted as part of the evaluation). We also included key company partners to which no publication was identified in Dimensions.

Table 7 Number of publications with co-authors from companies by IRC

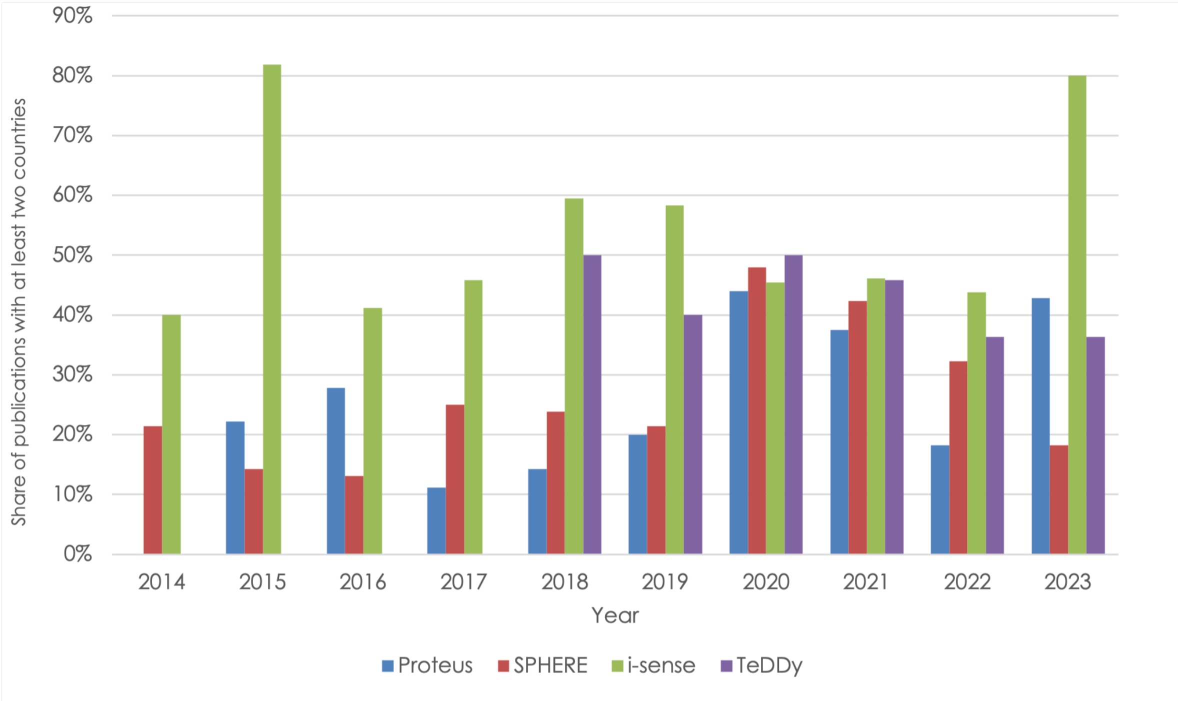
Number of publications with co-authors from companies						
Company names	**Involvement with IRC**	**i-sense**	**Proteus**	**SPHERE**	**TeDDy**	**Total**
Adobe Systems	Co-author of publication			1		**1**
Amazon; China Mobile	Co-author of publication			1		**1**
Aqdot	Key partner with IRC TeDDy					
AstraZeneca	Key partner with IRC TeDDy	1			3	**4**
BAE Systems	Co-author of publication			1		**1**
Cambridge Life Sciences	Key partner with IRC i-sense					
Facebook	Co-author of publication			1		**1**
Google	Key partner with IRC i-sense	1		1		**2**
Huawei Technologies	Co-author of publication			1		**1**
Ixico	Co-author of publication			3		**3**
Mauna Kea Technologies	Key partner with IRC Proteus		2			**2**
Microsoft Research	Key partner with IRC i-sense	1				**1**
Pragmatic Semiconductor	Key partner with IRC TeDDy					
Printed Electronics	Co-author of publication				1	**1**
Renishaw	Co-author of publication		1			**1**
Roche	Co-author of publication	1				**1**
STMicroelectronics	Key partner with IRC Proteus		4			**4**
Telefonica	Key partner with IRC i-sense			1		**1**
Toshiba	Key partner with IRC SPHERE			1		**1**
Total		**4**	**7**	**11**	**4**	**26**

Source: Technopolis analysis based on Dimensions data. Key partners information as identified via stakeholder mapping conducted for the evaluation

B.3.6 Share of total publications per publication year with co-authorship from at least two different countries (international collaborations)

Figure 4 illustrates the quantitative trend of IRC publications with authorship from two (or more) different countries per publication year. An upward trend is observed between 2014 and 2020, with share of multi-country publications doubling to reach nearly 50% of all publications (on average, in 2020, half of the IRC publications had co-authors from at least two different countries). Subsequently, there is a decline in the share of international publications to about 33% of all publications. Across all years, approximately 30% of all IRC publications were the result of collaborative efforts between authors from at least two different countries. Looking at individual IRCs, i-sense had the highest share of international collaborations as measured by its publications' co-authorship countries.

Figure 4 Share of total publications per publication year with co-authorship from at least two different countries



Source: Technopolis analysis based on Dimensions data. No publications with authorship from two different countries were identified for year 2013.

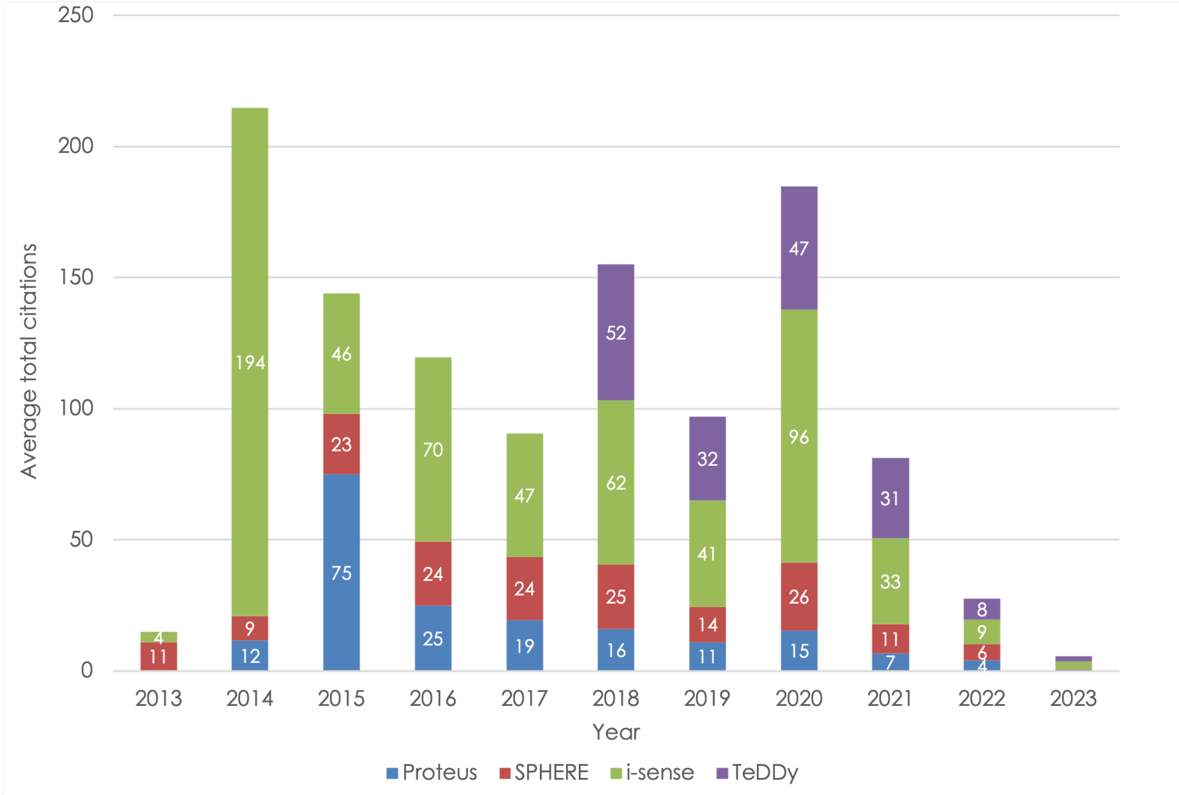
B.3.7 Average total citations of a publication per publication year

Dimensions citation data consists of publication date and total citations of the publication to date. The number of citations is often used as an indication of a publication's scientific impact, despite some limitations[33]. We calculate the average total citations for publications of a given publication year, shown in Figure 5. Note that publications with an earlier publication date have a longer period of time to accumulate citations; equally, publications in 2022 and 2023 had very little time to gather citations.

IRC publications had, on average, accumulated around 30 citations per publication since their respective publication year. Looking at individual IRCs, i-sense had the highest average total citations of 70 per publication between publication years 2014 and 2021. The highest cited i-sense papers were published in Science and Nature journals and obtained over 500 citations each to date.

[33] Some limitations include negative citations, self-citation, and technical challenges around indexing publications. The number of citations alone does not provide certainty of scientific quality or actual impact.

Figure 5 Average total citations of IRC publications per publication year



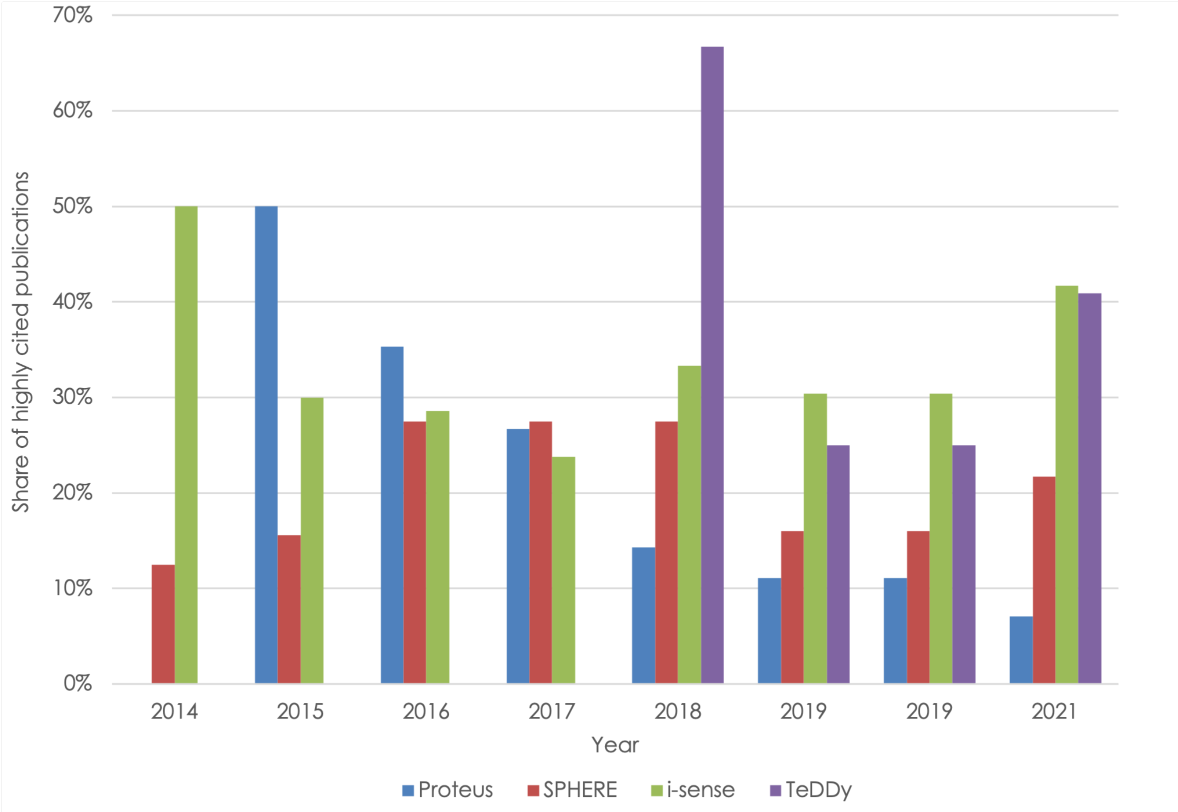
Source: Technopolis analysis based on Dimensions data. Note that the citation data shows citations over all years for publications of a given publication year (rather than total citations in a given year).

B.3.8 *Share of highly cited publications per publication year*

We also analysed the IRC programme's contribution to highly cited publications. Highly cited publications are identified based on field citation ratio (FCR) which is a normalised metric of 'scientific impact' comparing a publication to all others published in the same year and within the same field of research. A publication is 'highly cited' if it is in the top 10% of all field citation ratios. Figure 6 shows the share of highly cited publications per publication year among the IRC programme's research outputs.

Over a quarter of all IRC publications are highly cited publications (n = 145, 27%). Nearly 70% of these highly cited publications (n = 99) have a FCR value of 10 or higher, which means these have more than 10 times the citations of the average publication in the same field of research in the same year.

Figure 6 Share of highly cited publications per publication year



Source: Technopolis analysis based on Dimensions data. No highly cited publications identified for year 2013. Years 2022 and 2023 were removed as FCR is calculated for publications of 2 years or older.

B.3.9 *Analysis of research categories of IRC publications*

The association of individual IRC publications with established research categories helps to identify the focus area(s) of IRC research. In Table 8, we provide the share of field of research (FoR) tagged to publications in the dataset, displayed as the top 10 FoR for each IRC. We use fractional counting to account for publications with more than one FoR.

Table 8 Share of field of research of publications by IRC

IRC	Field of Research (1st level)	Field of Research (2nd level)
Proteus	Engineering (26.5%)	Electronics, Sensors and Digital Hardware (14.3%)
	Physical Sciences (18.2%)	Data Management and Data Science (9.1%)
	Biomedical and Clinical Sciences (17.7%)	Atomic, Molecular and Optical Physics (6.3%)
	Chemical Sciences (17.1%)	Clinical Sciences (6.1%)
	Information and Computing Sciences (12.9%)	Ophthalmology and Optometry (4.0%)
	Biological Sciences (5.5%)	Computer Vision and Multimedia Computation (3.9%)
	Mathematical Sciences (1.5%)	Biomedical Engineering (3.9%)
	Health Sciences (0.7%)	Analytical Chemistry (3.8%)
		Nanotechnology (3.8%)

		Oncology and Carcinogenesis (3.8%)
SPHERE	Information and Computing Sciences (61.0%)	Data Management and Data Science (26.2%)
	Engineering (23.6%)	Human-Centred Computing (14.0%)
	Health Sciences (5.0%)	Machine Learning (8.6%)
	Biomedical and Clinical Sciences (3.6%)	Communications Engineering (8.0%)
	Physical Sciences (2.9%)	Distributed Computing and Systems Software (6.2%)
	Chemical Sciences (0.8%)	Electronics, Sensors and Digital Hardware (6.0%)
	Psychology (0.7%)	Health Services and Systems (4.2%)
	Mathematical Sciences (0.4%)	Computer Vision and Multimedia Computation (3.9%)
	Biological Sciences (0.3%)	Artificial Intelligence (3.5%)
	Earth Sciences (0.3%)	Clinical Sciences (2.6%)
i-sense	Biomedical and Clinical Sciences (20.3%)	Clinical Sciences (10.6%)
	Chemical Sciences (19.7%)	Medical Microbiology (9.6%)
	Engineering (16.9%)	Health Services and Systems (8.1%)
	Information and Computing Sciences (14.3%)	Public Health (6.8%)
	Health Sciences (12.0%)	Biochemistry and Cell Biology (6.5%)
	Biological Sciences (10.2%)	Macromolecular and Materials Chemistry (5.5%)
	Physical Sciences (2.4%)	Data Management and Data Science (5.3%)
	Human Society (1.4%)	Human-Centred Computing (5.1%)
	Agricultural, Veterinary and Food Sciences (0.9%)	Analytical Chemistry (4.7%)
	Education (0.6%)	Electronics, Sensors and Digital Hardware (4.6%)
TeDDy	Biomedical and Clinical Sciences (38.5%)	Biomedical Engineering (24.1%)
	Engineering (37.6%)	Pharmacology and Pharmaceutical Sciences (20.6%)
	Chemical Sciences (14.3%)	Medical Biotechnology (6.9%)
	Biological Sciences (7.5%)	Materials Engineering (6.9%)
	Physical Sciences (0.9%)	Oncology and Carcinogenesis (6.4%)
	Earth Sciences (0.7%)	Macromolecular and Materials Chemistry (5.3%)
	Information and Computing Sciences (0.5%)	Biochemistry and Cell Biology (4.8%)
		Manufacturing Engineering (4.0%)
		Fluid Mechanics and Thermal Engineering (3.2%)
		Medical Microbiology (2.4%)

Source: Technopolis analysis based on Dimensions data

The share of fields of research categories varies across IRCs according to their specific research focus, however, in all cases, it also demonstrates a high level of interdisciplinarity within individual IRCs and thus in the overall IRC programme. For example, SPHERE's publications are focused on the field of Information and Computing Sciences (>60% of FoR 1st level);

publications by i-sense and Proteus exhibit high disciplinary diversity, with the top 60% shared across three different fields of research. All four IRCs have contributed to the following key fields of research to varying degrees: Engineering, Physical Sciences, Biomedical and Clinical Sciences, and Information and Computing Science.

The distribution of the share of field of research (2nd level) is broad and provides a unique signature for each IRC's research activity. For example, Proteus contributed to Electronics, Sensors and Digital Hardware; Data Management and Data Science, but also to Atomic, Molecular and Optical Physics; Clinical Sciences; and Ophthalmology and Optometry. SPHERE on the other hand contributed, among others, to Data Management and Data Science; Human-Centred Computing; Machine Learning; and Communications Engineering. i-sense's research contribution was spread across Clinical Sciences; Medical Microbiology; Health Services and Systems; Public Health; Biochemistry and Cell Biology; and Macromolecular and Materials Chemistry. TeDDy's fields of research included Biomedical Engineering; Pharmacology and Pharmaceutical Sciences; Medical Biotechnology; Materials Engineering; and Oncology and Carcinogenesis.

We also used tags from other research classification systems available in the dataset: the US Research Condition and Disease Categorization (RCDC) system and the UK Health Research Classification System – both the health category (HRCS-HC) and research activity codes (HRCS-RAC). However, as noted in the overview of data completeness in the methodology section, these research classification tags were less extensively associated with publications. Specifically, RCDC is tagged to around only 57% of publications and HRCS-HC and HRCS-RAC are tagged to 37% and 27% publications, respectively. For this reason, the data does not provide a complete view of research areas of all IRC publications in the dataset. Further, it is not known if the tagged publications can be considered representative of all publications. Yet, the analysis may still be useful to illustrate areas of research across the IRCs. Table 9 provides an overview of the top 10 areas for these research classification systems, by IRC.

Table 9 Share of RCDC, HRCS-HC and RAC of publications by IRC

IRC	RCDC	HRCS-HC	HRCS-RAC
Proteus	Bioengineering (32.3%)	Infection (46.2%)	Discovery and preclinical testing of markers and technologies (44.1%)
	Lung (16.8%)	Cancer (20.0%)	Evaluation of markers and technologies (19.1%)
	Infectious Diseases (10.0%)	Generic health relevance (15.0%)	Pharmaceuticals (14.7%)
	Cancer (7.2%)	Respiratory (13.8%)	Factors relating to the physical environment (8.8%)
	Biomedical Imaging (6.8%)	Inflammatory and immune system (3.8%)	Biological and endogenous factors (7.4%)
	Prevention (3.7%)	Eye (1.2%)	Medical devices (2.9%)
	Biotechnology (3.6%)		Organisation and delivery of services (2.9%)
	Eye Disease and Disorders of Vision (3.0%)		
	Clinical Research (2.7%)		
	Emerging Infectious Diseases (2.7%)		

SPHERE	Clinical Research (23.7%)	Generic health relevance (64.0%)	Individual care needs (37.7%)
	Bioengineering (18.8%)	Neurological (9.9%)	Discovery and preclinical testing of markers and technologies (24.1%)
	Behavioral and Social Science (8.7%)	Mental health (5.8%)	Organisation and delivery of services (13.0%)
	Aging (3.8%)	Cancer (5.8%)	Evaluation of markers and technologies (11.1%)
	Networking and Information Technology R&D (3.5%)	Musculoskeletal (4.1%)	Management and decision making (3.7%)
	Neurosciences (3.2%)	Metabolic and endocrine (3.9%)	Biological and endogenous factors (2.8%)
	Patient Safety (3.1%)	Cardiovascular (2.7%)	Policy, ethics, and research governance (2.8%)
	Health Services (3.1%)	Respiratory (2.3%)	Physical (1.9%)
	Cancer (2.7%)	Renal and urogenital (1.2%)	Research design and methodologies (health services) (1.9%)
	Lung (2.7%)	Oral and gastrointestinal (0.4%)	Medical devices (0.6%)
i-sense	Bioengineering (16.5%)	Infection (53.1%)	Discovery and preclinical testing of markers and technologies (34.9%)
	Infectious Diseases (10.2%)	Generic health relevance (38.4%)	Evaluation of markers and technologies (8.2%)
	Biotechnology (9.3%)	Cancer (5.3%)	Normal biological development and functioning (8.2%)
	Clinical Research (8.8%)	Renal and urogenital (1.0%)	Surveillance and distribution (6.9%)
	Nanotechnology (8.2%)	Reproductive health and childbirth (1.0%)	Pharmaceuticals (6.9%)
	Prevention (7.1%)	Cardiovascular (0.3%)	Biological and endogenous factors (4.8%)
	Emerging Infectious Diseases (5.1%)	Oral and gastrointestinal (0.3%)	Organisation and delivery of services (4.6%)
	Genetics (3.7%)	Inflammatory and immune system (0.3%)	Policy, ethics, and research governance (4.1%)
	HIV/AIDS (2.9%)	Stroke (0.3%)	Individual care needs (3.9%)
	Vaccine Related (2.7%)		Chemical and physical sciences (2.7%)
TeDDy	Bioengineering (25.0%)	Generic health relevance (37.2%)	Pharmaceuticals (35.9%)
	Biotechnology (15.6%)	Cancer (32.1%)	Biological and endogenous factors (24.7%)
	Neurosciences (5.3%)	Neurological (12.8%)	Normal biological development and functioning (11.6%)
	Digestive Diseases (5.0%)	Respiratory (7.7%)	Vaccines (6.1%)
	Rare Diseases (4.8%)	Infection (7.7%)	Medical devices (6.1%)
	Cancer (4.1%)	Oral and gastrointestinal (2.6%)	Organisation and delivery of services (4.5%)
	Genetics (3.9%)		Discovery and preclinical testing of markers and technologies (3.0%)

	Brain Disorders (2.9%)		Evaluation of markers and technologies (3.0%)
	Nanotechnology (2.8%)		Factors relating to the physical environment (1.5%)
	Clinical Research (2.2%)		Individual care needs (1.5%)

Source: Technopolis analysis based on Dimensions data

The analysis of these research classification tags confirms previous finding that IRC publications show great diversity of research areas. It also shows the IRC programme had strong focus on Bioengineering (RCDC), with a large share of publications produced by i-sense and Proteus on 'Infections' and TeDDy on 'Cancer' health category (HRCS-HC), while SPHERE's main focus was categorised as 'Generic health relevance'. In terms of the research activities (HRSC-RAC) of the three original IRCs, 'Discovery and preclinical testing of markers and technologies' was prominent. SPHERE's other focus was on 'Individual care needs' and TeDDy's on 'Pharmaceuticals'. This appears to demonstrate the focus of the original IRCs on developing models and diagnostics methods to improve understanding of disease and healthcare practices.

B.4 Patents

A total of 110 unique patent families were identified in the dataset. The majority of these are indirect matches (n = 99), where patents were identified because they cite one or more IRC publications. The remaining patents were directly matched with IRC programme grant references (n = 11) in the dataset. The number of directly matched patents aligns with the ResearchFish data on intellectual property outcomes. Table 10 below provides a breakdown of the number of patents by IRC and by type of matching.

Table 10 Number of unique patent families by IRC and by direct/indirect matching

IRC	Indirect matching	Direct matching	Total patents
Proteus	30	10	40
SPHERE	23		23
i-sense	45	1	46
TeDDy	1		1
IRC programme	**99**	**11**	**110**

Source: Technopolis analysis based on Dimensions data

The 'direct matching' data shows that some IRCs focused on advancing research towards future commercialisation through patenting of new inventions, exemplified by Proteus. In other IRCs, like SPHERE, focus was not on protecting intellectual property generated, or in the case of TeDDy, the collaboration has not yet resulted in any patent, although this is probably due to the shorter timeframe. Yet, these findings provide an indication of the potential future economic impact of the IRC programme. Beyond the patents directly attributed to the IRC programme, many IRC publications have informed, and have likely contributed to, many other patents beyond the IRC programme. This 'knowledge spillover' is considered an important impact of the IRC programme.

B.4.1 *Overview of tagged patents*

Table 11 below provides an overview of the number and share of the patents (including both indirect and direct matches) tagged with various dataset attributes. The extent of coverage of the attribute is provided in parentheses. It is clear that RCDC, HRCS-HC and RAC tags are missing for most of the identified patents. For this reason, we limit the analysis of research categories to FoR only. The below numbers in Table 11 also provide denominators for analysing each attribute.

Table 11 Number and share of tagged patents

IRC	Patent application jurisdiction	FoR first level	FoR second level	RCDC	HRCS-HC	HRCS-RAC
Proteus	40 (100%)	40 (100%)	40 (100%)	7 (18%)	4 (10%)	5 (13%)
SPHERE	23 (100%)	20 (87%)	20 (87%)	4 (17%)	2 (9%)	1 (4%)
i-sense	45 (100%)	45 (98%)	45 (98%)	16 (35%)	13 (28%)	6 (13%)
TeDDy	1 (100%)	1 (100%)	1 (100%)	1 (100%)		
IRC programme	**110 (100%)**	**106 (96%)**	**106 (96%)**	**28 (25%)**	**19 (17%)**	**12 (11%)**

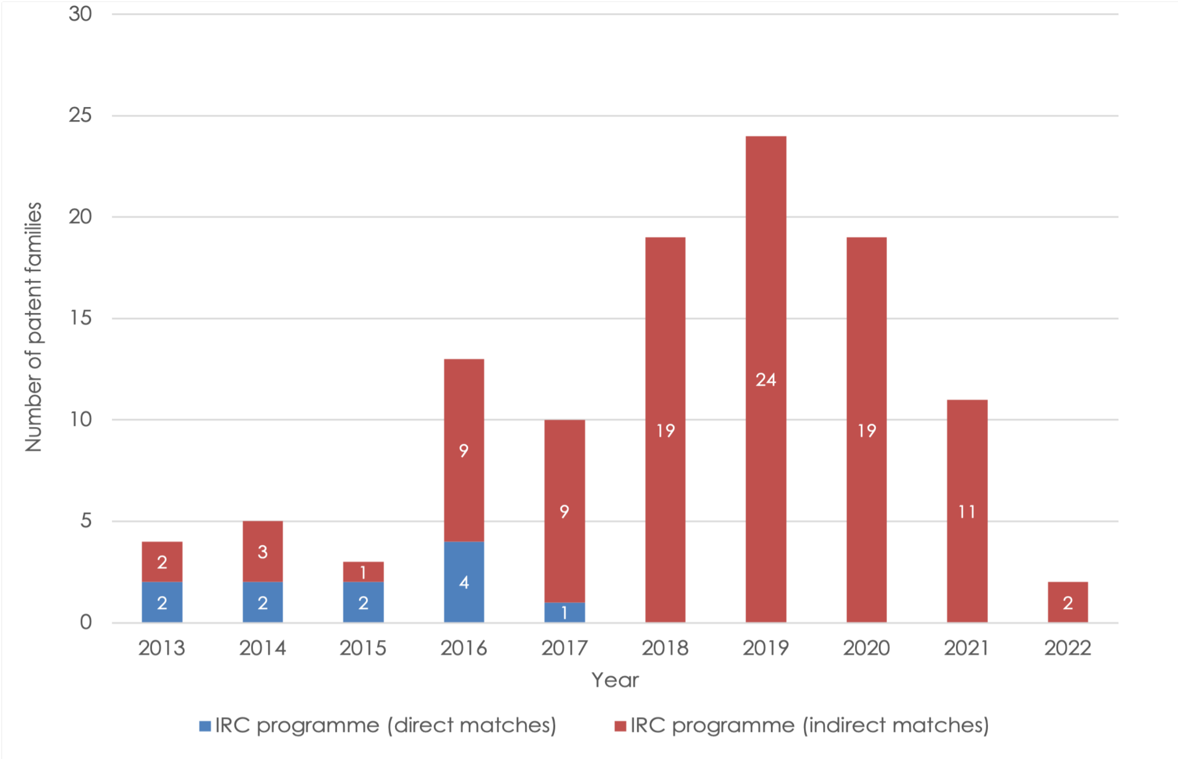
Source: Technopolis analysis based on Dimensions data

Below, we provide an overview of the number of patent families identified (both direct and indirect matches). We also showcase the jurisdictions of the patent's applications and their associated field of research (FoR).

B.4.2 *Number of unique patent families*

Figure 7 below provides an overview of the number of unique patent families (both identified via the direct and indirect matching routes) filed in a given year. Patents with direct attribution to the IRC programme were filed within the first five years of the programme (by Proteus and i-sense). No further patents were identified via direct matching after 2017, suggesting that key intellectual properties were developed within the first five years of the IRC programme. However, there is an emergence of a 'second wave' of patents from 2016 onwards, which had been informed by early IRC publications.

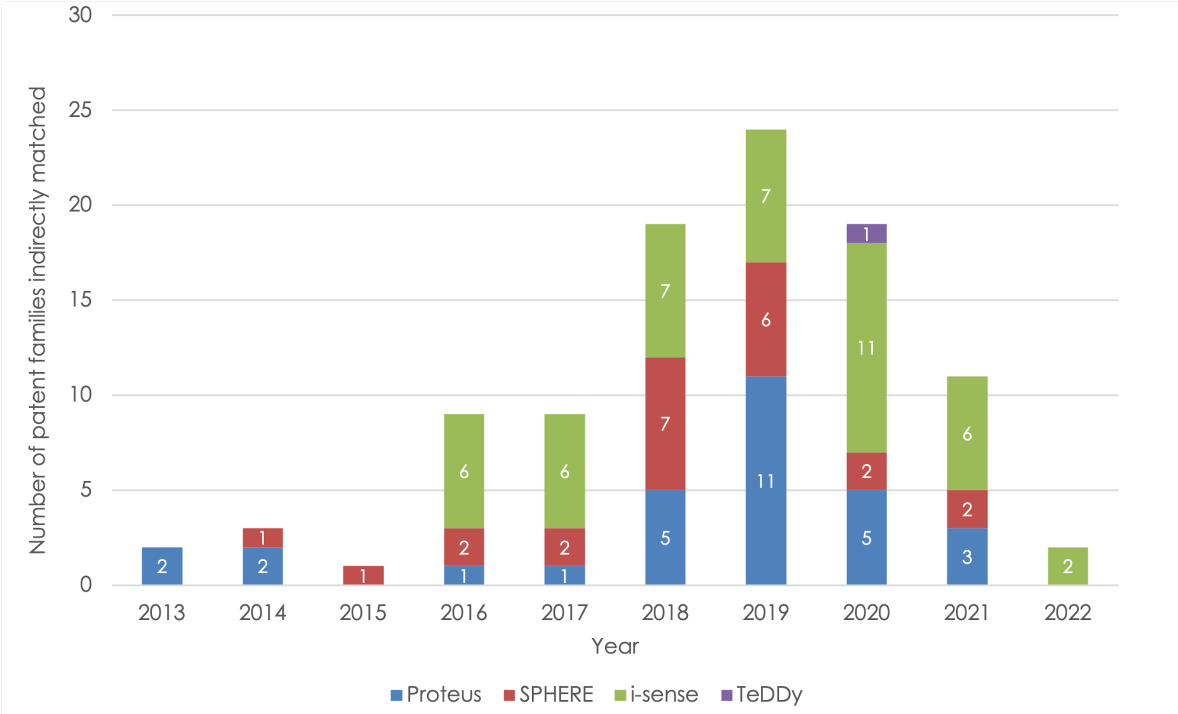
Figure 7 Number of unique patent families per priority year



Source: Technopolis analysis based on Dimensions data

Figure 8 below provides the indirectly matched patents by each IRC. It shows that IRCs without direct patents, such as SPHERE and i-sense, produced knowledge relevant to patenting activities by organisations beyond the IRC programme.

Figure 8   Number of unique patent families per priority year by IRC (indirect matches only)



Source: Technopolis analysis based on Dimensions data

B.4.3 Number of jurisdictions and total number of patent applications filed over all years

Table 12 below shows the number of distinct jurisdictions and patent applications filed over all years, including both directly and indirectly matched patent families. Most patents were filed with the World Intellectual Property Organization (WIPO), followed by the US Patent and Trademark Office (USPTO) and European Patent Office (EPO).

Table 12   Number of unique jurisdictions and patent applications over all years

IRC	Number of unique jurisdictions	Total number of patent applications	Number of patent applications by jurisdiction				
			World Intellectual Property Organization	United States PTO	European Patent Office	France	Spain
Proteus	5	57	31	18	7		1
SPHERE	2	30	10	9	9	2	
i-sense	5	52	29	15	6	2	
TeDDy	5	1	1				
IRC programme	**5**	**140**	**71**	**42**	**22**	**4**	**1**

Source: Technopolis analysis based on Dimensions data

According to Dimensions data, directly matched patent families (n = 11) produced 14 patent applications which are pending approval with the World Intellectual Property Organization, (thus not yet granted). Indirectly matched patent families (n = 99) produced 126 patent applications, of which 37 have already been granted.

B.4.4 Share of fields of research tagged to patents

Table 13 below provides an overview of the top 10 FoR of all patent families (direct and indirect matches), summarised by each IRC. The result confirms the previous analysis of publications, showcasing a diverse range of research areas within and across IRCs.

Table 13 Share of field of research of all patents by IRC

IRC	Field of Research (1st level)	Field of Research (2nd level)
Proteus	Engineering (39.2%)	Manufacturing Engineering (17.5%)
	Physical Sciences (22.5%)	Biochemistry and Cell Biology (14.0%)
	Biological Sciences (19.3%)	Electronics, Sensors and Digital Hardware (14.0%)
	Biomedical and Clinical Sciences (7.9%)	Oncology and Carcinogenesis (7.0%)
	Chemical Sciences (5.0%)	Microbiology (7.0%)
	Information and Computing Sciences (3.5%)	Electrical Engineering (5.3%)
	Mathematical Sciences (1.8%)	Physical Chemistry (3.5%)
	Earth Sciences (0.9%)	Communications Engineering (3.5%)
		Nanotechnology (3.5%)
		Applied Mathematics (1.8%)
SPHERE	Information and Computing Sciences (66.7%)	Human-Centred Computing (18.5%)
	Engineering (29.6%)	Data Management and Data Science (13.0%)
	Biomedical and Clinical Sciences (1.9%)	Computer Vision and Multimedia Computation (11.1%)
	Physical Sciences (1.9%)	Graphics, Augmented Reality and Games (11.1%)
		Communications Engineering (9.3%)
		Electrical Engineering (7.4%)
		Distributed Computing and Systems Software (5.6%)
		Artificial Intelligence (3.7%)
		Biomedical Engineering (3.7%)
		Classical Physics (3.7%)
i-sense	Chemical Sciences (27.0%)	Biochemistry and Cell Biology (14.0%)
	Biological Sciences (25.0%)	Medicinal and Biomolecular Chemistry (10.0%)
	Biomedical and Clinical Sciences (19.0%)	Nanotechnology (9.0%)
	Engineering (17.0%)	Analytical Chemistry (6.0%)

	Information and Computing Sciences (7.0%)	Electrical Engineering (6.0%)
	Physical Sciences (4.0%)	Organic Chemistry (6.0%)
	Mathematical Sciences (1.0%)	Medical Biotechnology (6.0%)
		Bioinformatics and Computational Biology (6.0%)
		Physical Chemistry (5.0%)
		Inorganic Chemistry (4.0%)
TeDDy	Engineering (100.0%)	Biomedical Engineering (100.0%)

Source: Technopolis analysis based on Dimensions data

B.5 Policy documents

Table 14 below provides an overview of the number of policy documents by IRC as well as the share of documents (in parentheses) that had been tagged with attributes for analysis.

Table 14 Number and share of tagged policy documents

IRC	Number of policy documents	FoR first level	FoR second level	RCDC	HRCS-HC	HRCS-RAC
SPHERE	7	7 (100%)	7 (100%)	6 (86%)	2 (28%)	4 (57%)
i-sense	51	51 (100%)	51 (100%)	50 (98%)	27 (53%)	17 (33%)
IRC programme	**58**	**58 (100%)**	**58 (100%)**	**56 (96%)**	**29 (50%)**	**21(36%)**

Source: Technopolis analysis based on Dimensions data

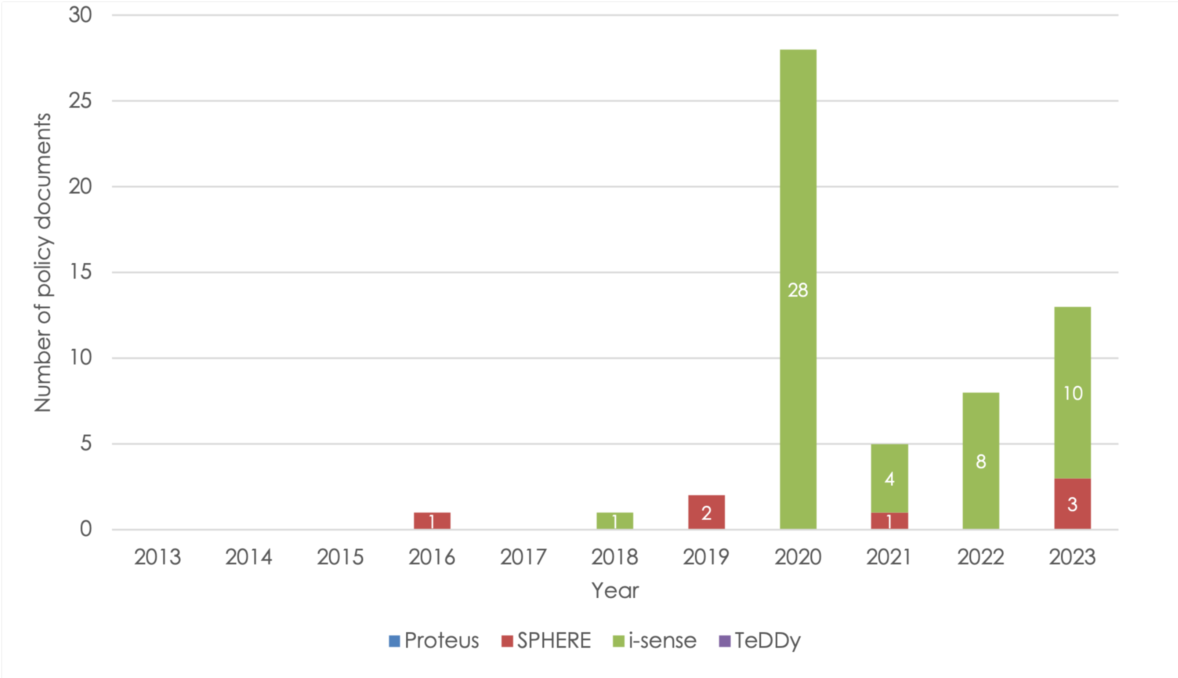
A total of 58 policy documents were identified via indirect matching (namely policy documents that cite publications from the IRC dataset). No policy document associated with Proteus and TeDDy was identified in the dataset. The high number of policy documents linked to publications by i-sense suggests that the focus of its research could directly, and in a timely manner, contribute to healthcare policy development; an example for that is i-sense's computer science work on monitoring COVID-19 outbreaks that informed national policy decision during the pandemic.

Below, we provide an overview of the number of policy documents over the years and their research classifications.

B.5.1 Number of policy documents per year

Figure 9 below shows, per year, the number of policy documents that cite IRC publications. Policy documents citing SPHERE publications were identified as early as 2016, only three years from the start of the programme. Policy documents citing i-sense publications rocketed in 2020, due to the timeliness of i-sense's work on influenza and COVID-19 surveillance, and related tools that were developed and adopted by the Public Health England (now UK Health Protection Agency).

Figure 9 Number of policy documents citing IRC publication per year



Source: Technopolis analysis based on Dimensions data

The above figure indicates the IRC programme, overall, took three to five years to impact healthcare policy. However, in some individual cases, the time lag may be significantly longer or shorter, dependent on the actual policy relevance of the research. The quantitative analysis presented here is not conducive to explore the links (and possible dependency) between specific IRC publications and the emergence of new policies.

B.5.2 Share of fields of research tagged to policy documents

Table 15 below provides an overview of the distribution of FoR tagged to policy documents. Many policy documents for SPHERE were tagged with the field of research 'Human Society' (FoR 1st level) and 'Policy and Administration' (FoR 2nd Level). Examples include two policy documents from the Alan Turing Institute about artificial intelligence, ethics and financial services. This provides an indication of how SPHERE may impact policy beyond healthcare. For i-sense, the main field of research identified in policy documents was 'Biomedical and Clinical Sciences'. Examples include COVID-19 surveillance reports from UK government and World Health Organisation (WHO) COVID-19 epidemiological reports.

Table 15 Share of field of research of policy documents by IRC

IRC	Field of Research (1st level)	Field of Research (2nd level)
SPHERE	Human Society (35.8%)	Policy and Administration (42.9%)
	Health Sciences (19.0%)	Health Services and Systems (21.4%)
	Creative Arts and Writing (14.3%)	Criminology (14.3%)
	Biomedical and Clinical Sciences (11.9%)	Screen and Digital Media (14.3%)

	Commerce, Management, Tourism and Services (7.2%)	Clinical Sciences (7.1%)
	Law and Legal Studies (7.2%)	
	Psychology (4.7%)	
i-sense	Biomedical and Clinical Sciences (48.0%)	Clinical Sciences (47.1%)
	Health Sciences (23.2%)	Health Services and Systems (14.7%)
	Law and Legal Studies (6.9%)	Public Health (9.8%)
	Human Society (6.5%)	Creative and Professional Writing (3.9%)
	Creative Arts and Writing (3.9%)	Policy and Administration (3.9%)
	Commerce, Management, Tourism and Services (2.9%)	Strategy, Management and Organisational Behaviour (3.9%)
	Agricultural, Veterinary and Food Sciences (2.0%)	Applied Economics (2.0%)
	Information and Computing Sciences (2.0%)	Commercial Law (2.0%)
	Biological Sciences (1.0%)	Development Studies (2.0%)
	Earth Sciences (1.0%)	Food Sciences (2.0%)

Source: Technopolis analysis based on Dimensions data

In Table 16 below, we provide results for two other research classification systems: US NIH Research Condition and Disease Categorization (RCDC) system and the UK Health Research Classification System - health category (HRCS-HC) and research activity codes (HRCS-RAC).

Table 16 Share of RCDC, HRCS-HC and RAC of policy documents by IRC

IRC	RCDC	HRCS-HC	HRCS-RAC
SPHERE	Behavioral and Social Science (54.9%)	Generic health relevance (100.0%)	Organisation and delivery of services (50.0%)
	Basic Behavioral and Social Science (19.2%)		Policy, ethics, and research governance (50.0%)
	Clinical Research (4.4%)		
	Mind and Body (4.4%)		
	Rehabilitation (4.4%)		
	Aging (2.4%)		
	Bioengineering (2.4%)		
	Brain Disorders (2.0%)		
	Depression (2.0%)		
	Health Services (2.0%)		
i-sense	Prevention (13.7%)	Infection (74.1%)	Surveillance and distribution (76.5%)

	Clinical Research (13.3%)	Generic health relevance (20.4%)	Resources and infrastructure (aetiology) (5.9%)
	Health Services (12.4%)	Mental health (1.9%)	Primary prevention interventions to modify behaviours or promote wellbeing (5.9%)
	Infectious Diseases (9.6%)	Cardiovascular (0.9%)	Organisation and delivery of services (5.9%)
	Behavioral and Social Science (8.5%)	Oral and gastrointestinal (0.9%)	Policy, ethics, and research governance (5.9%)
	Emerging Infectious Diseases (7.7%)	Stroke (0.9%)	
	Vaccine Related (6.8%)	Cancer (0.9%)	
	Lung (5.8%)		
	Biodefense (5.6%)		
	Pneumonia & Influenza (5.4%)		

Source: Technopolis analysis based on Dimensions data

The above findings show that i-sense's policy contribution cover a range of subjects, including prevention, infectious diseases and vaccination. While the majority of policy documents were tagged with health category 'Infection', i-sense also informed policy documents linked to mental health, cardiovascular diseases, cancer and other conditions. For SPHERE, the small number of policy documents were relevant for behavioural and social sciences and around the subjects of policy, ethics and research governance.

B.6 Clinical trials

No clinical trials were directly matched via IRC programme grant references. Three clinical trials were identified via indirect matching, namely those that cite IRC publications. The identified clinical trials were linked to publications from Proteus (n = 2) and SPHERE (n = 1), as summarised in Table 17 below.

Table 17 Clinical trials indirectly linked to IRC

IRC	Date	Title	Type of study	Number of participants
PROTEUS	2020-21	Diagnosing Corneal Infection - NCT04230811	Observational	120
	2020-22	Coronavirus Induced Acute Kidney Injury: Prevention Using Urine Alkalinization - NCT04530448	Interventional	3
SPHERE	2017-18	London Investigation Into diElectric Scanning of Lesions (LIESL) - NCT03302819	Interventional	994

Source: Technopolis analysis based on Dimensions data

The clinical trial linked to SPHERE's publication was expected to test the performance of the MARIA breast imaging system, which is a CE-marked radio-frequency (RF) medical imaging device.

The observational study linked to Proteus was expected to test two diagnostic techniques of serious eye infections: the standard of care of corneal scrape and the corneal impression membranes (CIM) that may detect microorganisms in the eye with greater sensitivity, safety and speed in a more patient friendly way at the bedside.

Several factors may have contributed to the small number of clinical trials identified. First, the IRC programme did not directly fund clinical trials. Second, the technologies created through the IRC programme over the years are still at an early stage to test those in clinical setting. Third, the technologies developed in the IRC may be used as enablers in clinical trials (see SPHERE's technology supporting clinical trials in new project TORUS) rather than directly assessed in clinical trials. Fourth, we may not have identified ongoing observational studies that are not registered in clinical trial databases.

Other consultation activities in this evaluation identified at least three additional studies beyond those summarised above. This discrepancy suggests potential gaps in Dimensions data, due to insufficient referencing of IRC grants in clinical studies or studies not registered in clinical trial databases, as discussed above.

Appendix C Online survey

An online survey was conducted with all participants from IRC programme funded projects. The survey was designed to extend our understanding of the outputs, outcomes and impacts. In addition, it served as a tool to collect data for economic analysis and case studies.

C.1 Survey dissemination

The online survey was distributed to all participants, including academic principal and co-investigators, partners and collaborators including industry, healthcare organisations and third-sector organisations. A small number of principal and co-investigators were identified as key contacts for spin-out companies. These individuals were asked to include in their survey responses data relevant to the outcomes and impacts of these companies.

The list of IRC programme participants for survey dissemination was put together through a review of programme documentation (for example, application forms). The list was iterated twice with IRC management teams for gap filling and necessary amendments (for example, additional project partners or collaborators). The final list of contacts for survey dissemination consisted of 145 individuals, of which over 80% represented partnering universities (see Table 18 below).

Table 18 Number of individuals invited to complete online survey by IRC and stakeholder type

Stakeholder type	IRC i-sense	IRC PROTEUS	IRC SPHERE	IRC TeDDy	Total by stakeholder type
University	30	42	25	21	118
Company	7	1	1	3	12
Research Institute	2	5	1		8
Healthcare provider		1	2		3
Non-profit		1	1		2
Government	1				1
R&D Centre				1	1
Total by IRC	40	50	30	25	145

The survey was launched on 16 August 2023 and closed on 29 September 2023. Following initial invitation, a reminder was sent on 29 August to encourage responses. On the 8 September 2023, a second email was sent to remind participants to complete the survey and to extend the deadline for submitting answers to 22 September 2023.

Due to a relatively low number of responses received in initial stages, the study team asked IRC leads (via email and/or during interviews) whether they could promote engagement with the survey through their internal IRC communication channels. To support this activity, the study team provided a list of contacts to those IRC leads who agreed to promote survey engagement. On 22 September 2023, the team at the EPSRC sent a final reminder on behalf of the study team, which included a second survey deadline extension to 29 September 2023.

C.2 Survey analysis

The online survey questionnaire consisted of both open and closed questions on areas relevant to the IRC evaluation. These areas were interdisciplinary research collaborations, scientific impact, skills & training impact, economic impact, and health & societal impact. In addition, the survey included questions for feedback on IRC programme design. Questions were routed based on profiling questions (namely, industry partners were asked additional economic questions). The survey questionnaire is shown in section 1.10.

Survey results were cleaned using R and Excel to remove duplicates, test data and other invalid inputs. Closed questions were analysed in R for the creation of graphs. Open questions provided context to the closed questions and important data for case studies. These text answers were manually coded by themes and reported accordingly.

The next sections present the results of the online survey, starting with information about respondents and followed by their views on the different areas discussed above.

C.3 About survey respondents

A total of 45 responses were received. Approximately 90% of survey responses originated from academic institutions, as shown in Table 19. The overall response rate to the survey was 31%, with IRC TeDDy having the highest response rate (52%) and IRC SPHERE the lowest response rate (23%). Note that not all respondents systematically answered every question and therefore we provide total responses (n) for each question shown in subsequent sections.

Table 19 Number of survey responses by IRC and stakeholder type

Stakeholder type	IRC i-Sense	IRC PROTEUS	IRC SPHERE	IRC TeDDy	Total by stakeholder type
University	11	12	6	11	40
Research Institute	1	1	0	0	2
Healthcare provider	0	0	0	1	1
Company	0	0	1	1	2
Total by IRC	12	13	7	13	45

Most survey responses were received from co-investigators involved in the IRC programme since 2013, as shown in Table 20. In general, survey responses are likely to emphasize the perspectives and experiences pertinent to the most recent years of the collaborations, due to relatively higher volume of responses associated with involvement with the second grant of the IRC programme (2018 to 2023).

Table 20 Number of survey responses by role and length of involvement with IRC programme

Role within IRC	Entire IRC programme (2013 to 2023)	First grant only (2013 to 2018)	Second grant only (2018 to 2023)	Total
Co-investigator	12	2	11	25
Collaborator	1	2	6	9

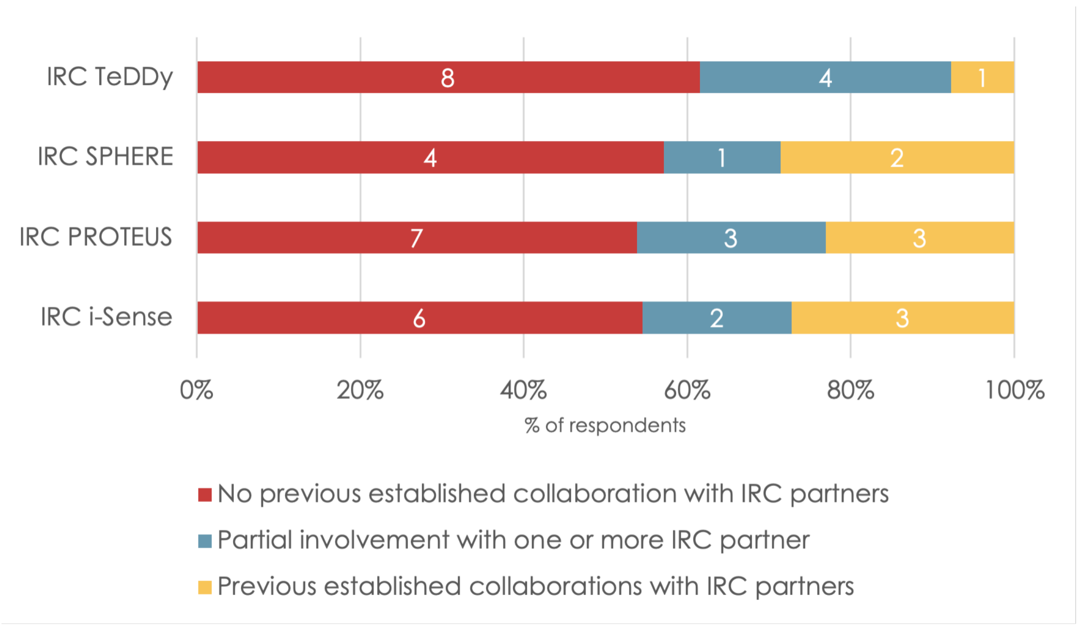
Other (PDRA, research associate, etc)	5	1	1	7
Principal investigator	2		2	4
Total	20	5	20	45

A total of 10 individuals indicated involvement with Next Step Plus projects: u-Sense[34] (n = 4), Smartphone mRNA[35] (n = 2), OPERA[36] (n = 2) and PPT[37] (n = 2).

C.4 Interdisciplinary research collaborations

Prior to the IRC Programme, 57% of survey respondents did not have previous established collaborations with IRC partners (see Figure 10 below). A further 23% of respondents reported some involvement with an IRC partner, but no established collaboration with all IRC partners.

Figure 10 Previous collaboration with IRC partners (n = 44)



As shown in Figure 11 below, over 70% of survey respondents indicated the IRC programme facilitated, to a very large or large extent, the following aspects:

- Exploration of new areas of research.

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[34] Ultra-Sensitive Enhanced NanoSensing of Anti-Microbial Resistance

[35] A Smartphone Powered mRNA Sequence Detector

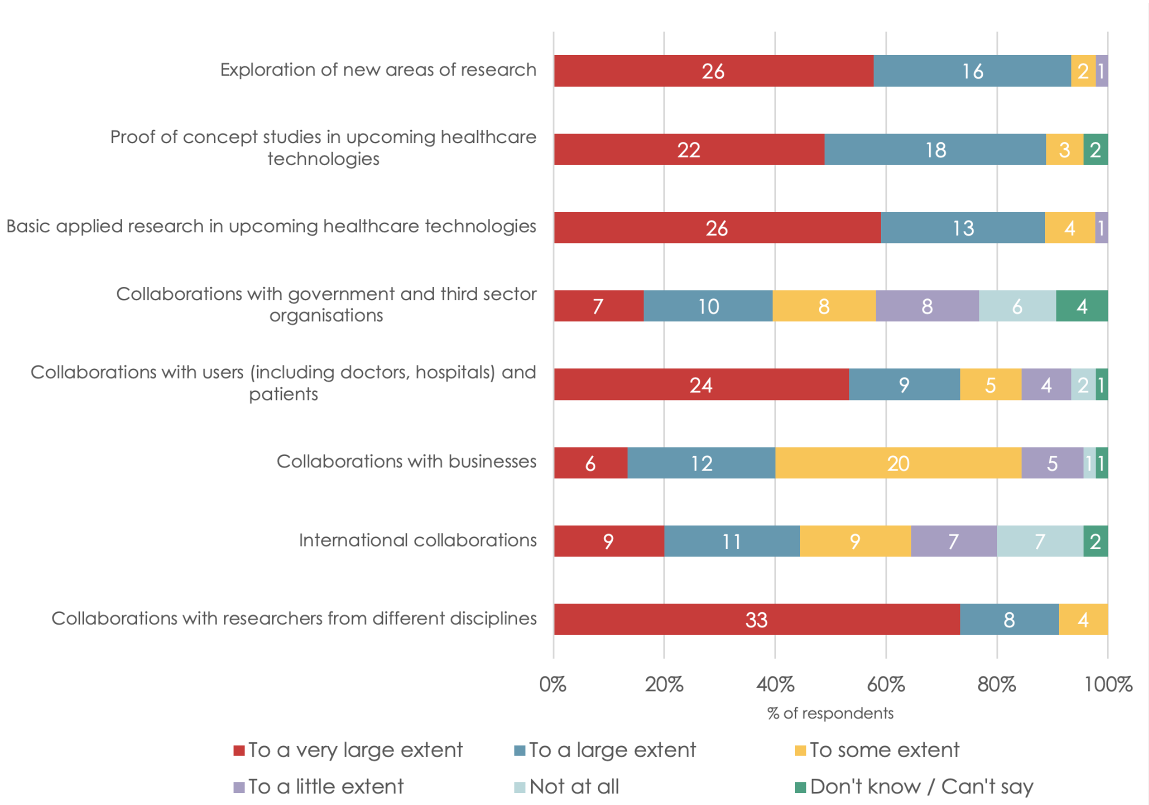
[36] Opportunistic Passive Radar for Non-Cooperative Contextual Sensing

[37] Photonic Pathogen Theranostics Point-of-care image guided photonic therapy of bacterial and fungal infection

- Basic applied research and proof of concept studies in healthcare technologies.
- Collaborations with researchers from different disciplines and with end-users (including patients and healthcare professionals).

However, respondents indicated the IRC programme was relatively less successful in facilitating other aspects, such as international collaborations and collaborations with businesses, government and third sector.

Figure 11 Types of collaborations and research within the IRC programme (n = 45)



In open text answers, most survey respondents highlighted the importance of the IRC programme in facilitating collaborations across disciplines and organisations. In particular, they mentioned engagement with clinicians as a key factor to advance research towards translation and deliver impactful research outputs. Respondents noted most collaborations were with universities in the UK. Rating of 'collaboration with businesses' was divergent (Figure 11) and qualitative answers confirm this lack of consensus. Those that had industry engagement expressed positive views (from three IRCs), while others noted limited industry input due to the early stage of their research (from two IRCs).

C.4.1 Main value of the partnerships enabled by the IRC programme

Several survey respondents noted the main value of the partnerships was enabling interdisciplinary research through a network of collaborators at international and local level (n = 21). According to respondents, the IRCs provided directionality to research (n = 6), training & skills (n = 5) and produced high-quality research (n =8). This was underpinned by the scale and timeframe of the funding, which enabled researchers to tackle big challenges in healthcare technologies. Several examples of research outcomes were provided. Respondents from IRC i-sense noted the programme helped to establish linkages with international organisations, such as the World Health Organisation (WHO). In addition, collaborations with public health agencies (namely, Public Health England) led to significant health impact through the creation of novel digital epidemiology approaches to monitoring influenza outbreaks. Some survey respondents from IRC SPHERE highlighted the programme enabled critical research on the ethical aspects of collecting data from home monitoring technologies. For respondents from IRC Proteus, the partnerships helped to create new research areas pursued within partnering universities, such as healthcare photonics. The creation of spin-outs to exploit the technologies developed at Proteus was also mentioned. Respondents from IRC TeDDy discussed technical progress around manufacturing and testing of new materials as a key value of the partnerships established in the programme.

C.4.2 Successes

Survey respondents were asked to highlight what aspects of the collaborations worked particularly well. Several survey respondents discussed the high-quality interdisciplinary research, underpinned by the IRC team's expertise, as a key success (n = 19). Examples of research outputs such as datasets and tools were mentioned.

The partnerships were also mentioned several times as a successful aspect of the IRC (n = 11), with survey respondents highlighting that workshops, conferences, technical meetings and other events, enabled researchers to learn from clinicians, patients, industry and experts from various disciplines. Similarly, training activities and career development events were discussed as a key factor for improving both technical and non-technical skills (n = 6).

Respondents from all IRCs mentioned regular project meetings provided an opportunity for researchers to share ideas and discuss findings from different project strands. This was considered a key enabler to obtain feedback from colleagues and understand how different project strands would be combined towards the IRC's overall objectives.

C.4.3 Challenges

Respondents were asked to highlight the main challenges encountered when collaborating in the IRC programme. Out of 37 responses, about 27% (n = 10) discussed general challenges around collaborating across disciplines and aligning research focus with all partners involved. The COVID-19 pandemic was also noted as a key challenge, with 19% of respondents (n = 7) mentioning its impact on research outputs.

Other challenges mentioned by survey respondents include difficulties in collaborating due to geographical location (14%, n = 5), absence of follow on funding to maintain collaborations 8% (n = 3) and staff recruitment and retention (8%, n = 3).

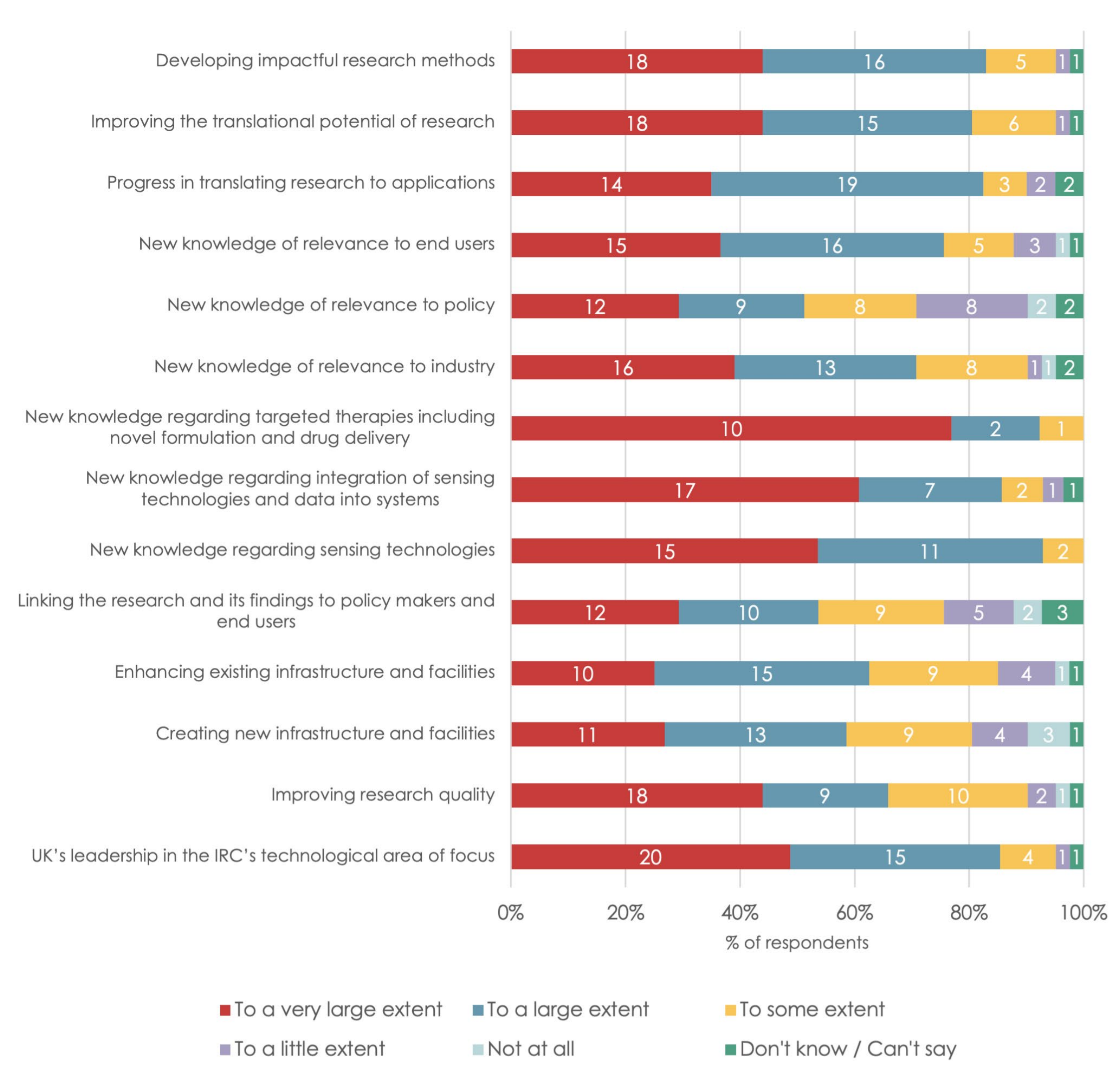
C.4.4 The sustainability of established collaborations

Respondents were asked if they have continued (or will continue) collaborating with IRC partners beyond the IRC programme (n= 44). Over 65% (n = 29) of respondents indicated they have continued or will continue collaborating, and a further 25% (n = 11) indicated partnerships are likely to continue. Only 9% of respondents (n = 4) noted they will not continue collaborating beyond the IRC programme.

C.5 IRC programme contribution to research and scientific impact

Figure 12 below shows the extent to which survey respondents believe the IRC programme has contributed to various aspects of research and scientific impact.

Figure 12 Outcomes of the IRC programme's contribution to research and science (n = 41)



Over 80% of respondents consider the IRC programme has made significant contributions (namely to a large or very large extent) to new knowledge in the IRCs focus area of research (sensing technologies and targeted therapies). Three quarters of the respondents stated that the IRC programme contributed to new knowledge relevant to end-users to a large or very large extent, and to a somewhat smaller extent relevant to industry. In addition, respondents also rated highly other aspects enabled by the IRC programme, such as 'developing impactful methods', 'improving the translational potential of research', and 'progress in translating research to applications'. This indicates an overall positive view about the IRC programme as an enabler of impactful research outputs and explains that 85% of respondents consider that the programme contributed to a large or very large extent to the UK's leadership in healthcare technologies. For other aspects, there was relatively less consensus among respondents, such as the IRC's contribution to creating or enhancing existing infrastructure, improving research quality, and informing policy and linking findings with end-users. Nevertheless over half of the respondents rated the programme's contribution to these aspects highly.

In open questions, respondents provided examples of research outcomes to contextualise their answers shown in the above figure. Some examples include IRC i-sense's computer science work on using internet data to support understanding of disease outbreaks and IRC Proteus' imaging platform for intensive care units. i-sense's work was used in the UK Health Security Agency's surveillance system to monitor influenza and COVID-19 outbreaks, helping policy makers to make decisions during the COVID-19 pandemic. Proteus' imaging platform is being tested in clinical trials and is being further exploited for commercialisation opportunities.

When asked about research outputs, most respondents (n = 16) discussed the production of several peer-reviewed publications throughout the IRC programme, including articles published in leading scientific journals. It was also noted some research findings are still being published. The development of instruments, databases and software was also highlighted by several researchers as important research outputs (n = 13).

C.5.1 Research outcomes and impact

When asked how research outputs have been taken up by IRC partners and others outside the IRC, several examples were provided. For example, impact on research was discussed in the context of publication citations by the academic community (n = 4) and research findings used in exploratory or follow-on projects by other research groups (n = 4). Several specific examples were provided:

- i-sense's collaboration with the Africa Health Research Institute on lateral flow testing and mHealth protocols for HIV surveillance in rural South Africa.
- Large-scale follow-on project underpinned by research conducted at SPHERE: 'Transforming the Objective Real-world measurement of Symptoms (TORUS)', a new EPSRC-funded project to support generation of data relevant to clinical trials.
- Further funding obtained to test Proteus' imaging platform in clinical trials.
- Evaluation of new materials by clinical groups for novel targeted drug delivery approaches at TeDDy.

Importantly, survey respondents observed that research findings underpin ongoing and future translational activities towards impact. For example, spin-out companies are being formed to exploit the technologies developed in the IRC programme. These include Singular Photonics, a spin-out company from Proteus, that will exploit and further develop the semiconductor work conducted in the IRC. From IRC TeDDy, spin-out Vector Bioscience aims to test new materials, such as metal organic frameworks, to improve effectiveness of therapies for hard-to-treat cancers.

When asked about the research outcomes emerging from the IRC with the highest potential for future impact, 30 survey respondents provided answers. Nearly 50% (n = 14) mentioned technical outputs, which are summarised below:

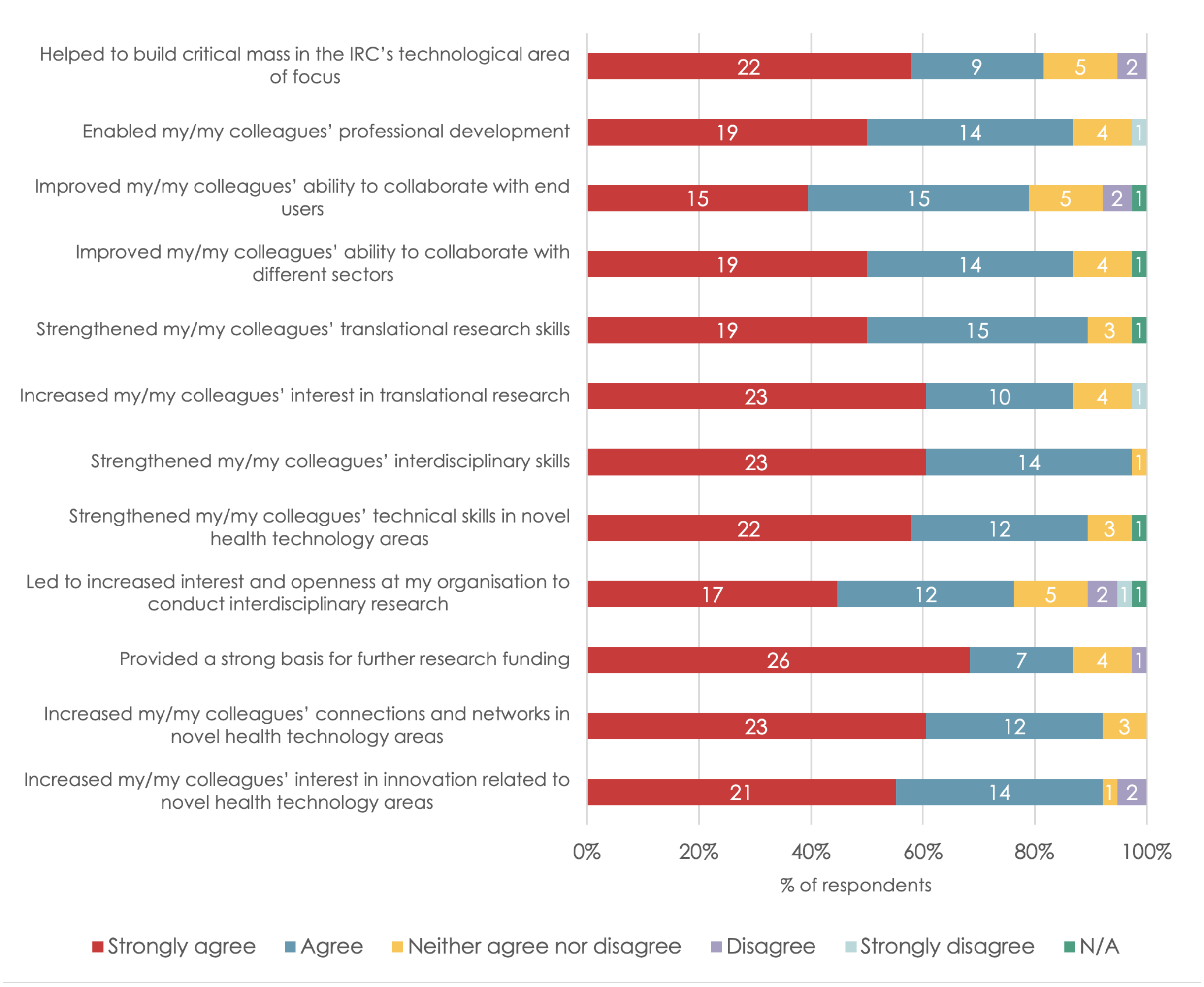
- IRC i-sense

- Digital epidemiology approaches to support surveillance systems.
    - Ultrasensitive diagnostics tools for infectious diseases.
- IRC Proteus
    - Ultrafast imaging sensors for applications in healthcare and life sciences more broadly.
    - Fibre-based imaging instruments for intensive care.
- IRC SPHERE
    - Multimodal sensing hardware and software for understanding the evolution of symptoms in Parkinson's disease.
- IRC TeDDy
    - Device for continuous delivery of drugs using electrophoresis, with implications for effectiveness of chemotherapy.
    - Injectable hydrogel for better delivery of drugs for brain tumours.

C.6 IRC programme's contribution to skills and training

Survey respondents overwhelmingly agree (>80%) that the IRC programme has helped to build critical mass in the technological areas of focus. Figure 13 shows the various elements that contributed to capacity building through training and skills development. According to respondents, the programme enabled professional development, collaborations across sectors, strengthening interdisciplinary skills and specific skills relevant to healthcare technology. Respondents also stated that the participation in the programme has increased their and their colleagues' interest and skills in translational research and improved their ability to collaborate with end users. Overall, the programme has contributed to increased interest in innovation in novel health technology areas, created connections and networks, and provided a strong basis for further research funding. Three-quarters of the respondents also confirmed that within the respondent's organisation, the IRC programme led to increased interest and openness to conduct interdisciplinary research.

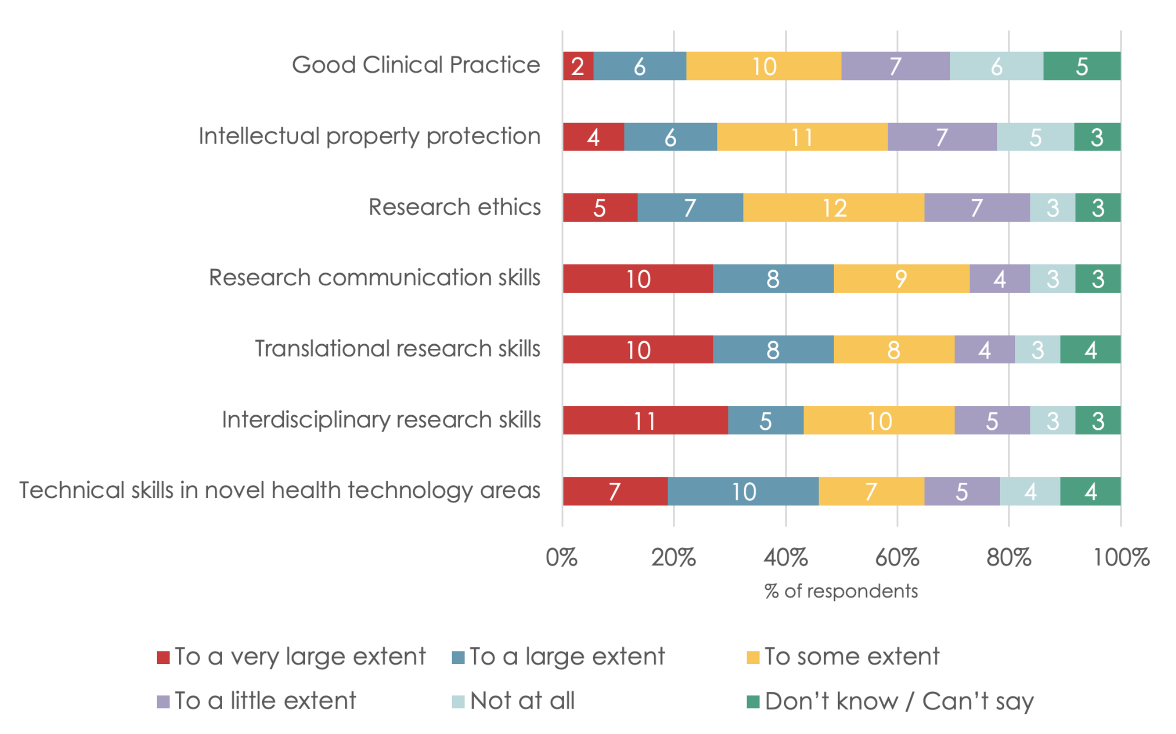
Figure 13 Outcomes of participation in the IRC programme regarding skills & training (n = 38)



Several examples were provided by survey respondents to contextualise the answers shown in the figure above. The career development of early-career and mid-career researchers was highlighted by respondents from all IRCs (n = 7). Postdoctoral researchers gained technical and management skills and benefited from a collaborative network within and beyond the IRC. Cross-cutting themes (for example, manufacturing practices at TeDDy) helped researchers to consider translational challenges early on and understand barriers to adoption of technologies in healthcare settings.

The survey explored the extent to which the IRC programme has supported the development and delivery of new courses and training at respondents' organisations (Figure 14).

Figure 14 IRC programme's support to organisations to develop and deliver new courses and training in specific areas (n = 37)



Approximately 45% of respondents stated the IRC programme has supported, to a large or very large extent, new courses and trainings to develop skills around novel health technologies, translational research, interdisciplinary research and research communication. Courses were also developed and delivered in other more specialised areas, such as research ethics, intellectual property protection, and good clinical practice, but to a lesser extent. IRCs i-sense and TeDDy rated these aspect 'to a very/large extent', while Proteus and SPHERE 'to some/little extent'.

A few respondents (n = 5) noted the IRCs benefited from existing courses and training available at universities, such as good clinical practice and interdisciplinary science. This indicates the IRCs have benefited from existing university resources rather than creating new formal courses.

Specific examples by respondents (n = 4) included i-sense's Education Alliance, which provided opportunities for training and career development to early-career and mid-career researchers, and SPHERE's impact in creating a new MSc in Digital Health and a Centre for Doctoral Training (CDT) in Digital Health and Care at the University of Bristol.

C.7 IRC programme contribution to economic impact

Survey respondents were asked to provide information on the IRC's contribution to economic impact, including further funding obtained and creation of spin-outs and intellectual properties. Respondents from companies were asked additional questions relevant to commercialisation activities. However, due to small number of responses from companies (n = 2), the survey data provides limited information about economic impact from the perspective of industrial partners.

C.7.1 Further funding

Survey respondents were asked to provide information about further funding obtained as a result of their participation in the IRC programme, including grants, venture capital and other sources. Respondents reported over £30 million in further funding, obtained largely from public funders, including Innovate UK, MRC and EPSRC. This funded not only new research projects in healthcare technologies and a centre for doctoral training but included public investment (£2.7 million) to create and grow spin-out companies, which will further exploit the technologies developed in the IRCs. Table 21 below shows examples submitted by survey respondents. They include large-scale collaborations and training initiatives, providing evidence to the IRC programme's impact on different research disciplines.

Table 21 Examples of further funding obtained as a result of researchers' participation in the IRC programme

Source	Project title	Value	Date
EPSRC	Centre for Doctoral Training in Digital Health and Care[38]	£6.3 million	2019 - 2027
	U-care: Deep ultraviolet light therapies[39]	£6.1 million	2021 - 2025
	Transforming the Objective Real-world measUrement of Symptoms[40]	£6.1 million	2023 - 2028
	Digital Health Hub for Antimicrobial Resistance[41]	£4.2 million	2023 - 2026
	PreCisE: A Precision laser scalpel for Cancer diagnostics and Eradication[42]	£1.2 million	2021 - 2024
	Metabolic photosensitizers for photodynamic therapy of brain cancer[43]	£600,000	2022 - 2025
MRC	Optical Confirmation of Nasogastric Tube Placement with Early Photon Imaging[44]	£1.3 million	2022 - 2025
	m-Africa: Building mobile phone-connected diagnostics and online care pathways to support HIV prevention and management in decentralised settings[45]	£606,000	2017 - 2019
Innovate UK	Metal-organic frameworks as a modular platform for advanced drug delivery[46]	£314,000	2022 - 2024

[38] https://gtr.ukri.org/projects?ref=EP%2FS023704%2F1
[39] https://gtr.ukri.org/projects?ref=EP%2FT020903%2F1
[40] https://gtr.ukri.org/projects?ref=EP%2FX036146%2F1
[41] https://gtr.ukri.org/projects?ref=EP%2FX031276%2F1
[42] https://gtr.ukri.org/projects?ref=EP%2FV006185%2F1
[43] https://gtr.ukri.org/projects?ref=EP%2FW015706%2F1
[44] https://gtr.ukri.org/projects?ref=MR%2FW029979%2F1
[45] https://gtr.ukri.org/projects?ref=MR%2FP024378%2F1
[46] https://gtr.ukri.org/projects?ref=10037486

European Innovation Council – Transition Challenge Award	GENERA: A revolutionary, highly versatile drug delivery platform based on Metal-Organic Frameworks[47]	€2.5 million	2023 - 2025

C.7.2 *Contribution to businesses*

Figure 15 below shows the contribution of the IRC programme to businesses in the UK, in relation to training or services provided to companies: 50% of respondents to this question indicated their organisation contributed to improving UK businesses.

Figure 15 Contribution of organisations to improving UK businesses (n = 36)

Survey responses indicate this contribution originated from creating new knowledge relevant to industry, including improvements to processes and knowledge transfer activities through collaborations. In some cases, respondents noted these activities had 'high impact' on businesses. One example is the work conducted at IRC i-sense on Google's Flu Trend algorithm, which may have supported decisions around Google's Health Trends teams moving to London and thereby having a subsequent impact on UK employment opportunities.

When asked about the IRC programme's contribution to company activities and finances, only one company provided data. The respondent noted the IRC programme increased the company's focus on innovation in healthcare technologies to some extent and enhanced the company's potential for innovation in this area to a little extent. Other aspects, such as increased private investment, turnover and cost-savings were not impacted as a result of the programme. Due to limited data received, it is not possible to ascertain the programme's contribution to businesses.

In terms of new companies, survey respondents reported at least six spin-outs created as a result of the IRC programme. These include three spinout companies from IRC Proteus, two from IRC i-sense and one from IRC TeDDy. These new entities will further develop the technologies created in the IRCs and explore their uses within and beyond healthcare.

[47] https://www.strata.team/eic-transition-winners-and-statistics-september-2022/

C.7.3 Contribution to employment

A total of 29 survey respondents provided estimates on the number of people involved in IRC programme activities. Their answers indicate over 200 individuals were involved in the programme, of which at least 100 were hired as a result of the IRC. Respondents were also asked to rate their confidence that new jobs will be created in the future as a result of the IRC programme. A total of 33 survey respondents provided an answer to the question, of which 30% (n = 10) provided a 100% confidence rating that new jobs will be created, and an additional 18% (n = 6) provided an 80% confidence rating. Only three respondents provided a low confidence rating of 20%. When estimating the number of new jobs to be created by their organisation or department as a result of the IRC programme, a few survey respondents indicated at least 1 to 2 jobs will be created (n = 8). A small number of respondents indicated more jobs will be created: 10 or more jobs (n = 2) and 100 or more jobs (n = 1). Importantly, a few survey respondents also estimated that no additional jobs will be created in their organisation or department (n = 9).

While this data suggests a positive impact on current and future employment, it is important to note these employment statistics are estimates and do not provide a comprehensive view of the IRC programme's overall contribution to employment. Not enough data was received from industry partners and most data on employment originated from university respondents. The two companies that participated in the survey had reported no additional or future employment outcomes.

C.7.4 Contribution to intellectual properties, licensing agreements and revenues

Out of 39 respondents, 46% (n = 18) reported their organisation generated new intellectual properties (IP), with approximately 11 patents filled by universities as a result of the IRC programme. Based on the survey responses, no patents were filed by companies or other organisations. Seven respondents also indicated licensing agreements are (or will) take place to exploit the IP generated, however, responses indicated it was too early to assess the value of these licensing agreements.

Respondents were also asked to provide data on revenues arising as a result of the IRC programme, including sales of products or services. Due to limited responses to these questions from all stakeholders, and overall low survey responses from companies, it was not possible to provide an indication of IRC programme contribution to additional attributable revenues.

C.8 IRC programme contribution to health and societal impact

A total of 31 survey respondents provided answers to questions around health and societal impact. Approximately 25% of respondents (n = 8) noted the research had already led to changes in healthcare policy or practice. In addition, over 60% of respondents (n = 19) indicated the research conducted in the IRCs are likely to lead to changes in healthcare policy and practice in the future. Only 13% (n = 4) reported the IRC is not likely to lead to any changes in healthcare policy or practice.

Several respondents highlighted it was too early to assess health and societal benefits and impacts due to the technology readiness level (1 to 3) where the IRC programme operates. However, it was observed that significant progress has been made to accelerate translation of diagnostics and novel approaches to therapies. It is expected that these technologies will move into clinical trials and make an impact in the years to come. Yet, some research has already produced impact on healthcare policy, with the following examples provided by survey respondents:

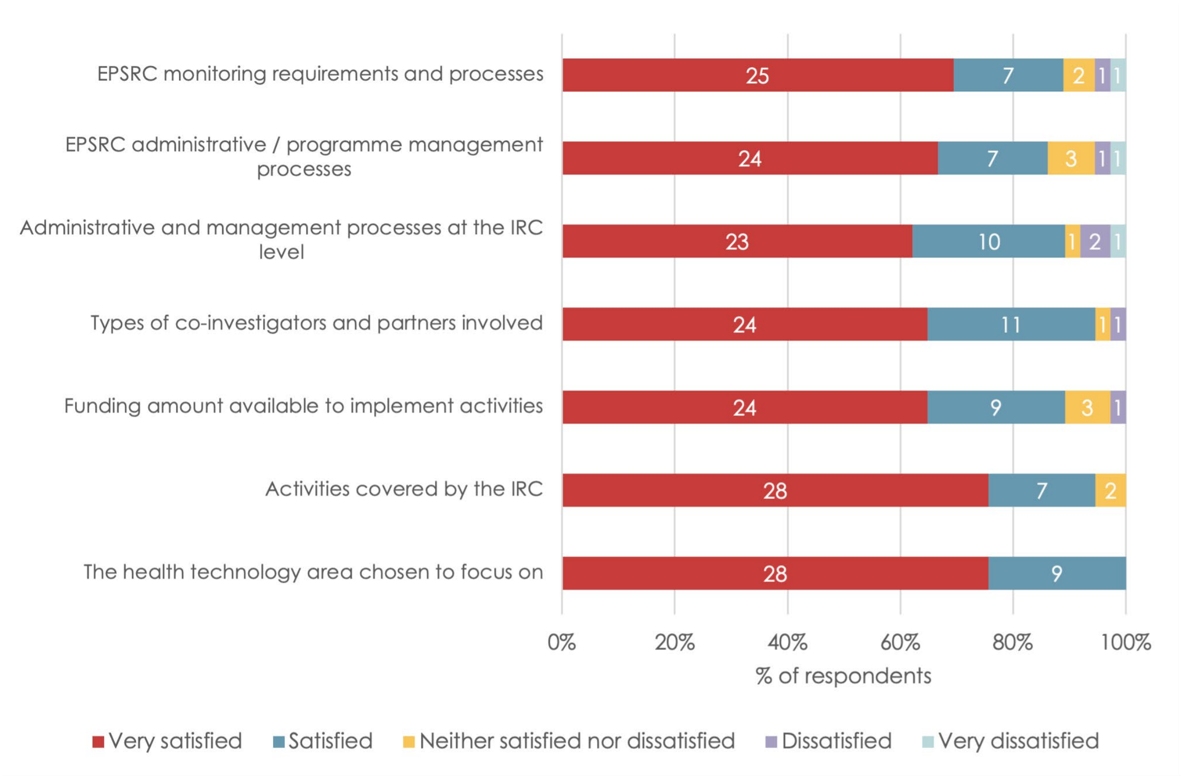
- IRC i-sense's machine learning algorithms and dashboards for early warning systems for influenza and COVID-19 were used by public health agencies and influenced national policy during the COVID-19 pandemic.
- IRC i-sense's machine learning models of symptoms reported online contributed to Public Health England's decision on rolling out national influenza vaccine for children.
- IRC TeDDy's contribution to neurotechnology regulation[48] via researcher participation in independent expert committees.

These examples indicate the IRC programme has already impacted health outcomes and created indirect economic benefits associated with the reduction of influenza and COVID-19 rates.

C.9 IRC programme design

Respondents were asked the extent to which they were satisfied with different aspects of the IRC programme design; results are shown in Figure 16 below.

Figure 16 Participant satisfaction with the design of IRC programme (n = 37)



48 https://www.gov.uk/government/publications/regulatory-horizons-council-the-regulation-of-neurotechnology

Most survey respondents were satisfied with the IRC programme design, with over 80% reporting 'very satisfied' or 'satisfied' in relation to all aspects, including monitoring, administrative and management processes. The scale of funding, activities, research areas and partners involved in the IRC were also rated highly.

In open questions, survey respondents were mostly positive about the management of the IRC programme, reporting positive feedback from external stakeholders, adequate advisory boards and strong leadership. However, a few respondents (n = 3) noted project management challenges around aligning 'research interests' and implementing project resources.

C.9.1 Main strengths and weaknesses

Out of 27 responses to a question on the strengths and weaknesses of the IRC programme, approximately 46% (n = 11) highlighted the scale and timeframe of the funding as a key strength of the programme. The funding provided researchers job security, enabled building partnerships, and allowed participants to focus on solving difficult technical challenges. Similarly, it was noted the IRC programme's design supported the creation of critical mass in healthcare technologies and allowed researchers to test new ideas. For example, one survey respondent from IRC TeDDy highlighted the creation of a postdoctoral research community which benefitted from knowledge sharing activities, access to facilities and equipment and career development.

In terms of weaknesses, there was no clear consensus about the key weaknesses of the programme's design, with a few weaknesses and challenges reported. In terms of research activities, respondents reported two hindering factors: the geographical spread of partnering universities and conflicts around researchers interests and priorities. It was also noted the network of partners and collaborators may not continue without further funding. Lastly, lack of consistent programme monitoring was also mentioned as a weakness by one survey respondent.

C.9.2 Future Impact

Survey respondents were asked to highlight how the IRC programme design may enable future impact in comparison to other funding programmes. Out of 24 responses, nearly 50% mention the scale of the IRC programme is necessary to create critical mass in healthcare technologies to solve complex challenges. They noted that challenges around tackling infectious diseases or hard-to-treat cancers require collaborations across disciplines and flexibility to adapt to emerging findings. In this way, the IRC programme helps to break silos between disciplines and accelerate research underpinning translation of medical devices, diagnostics and other outputs. According to survey respondents, this may not be possible without the scale of funding of the IRC programme and the expertise of participants involved.

C.9.3 Suggestions for future programmes

A total of 17 survey respondents provided suggestions for the EPSRC for the design of future programmes. Around 40% (n = 7) highlighted the importance of the IRC programme for career development and conducting impactful research, suggesting this type of funding should continue in the future. Suggestions were made to increase diversity (for example, women in leadership positions) and to increase funding for pump priming activities and new partnerships. It was also suggested that new funding programmes include considerations around ethical and social issues, as these areas are often neglected in engineering projects.

To maximise impact, it was suggested by one survey respondent that the EPSRC should have more monitoring and oversight over the programme's milestones. In addition, one survey respondent noted future programmes should consider the challenges of commercialising inventions in the UK and try to reduce the negative impact of research outputs being taken abroad for commercialisation.

C.10 Survey questionnaire

Introduction

This survey is part of a study commissioned by the Engineering and Physical Sciences Research Council (EPSRC) to evaluate the value and impact of the Healthcare Technologies Interdisciplinary Research Collaborations (IRC). The survey seeks to capture the results and impacts of the IRC investment to-date. The findings are to inform decisions on potential new investments and strategy development within the theme of healthcare technologies, as well as in the broader remit of EPSRC and UKRI.

Your views and contributions will not be published directly as received; they will be published in the form of an aggregated summary report. You have the right to withdraw from the study at any time. For further information on your rights and how to contact us, please refer to Technopolis Group's Privacy Policy. If you have any questions or comments regarding this consultation, please contact the Technopolis study team leader, Dr. Peter Varnai, via email: peter.varnai@technopolis-group.com.

Thank you for taking the time to complete the survey – your participation is extremely important to inform the evaluation.

Before you begin, please make sure that your browser is maximised. It's easy to navigate through the questionnaire: just click on the answer or answers that apply for each question. You may need to use the scroll bar to see the next question. To continue, click on the next button at the bottom of each page.

The survey contains around 30 questions and should take about 30 to 40 minutes to complete. You do not have to answer all questions at once – answers will be stored at every page and you can return to the survey at any stage before completing it, provided the same device/browser is used and it is allowed for internet cookies.

Please note the survey will close on **8th September 2023**.

Please click 'next' to enter the survey.

About your role in the IRC

[* indicates that a response is mandatory]

- *Please select the option that best describes your organisation [drop down menu]
  - University Department
  - Research Institute
  - Healthcare provider
  - Professional Body / Learned Society
  - Research charity
  - Government Department
  - Large company (more than 250 employees and an annual turnover over €50 million)
  - Small or medium sized company (less than 250 employees and an annual turnover under €50 million)
  - Other (please specify) [textbox]

- *Which IRC have you participated in? [drop down menu]
  - SPHERE
  - PROTEUS
  - i-sense
  - TeDDy

- *What was/is your role in the IRC? [drop-down menu]
  - Principal investigator from 2013 to 2018 only
  - Principal investigator from 2018 to 2023 only
  - Principal investigator from 2013 to 2023
  - Co-investigator from 2013 to 2018 only
  - Co-investigator from 2018 to 2023 only
  - Co-investigator from 2013 to 2023
  - Collaborator from 2013 to 2018 only
  - Collaborator from 2018 to 2023 only
  - Collaborator from 2013 to 2023
  - Other (please specify) [textbox]

- *Were you involved in a Next Step Plus project? [drop down menu]
  - Yes
  - No
  - Don't know

- [If yes – new page] Please identify which Next Step Plus project/s below you were involved with (tick all that apply) [tick box]

- u-Sense (Ultra-Sensitive Enhanced NanoSensing of Anti-Microbial Resistance)

- Smartphone mRNA (A Smartphone Powered mRNA Sequence Detector)
- OPERA (Opportunistic Passive Radar for Non-Cooperative Contextual Sensing)
  - PPT (Photonic Pathogen Theranostics - Point-of-care image guided photonic therapy of bacterial and fungal infection)
  -

- Was your involvement in the IRC based on an existing collaboration/partnership(s)? [drop-down menu]
  - Yes, my research team had collaborated with IRC partners previously
  - Partially, my research team had collaborated with IRC partners previously
  - No, my research team had not collaborated with any of the IRC partners previously
  - Other (please specify) [textbox]

-

About the collaboration

- In your view, to what extent has the IRC overall facilitated the following aspects:

	To a very large extent	To a large extent	To some extent	To a little extent	Not at all	Don't know / Can't say
Collaborations with researchers from different disciplines	☐	☐	☐	☐	☐	☐
International collaborations	☐	☐	☐	☐	☐	☐
Collaborations with businesses	☐	☐	☐	☐	☐	☐
Collaborations with users (including doctors, hospitals) and patients	☐	☐	☐	☐	☐	☐
Collaborations with government and third sector organisations	☐	☐	☐	☐	☐	☐
Basic applied research in upcoming healthcare technologies	☐	☐	☐	☐	☐	☐
Proof of concept studies in upcoming healthcare technologies	☐	☐	☐	☐	☐	☐
Exploration of new areas of research	☐	☐	☐	☐	☐	☐

Please elaborate on your responses above. [Open text]

-
- What has been the main value of the IRC partnership to you and your organisation/department? Please provide details. [Open text]

-
- What has worked particularly well in your IRC and why? [Open text]
-
- What has been the main challenge encountered regarding collaboration in your IRC? [Open text]

- Have you continued / are you going to continue collaborating with your IRC partners beyond the end of the IRC funding?
  - Yes

- No
- Possibly
- Not applicable or Can't say

Please elaborate on your response above. [Open text]

Contribution to research and scientific impact

[Answer options will be tailored to each IRC]

- In your view To what extent has the programme contributed to the following aspects:

	To a very large extent	To a large extent	To some extent	To a little extent	Not at all	Don't know / Can't say
UK's leadership in the IRC's technological area of focus [ALL]	☐	☐	☐	☐	☐	☐
New knowledge regarding sensing technologies [SPHERE, I-SENSE & PROTEUS]	☐	☐	☐	☐	☐	☐
New knowledge regarding integration of sensing technologies and data into systems [SPHERE, I-SENSE & PROTEUS]	☐	☐	☐	☐	☐	☐
New knowledge regarding targeted therapies including novel formulation and drug delivery [TeDDy]	☐	☐	☐	☐	☐	☐
New knowledge of relevance to industry [ALL]	☐	☐	☐	☐	☐	☐
New knowledge of relevance to policy [ALL]	☐	☐	☐	☐	☐	☐
New knowledge of relevance to end users [ALL]	☐	☐	☐	☐	☐	☐
Progress in translating research to applications [ALL]	☐	☐	☐	☐	☐	☐
Improving the translational potential of research [ALL]	☐	☐	☐	☐	☐	☐
Developing impactful research methods [ALL]	☐	☐	☐	☐	☐	☐
Improving research quality [ALL]	☐	☐	☐	☐	☐	☐
Creating new infrastructure and facilities [ALL]	☐	☐	☐	☐	☐	☐
Enhancing existing infrastructure and facilities [ALL]	☐	☐	☐	☐	☐	☐
Linking the research and its findings to policy makers and end users [ALL]	☐	☐	☐	☐	☐	☐

Please elaborate on your responses above. [Open text]

- Are you aware of any research outputs such as publications, tools, databases, technical products, software, research materials and methods? If yes, please specify the type and number. [Open text]
- Please provide any examples of how the IRC research or its results have been taken up by IRC partners (e.g. industry or hospitals).

- Please provide any examples of how the IRC research or its results have been taken up by others outside the IRCs.

- What in your view is the single most important result from the IRC that has generated / will likely generate the most impact in the future? Please explain the reasons for your answer. [Open text]

Contribution to skills and training

- To what degree do you agree or disagree with the following statements regarding your participation in the IRC?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	N/A
The IRC has increased my/my colleagues' interest in innovation related to novel health technology areas	☐	☐	☐	☐	☐	☐
The IRC has strengthened my/my colleagues' technical skills in novel health technology areas	☐	☐	☐	☐	☐	☐
The IRC has strengthened my/my colleagues' interdisciplinary skills	☐	☐	☐	☐	☐	☐
The IRC has increased my/my colleagues' interest in translational research	☐	☐	☐	☐	☐	☐
The IRC has strengthened my/my colleagues' translational research skills	☐	☐	☐	☐	☐	☐
The IRC has improved my/my colleagues' ability to collaborate with different sectors (e.g., academic/clinical/industry/others)	☐	☐	☐	☐	☐	☐
The IRC has improved my/my colleagues' ability to collaborate with end users	☐	☐	☐	☐	☐	☐
The IRC has enabled my/my colleagues' professional development	☐	☐	☐	☐	☐	☐
The IRC has helped to build critical mass in the IRC's technological area of focus	☐	☐	☐	☐	☐	☐
The IRC has increased my/my colleagues' connections and networks in novel health technology areas	☐	☐	☐	☐	☐	☐
The IRC is providing a strong basis for further research funding	☐	☐	☐	☐	☐	☐
The IRC has led to increased interest and openness at *my institution/organisation* to conduct interdisciplinary research	☐	☐	☐	☐	☐	☐

Please comment on your responses above. [Open text]

- To what extent has the IRC supported your organisation/department to develop and deliver courses and training in the following areas?

	To a very large extent	To a large extent	To some extent	To a little extent	Not at all	Don't know / Can't say
Technical skills in novel health technology areas	☐	☐	☐	☐	☐	☐
Interdisciplinary research skills	☐	☐	☐	☐	☐	☐
Translational research skills	☐	☐	☐	☐	☐	☐
Research communication skills	☐	☐	☐	☐	☐	☐
Research ethics	☐	☐	☐	☐	☐	☐
Intellectual property protection	☐	☐	☐	☐	☐	☐
Good Clinical Practice	☐	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐	☐

Please provide details on your responses above. [Open text]

-

Contribution to economic Impact

- Please provide details of any further funding captured as a result of your participation in the IRC. Please include details of grants, venture capital funding, etc. including amount, date and source of funding.
-
- [For businesses only] To what extent has the programme contributed to the following aspects:

-

	To a very large extent	To a large extent	To some extent	To a little extent	Not at all	Don't know / Can't say
Increased my company's focus on innovation in healthcare technologies	☐	☐	☐	☐	☐	☐
Enhanced my company's potential for innovation in healthcare technologies	☐	☐	☐	☐	☐	☐
Enhanced my company's potential for innovation outside healthcare technology areas	☐	☐	☐	☐	☐	☐
Cost-savings for my company	☐	☐	☐	☐	☐	☐
Increased turnover for my company in healthcare technology areas	☐	☐	☐	☐	☐	☐
Increased turnover for my company outside healthcare technology areas	☐	☐	☐	☐	☐	☐

Private investment for my company from UK sources	☐	☐	☐	☐	☐	☐
Private investment for my company from non-UK sources	☐	☐	☐	☐	☐	☐
Increased exports achieved by my company	☐	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐	☐

Please explain your answer and/or provide examples [Open text]

- What is the total number of spinout companies created by employees of your organisation/department as a result of the IRC? [Number only]

Please provide the exact names of the spinout companies formed. [Open text]

- Has your organisation/department conducted research, provided training or any services which contributed to improving businesses in the UK?
  - Yes
  - No
  - Don't know

- Please elaborate on your response and provide examples if possible [Open text]

- [For businesses only] In the year in which your company joined the IRC, what was your company's approximate turnover?

- Zero – pre- revenue/no turnover
- Less than £50,000 but not zero
- £50,000 to less than £100,000
- £100,000 to less than £500,000
- £500,000 to less than £2 million
- £2 million to less than £10 million
- £10 million to less than £50 million
- £50 million or more
- Don't know / Cannot disclose information

Approximately what percentage of this turnover was derived from activities relating to your company's involvement with the IRC?

[small textbox]

- [For businesses only] Has your company's turnover increased as a result of your company's involvement with the IRC? For example, through cost-savings, new processes or products using knowledge created by the IRC, etc.
  - Yes

- No
- Don't know / Cant's say
-

[If yes – new page] Please provide an approximate figure for the percent increase in turnover as a result of your company's involvement with the IRC. [small textbox]

[If yes – new page] Please describe the reasons for the increase (e.g. cost-savings, new processes or products marketed) [Open text]

- In the year in which your organisation/department joined the IRC, what was the total number of full-time equivalent staff employed? Please only include staff <u>in the UK</u> if your organisation has an international presence.

- None
- 1 to 9
- 10 to 49
- 50 to 249
- 250 to 499
- 500 to 999
- 1,000+

- Of these staff members (i.e. staff that were in post when your organisation joined the IRC), how many were involved in activities related to the IRC programme?
- [small textbox]

- How many <u>additional people were hired</u> by your organisation/department as a result of the IRC?
- [small textbox]

- How many additional people do you expect will be hired by your organisation/department <u>in the future</u> as a result of the IRC?
- [small textbox]
-

How confident are you that the new jobs will be created after the end of the IRC? Please provide a confidence rating as a percentage where 100% is fully confident.[dropdown menu]

- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
- Can't say

-

- Has your organisation protected any intellectual property as a result of the IRC?
  - Yes
  - No
  - Don't know

[If yes – new page] Please provide details about the number of patents and other IP, as well as their identifiers (if available) [Open text]

- Has your organisation/department entered into any agreements to license out any intellectual property created as a result of the collaboration with the IRC?
  - Yes
  - No
  - Don't know / Cant's say

[If yes – new page] What is the current approximate annual value of the license agreement?

- Less than £50,000
- £50,000 to less than £100,000
- £100,000 to less than £500,000
- £500,000 to less than £2 million
- £2 million to less than £10 million
- £10 million to less than £50 million
- £50 million or more

- [If yes – new page] How much licensing revenue do you expect annually from the license agreement in the future?
- GBP per annum: [small textbox]
-

[If yes – new page] How confident are you that this revenue will be created after the end of the IRC? Please provide a confidence rating as a percentage where 100% is fully confident. [dropdown menu]

- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
- Can't say

- If the IRC has resulted in your organisation/department putting a product on the market, what is the current approximate annual sales value of the product?
- N/A

- Less than £50,000
- £50,000 to less than £100,000
- £100,000 to less than £500,000
- £500,000 to less than £2 million
- £2 million to less than £10 million
- £10 million to less than £50 million
- £50 million or more

- How much sales revenue do you expect annually in the future?
- [small textbox] GBP per annum
-

How confident are you that this revenue will be created after the end of the IRC? Please provide a confidence rating as a percentage where 100% is fully confident. [dropdown menu]

- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
- Can't say

Contribution to health and societal impact

- Has the IRC led to any changes in healthcare policy or practice?
  - Yes, change in healthcare policy or practice, with evidence of health-related benefits
  - Yes, change in healthcare policy or practice, but no evidence of health-related benefits yet
  - No change in healthcare policy or practice yet, but this is likely to happen in the future
  - No change in healthcare policy or practice, and not likely to lead to any change in the future
  -

Please elaborate on your response above. If change in policy or practice and health benefits have been achieved or likely to be achieved, please provide details about the changes, the type and number of people benefiting, reference to an online document, etc.

- [Open text]

- In case of likely future health and other societal impact, please provide details of the status of the innovation/intervention being developed and its uptake. For example, the technological readiness level (TRL), clinical trial status, regulatory approval status, adoption within the NHS, etc.
- [Open text]

Design of the IRC

- To what extent were you satisfied with the following aspects of the IRC?

	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied	N/A
The health technology area chosen to focus on	☐	☐	☐	☐	☐	☐
Activities covered by the IRC	☐	☐	☐	☐	☐	☐
Funding amount available to implement activities	☐	☐	☐	☐	☐	☐
Types of co-investigators and partners involved	☐	☐	☐	☐	☐	☐
Administrative and management processes at the IRC level	☐	☐	☐	☐	☐	☐
EPSRC administrative / programme management processes	☐	☐	☐	☐	☐	☐
EPSRC monitoring requirements and processes	☐	☐	☐	☐	☐	☐
Any other aspect, please specify ______________	☐	☐	☐	☐	☐	☐

Please elaborate on your responses above. [open text box]

- What do you consider to be the main strengths and weaknesses of the IRC model?
- [open text box]

- In your view, what results and potential future impacts do the IRCs enable more readily compared to other funding programmes?
- [open text box]

Close

- Do you have any other comments about the IRCs or any suggestions for the EPSRC?
- [Open text]

Thank you very much for your time and insights; this is extremely helpful to inform the study.

Please leave your contact information below if you are happy with the study team to contact you with clarification questions and/or to request further information for the evaluation

- Name
- Organisation
- Email

Please note, your contact details will not be shared outside the study team and will be deleted on completion of the study. Full details on how the study team will handle your data are available at http://www.technopolis-group.com/privacy-policy/.

- **Please click 'Done' once you have completed the survey and you are content with your answers. Note that you will not be able to return to the survey and change your answers once you have clicked 'Done'.**

Appendix D Interview programme

A programme of 30 in-depth semi-structured interviews was conducted with academic principal and co-investigators, partners and collaborators, as well as external stakeholders with knowledge about the wider environment relevant to the IRC programme. The programme of interviews sought to extend our understanding of the outcomes and impacts and their attribution to the programme. In addition, it was aimed at identifying key enabling factors, challenges and lessons learned, as well as the qualitative counterfactual scenario.

D.1 Recruitment

Due to the relatively low survey response rate (31%), interviews were essential to fill gaps in the data required for case studies. For this reason, the selection process for inviting **co-investigators and project partners** for an interview was driven by the shortlisted case studies and by interviewee availability. Both co-investigators and project partners are formally linked with the IRC (namely as co-applicants in the grant application), however they have different roles. Co-investigators are usually senior researchers that support the principal investigators in the management of the IRCs and/or lead research strands and projects within the IRC. Project partners refer to individuals or organisations who will provide essential inputs to specific tasks of the proposed projects but are not usually involved in the management of the IRC. In some cases, co-investigators were not available, but suggested other researchers involved in the project as an alternative. All four IRC **principal investigators** were interviewed. **External stakeholders** were selected from a list of members of the EPSRC's strategic advisory board, based on expertise relevant to the programme and balance across stakeholder groups (industry, academia and others).

Additional interview invitations were sent to individuals from stakeholder groups with low survey responses (for example, companies) and to academics representing spin-outs. To complement data for case studies, the study team also sent additional interview invitations via a snowballing process, following up on suggestions made by interviewees.

A total of 58 interview invitations were sent between 25 August 2023 and 29 October 2023. Most invitations were sent to universities (n = 44), companies (n = 9) and other stakeholders, such as healthcare professionals and research institutes (n = 5). Several invitation reminders were sent throughout September and October 2023. The key challenges to engage stakeholders in interviews can be summarised as per below:

- Low engagement from industry partners. One possible reason for this is that companies may have played an advisory role in projects and as such, they felt they had limited views on the IRC programme and on project implementation.
- Some individuals moved on from the IRCs to different organisations throughout the 5- to 10-year period of the IRC programme, which may have hindered engagement with the interview programme.
- Some individuals were unavailable due to holiday and other commitments, such as funding applications.

D.2 Interview analysis

All interviews were conducted via video call online. They were recorded, transcribed and thematically coded to capture emerging findings and other specific content relevant to the evaluation. Two interview topic guides were used for interviews: 1) one for IRC leads and external stakeholders; and 2) one for co-investigators, project partners and others involved in the IRC[49]. In some cases, interview topic guides were adapted to cover specific questions as relevant to a case study. The interview guides are provided in sections 1.9 and 1.10.

D.2.1 Scope of analysis

Interviews with IRC leads and external stakeholders focused on the overall impact of the IRC programme along different impact dimensions, as well as questions around programme design and processes.

Interviews with co-investigators, project partners and others, focused on topics relevant to case studies, such as project implementation and outputs. This data was analysed and reported separately in case studies, and therefore it is not provided here. Six additional questions around IRC programme design were asked to these stakeholders, such as the value of the IRC programme to researchers. These additional questions were coded and reported here along with the interview data of IRC leads and external stakeholders.

The next sections present the results of the interview programme, starting with profiling information about interviewees, followed by a synthesis of their views on the IRC programme and emerging topics discussed. The synthesis is presented by **type of impact (research, skills, etc), informed by IRC leads and external stakeholders**, and then by **feedback on IRC programme design and processes**, **informed by all interviewees**.

D.3 About interviewees

A total of 34 interviews were conducted between 8 September 2023 and 9 November 2023. Most interviews were conducted with stakeholders from universities (n = 26), followed by companies (n = 5), healthcare professionals (n = 2) and research institute (n = 1). Table 22 below provides an overview of the number of individuals interviewed by their role and by IRC.

Table 22 Number of individuals interviewed by IRC and role of interviewee

Role of interviewee	i-sense	PROTEUS	SPHERE	TeDDy	Experts	Total by interview group
Co-investigators	3	3	1	1		**8**
Postdoc researchers	1	1	2	3		**7**
IRC leads	1	1	1	1		**4**
Project Partners	1	1	1	1		**4**
PhD students	1	2				**3**
Communications Manager	1					**1**
Project Manager		1				**1**
External Stakeholders					6	**6**
Total by IRC	**8**	**9**	**5**	**6**	**6**	**34**

[49] Programme and communications manager, postdocs and PhD students.

A small number of co-investigators and postdoctoral researchers provided data on spin-outs for case studies. Postdoctoral researchers and PhD students were interviewed for a case study on training, skills and career development. There were relatively low responses to interview invitations from project partners. For this reason, interviews provided limited perspective of industry and other type of partners involved in the programme.

D.4 Impact on research

According to IRC leads (n = 3), the IRC programme successfully enabled building critical mass for research on technologies relevant to address key healthcare challenges. They highlighted collaborations and workshops with clinicians, patients and other end-users as a key factor for linking engineering and other disciplines with relevant societal needs. The scale and timeframe of the IRC programme funding enabled researchers to focus on highly technical challenges, such as the optical imaging platform at Proteus and novel drug delivery approaches for hard-to-treat cancers at TeDDy. IRC leads (n = 2) noted the IRC programme was essential to develop and scale the technologies to progress towards clinical trials.

As evidence of IRC programme impact on research, IRC leads (n = 2) noted the production of highly cited publications in leading journals in several fields, such as engineering and computer science. New datasets and methods were developed, with applications within and beyond healthcare. For example, computer models developed at i-sense for modelling infectious diseases using internet data have supported surveillance systems at the UK Health Security Agency. However, IRC leads (n = 3) noted that most technologies still require further research and development to achieve health impact. To enable this, researchers have applied for further funding to continue research, start clinical trials and spin-out companies to exploit the technologies. Two IRC leads mentioned some difficulties in aligning research focus among partners and collaborators (those not listed as co-applicants on the grant but providing inputs, such as sub-contractors). One IRC lead noted they could have put more emphasis on publishing their research findings.

There was no clear consensus from external stakeholders about the IRC programme's impact on research. Some experts (n = 3) noted the IRCs produced a significant number of impactful publications and overall research outcomes have high potential for impact within and beyond healthcare. Examples of potential impact beyond healthcare included semiconductor work at Proteus and data analysis framework developed at SPHERE. A few experts (n = 3) believe the programme advanced technologies beyond expectations, resulting in good value for money and a large number of knowledge dissemination activities. However, other experts (n = 2) suggested limited interdisciplinary research in research outputs due to lack of clinicians and other stakeholders in the authorship of publications. Additionally, they noted relatively slow progress in translation of technologies for practical applications in healthcare.

D.5 Skills impact

In general, all IRC leads were positive about the impact of the IRC programme on the development of researchers' skills. They highlighted the importance of the programme in enabling team building activities, lab tours and skills sharing events to promote knowledge dissemination. Researchers were given the opportunity to undertake training courses in several areas, including computer coding, good manufacturing practices and software/hardware system integration. Empowering postdoctoral researchers to take leadership roles within projects was also mentioned as an enabling factor for early-career researchers to develop project management skills and present findings to a wide audience. To attract highly skilled researchers and build on their expertise, IRC leads (n = 2) mentioned the importance of leadership skills to communicate IRC objectives to partners and foster relationships across disciplines.

Most external stakeholders (experts) interviewed (n = 4) observed the IRC programme successfully attracted highly skilled researchers. It was noted by one expert that interdisciplinary research programmes are attractive to early-career searchers as they often involve projects with unique datasets and flexibility to be creative. In addition, they noted that IRCs help to build institutional knowledge at universities, strengthening the argument for further investments. For example, the creation of a Centre for Doctoral Training (CDT) in Digital Health and Care at the University of Bristol was mentioned by one expert as an impact arising from SPHERE. However, one expert suggested the IRCs could have placed greater emphasis on establishing links with existing PhD programmes and CDTs. In addition, the expert recommended that IRCs would have benefitted from more participation of clinicians in the projects.

D.6 Economic impact

Interviews with IRC leads helped to further our understanding of the differences between IRCs in relation to translational activities. For example, SPHERE did not set out to commercialise the technologies developed in the project. However, research conducted at the IRC enabled funding to be secured for a new large-scale follow-on project to support data generation for clinical trials[50]. Other IRCs reported more efforts towards commercialising technologies. They reported the filing of approximately 11 patents over the course of the programme and the creation of six spin-out companies to exploit the technologies:

- IRC Proteus: three spin-outs – BioCaptiva, Singular Photonics and Prothea Technologies.
- IRC i-sense: two spin-outs – Zyme Dx and Signatur Biosciences.
- IRC TeDDy: one spin-out – Vector Bioscience.

These companies are starting to produce economic impact by attracting investments and hiring staff. However, IRC leads cautioned that it is likely too early to assess economic impact as translational activities are still ongoing. One IRC lead observed some challenges around commercialising inventions through universities, due to difficulties in protecting intellectual property at the required speed. It was also noted that geographical location is a key factor for enabling commercialisation activities, as it impacts on the availability of staff and funding to grow spin-out companies.

Experts interviewed discussed similar themes, noting it may be too early to assess economic impact and that commercialisation activities at universities can be challenging. One expert highlighted indirect economic impacts from research conducted at IRCs, exemplified by i-sense's work on identifying outbreaks of influenza and COVID-19. In terms of collaborations, an expert noted the IRCs attracted interest from international companies, while another expert remarked on the lack of involvement from small and medium-sized UK enterprises.

[50] https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/X036146/1

D.7 Societal impact

Similar to the above findings on economic impact, IRC leads cautioned that the technologies developed at the IRCs are still undergoing testing and further development to enable uptake by healthcare organisations. With the exception of i-sense's work with the UK Health Security Agency, which produced large societal impact and influenced national policy, other technologies would require clinical testing for adoption in healthcare systems. Some of these technologies include novel approaches to imaging tissues developed at Proteus, which are currently being tested in clinical trials. For this reason, the IRC programme's societal impact to date has been limited. While ongoing trials may offer potential benefits for trial participants, widespread adoption and improvement to patient outcomes will likely take many more years. IRC leads (n = 2) also noted there is a perception by stakeholders that the UK's National Health Service can be slow to recruit individuals for trials, ultimately making the UK less attractive for companies to fund translation activities.

External experts who were interviewed confirmed the opinion that societal impact within the timeframe of the programme was not expected. While there was agreement among experts that IRCs were aligned with EPSRC's healthcare technologies strategy, there was no agreement about the potential for future impact. Some experts (n = 2) highlighted the research outputs have high potential for future societal impact. Others (n = 2) observed lack of evidence that technologies will be adopted by healthcare systems in the future or continue to be relevant in the context of evolving healthcare demands.

D.8 Programme design and processes

In this section, we report the feedback on IRC programme design and processes, as discussed in all interviews. Importantly, for some interviews focused on case studies, not all questions on programme design were asked due to time constraints. This resulted in limited data that could be collected from some co-investigators, postdoctoral researchers and PhD students. In addition, questions around the IRC programme's processes, such as governance and reporting to the EPSRC, were only asked to IRC leads and experts involved in advisory boards.

D.8.1 Main value of IRC programme

Several interviewees (n = 10) highlighted the IRC programme helped to break silos between disciplines. Co-investigators, postdoctoral researchers (postdocs), programme managers and PhD students (n = 6) involved with the IRCs noted the programme enabled discussions with clinicians, which improved project outcomes and facilitated new collaborations. For example, feedback from clinicians on a drug delivery system developed by the IRC TeDDy enabled researchers to test the system in additional types of cancers.

By fostering collaborations with different disciplines, some researchers (n = 7) noted the IRC helped them to understand challenges related to interdisciplinary research and develop a common language. Co-investigators and postdocs (n = 5) also noted the IRC programme provided a platform to explore new ideas and adapt the project to emerging research findings. To facilitate this, regular meetings and workshops were conducted to ensure focus on technical challenges and sharing knowledge. Other benefits of the IRC programme mentioned by interviewees (n = 5) include career progression, job security and mentorship.

When asked **what would have happened without IRC programme funding**, interviewees (n = 7) noted technical progress in their fields would have been limited in scale or executed more slowly with less interdisciplinarity. According to a few co-investigators (n = 2), the IRC programme helped researchers to understand how research in their fields may be used in different applications. One IRC lead noted such applications often require overcoming highly technical challenges, which would not have been possible without the scale and timeframe of the IRC funding. Another IRC lead mentioned the funding enabled a shift of focus from frequent applications for research funding to more attention to recruiting and training staff. Limited data was collected on interviewees' opinion about the **sustainability of the IRCs** beyond the programme funding. A few interviewees (n = 3) noted partnerships and research projects might not continue without funding.

D.8.2 The pros and cons of large-scale funding programmes

When asked about the pros and cons of large-scale funding programmes compared to funding a larger number of small project grants, both IRC researchers and external experts (n = 5) highlighted the importance of having a diversity of types of funding.

Interviewees (n = 8) noted the most important benefit of large-scale funding is the creation of critical mass. For example, co-investigators (n = 6) noted large-scale programmes facilitate interactions across disciplines, which supports innovation and help researchers to tackle difficult challenges (for example, developing highly sensitive sensors for infectious diseases). External experts (n = 2) also highlighted building critical mass in new areas supports institutional adaptation to new challenges within universities and creates an ecosystem of partners to maximise the impact of interdisciplinary research. Other benefits of large-scale funding programmes mentioned include better governance systems through advisory boards, reduced time spent on smaller funding applications and job security for early career researchers.

Interviews provided limited insight into the disadvantages of large-scale funding programmes. A few external experts (n = 3) highlighted that large-scale projects often have less defined goals from the outset, which can slow down research progress. They suggest more focus on tracking milestones and linking the programme with other research infrastructure, such as Centres for Doctoral Training, may help to maximise the outcomes and potential for impact. One co-investigator also noted large-scale programmes are organised in a top-down approach to build critical mass, which can be effective. However, ground-breaking research also requires a bottom-up approach driven by researchers' own interests and expertise.

D.8.3 Challenges and COVID-19

There was no single key challenge experienced by IRC researchers, and limited data was provided on this topic during interviews. Some co-investigators and project partners (n = 3) noted lack of funding as the main challenge for translating the basic research conducted at the IRCs. Specifically, they mentioned difficulties around manufacturing activities, obtaining laboratory certifications and navigating through regulatory affairs for clinical trials. Other co-investigators (n= 2) mentioned there were challenges to recruit staff with the relevant skills required for the project.

According to some interviewees (n = 4), the COVID-19 pandemic had some (negative) impact on technological progress, causing delays in deploying prototypes and in protecting intellectual property. However, others noted (n = 2) this impact may have been limited as some projects had already collected data and were in analysis and reporting stage. Programme managers (n = 2) mentioned public engagement and other events were also affected by the pandemic, with online solutions pursued in some cases.

D.8.4 Lessons learned

A few co-investigators and IRC leads (n = 4) highlighted the governance arrangements of the IRC programme as an enabling factor to the success of the IRCs. In particular, they noted the advisory boards provided essential inputs to the research teams, underpinned by the board's varied expertise across academia, industry, and healthcare. Postdocs and PhD students shared similar views about an adequate level of support available, but a few (n = 3) noted learning opportunities and training activities would have benefitted from more structure. Below are other lessons and suggestions reported by interviewees:

- Suggestions from IRC leads and co-investigators for future programmes:
    - Increase funding allocation for mobility fellowships due to its positive effect on facilitating career progression and new collaborations (n = 1).
    - Increase interactions across IRCs to share knowledge (n = 1).
    - Consider reviewing timeframe of funding as five to seven years appears to be enough to maximise outcomes. The interviewee observed some diminishing returns in research activities at end of the second grant (n = 1).

- Suggestions from project partners and external experts for future programmes:
    - Support researchers to link the EPSRC funding with other grants aimed at translating technologies beyond technology readiness level 3 (n = 1).
    - Ensure review panels for interdisciplinary research funding avoid discrimination against interdisciplinary projects. Such projects often need to limit the inclusion of technical details in their applications compared to non-interdisciplinary ones (n = 1)
    - Balance freedom of IRC management teams to manage the project with more robust monitoring mechanisms, such as annual reports to track milestone against original objectives. Example of National Institute for Health and Care Research (NIHR) grant was provided, in which researchers must justify deviations from original objectives, or funding can be halted (n = 1).

D.8.5 IRC programme processes

There was no consensus across interviewees regarding the EPSRC's contribution to the management of the IRC. While some co-investigators, IRC leads and project partners (n = 3) observed the EPSRC staff were highly supportive, others (n = 2) reported the lack of involvement and irregular engagement from the EPSRC teams.

Partnership resource funding was highlighted by IRC leads (n = 4) as an important element of the IRC programme, but the administrative burden around drafting and signing contracts was a significant factor slowing down new projects (n = 1). One IRC lead also suggested that capturing programme metrics was very useful for successfully managing the IRC, albeit challenging and required additional resources (for example, programme manager).

D.9 Interview guide for IRC leads and external stakeholders

The interview guide is semi-structured and will be tailored further based on interviewees' backgrounds and how they are linked to the IRCs.

Introduction

The Engineering and Physical Sciences Research Council (EPSRC) has commissioned a study to evaluate the value and impact of the Healthcare Technologies Interdisciplinary Research Collaborations (IRC) to inform decisions on potential new investments and strategy development within the theme of healthcare technologies as well as in the broader remit of EPSRC and UKRI.

This interview is part of an interview programme that will help the study team gather evidence on the types of outcomes and impacts emerging from IRCs, and how the different IRC activities – such as research projects, collaborations and training opportunities - are contributing to these. The aim of the interview programme is to take stock of the programme's overall achievements, rather than to evaluate individual projects or a specific IRC.

This interview explores the 'big picture' related to IRC achievements. It will allow the study team to gather views and insights from **Principal Investigators and external stakeholders** (e.g. those that served on the IRC or EPSRC Advisory Boards) on the overall legacy of the IRCs and the EPSRC-funded programme.

Before we continue, do you have any questions on the study or this interview?

Consent/confidentiality

To confirm, may I request your permission for the following:

We will report this information, such as data, opinions and views expressed, and any analysis we carry out as part of the evaluation study in aggregate to the EPSRC and it will be published in the study report. Where your contribution may be identifiable, we will ask for your permission to include this information in the report. Do you agree to this?

Can I have your permission to audio record the interview? The recording will be only used to ensure that we transcribe details correctly. It will not be provided to anyone outside of Technopolis, and will be destroyed as soon as we have completed analysis of the whole set of interviews.

Thank you, I have now started the recording.

Background

1. Please could you describe your current position(s) and your role at or link to the IRC <<name>>?
    - For external stakeholder: Could you briefly describe your expertise and level of knowledge of the IRC programme?

Impact on research

2. In your view, in what ways has the programme created new knowledge that has progressed

- (for IRC SPHERE, Proteus and i-sense) approaches to integrating sensing technologies into systems, data integration and sensing technologies for end users?
- (for IRC TeddY) the design of novel formulations, drug vehicles and therapeutic medicines for targeted therapies
  - What were the key challenges the IRC aimed to address?
  - What progress was made in these areas?
  - What is your view on how the developed technologies can be scaled up?

3. What role has the IRC <<name>> played in creating or catalysing growth of new area(s) of R&D?
   - Please describe the new growth area(s) supported by the IRC and their role within healthcare technologies.
   - Are there areas <u>outside healthcare technologies</u> that have been affected by the IRC?
   - What was the IRC's contribution to the field(s)? E.g., increased quality of research, created critical mass of research, new or strengthened collaborations and networks.

For IRC leads:

4. What has been the value of collaboration within the IRC, in terms of achieving outputs, outcomes and impact?
   - Please comment on how collaborations have helped in:
     - Linking researchers from different disciplines and different sectors
     - Developing impactful methods
     - Improving research quality
     - Achieving or improving the potential for translational impact
     - Establishing new and/or enhancing existing infrastructure and facilities

For IRC leads:

5. In your view, in what ways has the IRC <<name>> been successful in linking research with users of its outputs and outcomes (e.g. NHS, government, patients)?
   - What were the enablers and barriers to engagement?
   - How important was this linkage, or failure to link? What were the consequences?
   - What are the main lessons learnt from the experience?

Skills impact

For IRC leads:

6. Please describe the type of training opportunities and skills development activities that occurred during the lifespan of the IRC <<name>>.
   - Which skills gaps/needs did these address and what have they achieved?

- What was the main value for individuals taking part in the following types of opportunities: secondments, studentships, exchanges, others
- What were the main enablers and barriers to delivering these activities?
- Were there any lessons for the future? In hindsight, what would you have done differently?

7. In your view, was the ESPRC investment successful in attracting highly skilled individuals with demonstrable expertise, knowledge and recognition?
    - Deep understanding of research area
    - High-quality and impactful research
    - Ability to collaborate efficiently
    - Leadership skills

Economic impact

8. In your view, how has the IRC <<name>> supported (or will support) the innovative potential, capabilities, and economic growth of the UK private sector?
    - Could you summarise the key support pathways for me?
        - E.g.:
        - - provided/increased skilled workforce in healthcare technologies
        - - de-risked private investment into further innovation
        - - accelerated translation to new product/service development and manufacture
        - - provided essential (reproducible) data to industry
        - - contributed to market knowledge
        - - diversified adoption routes
        - - contributed brand and leadership
        - - any other
    - Did any of the effects fall outside of the healthcare technologies areas?

9. Has the IRC <<name>> contributed to the growth of new businesses and/or improved business success?
    - What are the specific areas that attracted **additional investment**, and why?
    - Were there any outputs that have produced or may produce **cost savings** to businesses?
    - Have any of the IRC's outcomes contributed to **increased turnover** for companies? Or have the clear potential to do so in the future?

For IRC leads:

10. What specific research outputs and outcomes from the IRC <<name>> fed into new business opportunities?
    - Has the IRC created knowledge that is now used by other businesses for innovation?
    - Please describe how any new patent or other intellectual property contributed to commercial opportunities?
    - Please describe any spin-outs created as a result of the IRC

11. Did the IRC <<name>> and impact stemming from its research lead to any effects on regional growth, local economies and jobs?

Societal impact

12. In your view, in what ways have the IRCs contributed to EPSRCs priorities, namely:
    - the Healthcare Technologies theme strategy
    - the Healthy Nation Ambition?

13. What innovations with high potential for societal impact can be linked directly to the research conducted at the IRC <<name>>?
    - E.g.:
        - - accelerated/improved prediction, detection and monitoring of disease for the UK and LMIC populations
        - - enhanced UK and global epidemic preparedness
        - - new (targeted) therapy, lowered cost of an intervention for the healthcare system, scaled up an effective intervention, etc.
        - - environmental benefits
        - - any other
    - How will these innovations bring about positive societal impact?

For IRC leads:

14. Have outcomes from the IRC <<name>> improved patient outcomes or is there an indication that this may happen in the future?
    - Did the IRC develop outputs such as new pathways, standards, and best practices that can facilitate future NHS pilots / implementation?
    - Have IRC staff engaged with NHS?

      If yes, how and at what stage (e.g. research planning, result dissemination)? What effect did engagement have on IRC activities?

      If no, why not?
    - In hindsight, would you take a different approach to engagement/ dissemination?

15. Have the outcomes from the IRC influenced approaches to public health at national or local level, or is there an indication that this may happen in the future?
    - Have IRC staff engaged with public health bodies?

      If yes, how and at what stage (e.g. research planning, result dissemination)? What effect did engagement have on IRC activities?

      If no, why not?
    - In hindsight, would you take a different approach to engagement/ dissemination?

16. Does the IRC have plans in place to continue disseminating results after ESPRC funding has ended?
    - For IRC leads: Did the IRC encounter barriers when attempting to disseminate its findings to the wider stakeholder community (e.g., NHS, public health bodies, industry)

      If yes, what were these barriers and challenges? In hindsight, would you change your approach to dissemination?

Process evaluation

For IRC leads:

17. Please could you outline how the IRC <<name>> was set up to manage the following activities, and if there were any lessons learned:
    - Technical work packages;
    - Collaboration with partner universities, industry and other stakeholders;
    - Funding of exploratory risk projects within the IRC;
    - Training and professional development activities;
    - Managing intellectual property rights arising;
    - Governance arrangements;
    - Reporting to EPSRC

18. How did the EPSRC programme management help the IRC to achieve its objectives?
    - In hindsight, what could be done differently in the way the EPSRC manages the programme that would make the interactions more efficient and enhance the IRCs' impact?

Reflection and Conclusions

19. How did COVID-19 pandemic influence the (potential for) impact for the project / research activity / IRC overall?
    - Please describe both any negative and positive effects of the pandemic.

For IRC leads:

20. Has the IRC <<name>> been able to build linkages with other programmes and translation mechanisms to drive outcomes and impact?
    - E.g.:
        - - other research programmes within and outside the UK
        - - key partnerships with industry, the NHS and other stakeholders in the health technology ecosystem
    - If yes, what effect did this have on the IRC's research and activities? How did these linkages support progress towards outcomes and impact?
    - What effects go (or are expected to go) beyond the IRC?

For IRC leads:

21. In conclusion, what has been the main value of the IRC partnership to you and your department/organisation?

For IRC leads:

22. How would you have progressed research and assets in healthcare technologies if the IRC had not been funded by EPSRC?
    - E.g., would you have:
        - - conducted the same research from other funding sources. If yes, what were the alternatives?
        - - altered the research objectives and design to fit another funders remit. If yes, what were the alternatives?
        - - not been able to conduct the research

23. In your view, has the IRC achieved (or is on the path to achieve) long-term financial sustainability as a result of the EPSRC funding?
    - If yes, how was this / will this be achieved? What are current follow-on funding sources? Where will the future funding come from?
    - For IRC leads: Are there plans to build on the achievements of the IRC? If so, what new objectives will the future initiative target?

24. About programme design: Overall, in your view, what are the pros and cons of selecting a few long-term, large-scale funding programmes (such as the IRC), compared to funding a larger number of direct project grants?
    - What were the benefits and challenges of creating Next Step Plus projects (smaller projects funded by the EPSRC to build on findings from the IRC) and other exploratory risk projects funded directly by the IRC.
    - Are you aware of alternative programme designs that UKRI/EPSRC could also adopt or learn from, with relevance to the IRC programme?

25. Do you have any other thoughts, views or lessons learnt regarding the IRC? Or do you have further suggestions for the EPSRC relating to the IRC programme?

26. Finally, we are developing case studies to showcase different impacts at each IRC and across all investments. Do you have suggestions for projects, findings or outcomes that we should consider?
    - Please provide information on key people and relevant data

Thank you very much for your time and insights; this is extremely helpful to inform the study.

If there are any clarification questions or additional aspects to check with you, may I contact you again? I will make sure to keep any questions as brief as possible

D.10 Interview guide for co-investigators and project partners

Note: Case studies will be identified and explored first through a rapid desk review, and in agreement with EPSRC, further developed via document reviews to prepare for the stakeholder interviews. This will focus interview questions on remaining information gaps and optimise use of the available interview time.

Interviewees will include IRC co-investigators, partners and collaborators, other research team members and students.

The interview guide is semi-structured and will be tailored further to individual cases.

Introduction

The Engineering and Physical Sciences Research Council (EPSRC) has commissioned a study to evaluate the value and impact of the Healthcare Technologies Interdisciplinary Research Collaborations (IRC) to inform decisions on potential new investments and strategy development within the theme of healthcare technologies as well as in the broader remit of EPSRC and UKRI.

This interview is part of an interview programme that will help the evaluation team gather evidence on outcomes and impacts emerging from IRCs, and how the different types of IRC activities – such as research projects, collaborations and training opportunities - are contributing to these. The aim of the interview programme is to take stock of the programme's overall achievements, rather than to evaluate individual projects or a specific IRC.

This interview aims to identify specific examples of outcomes and impacts, which we may then develop into case studies, or 'impact stories'. We would hence like to ask you about your specific project or involvement with the IRC programme, including information such as:

- how the project or opportunity arose, its background and its aims
- the composition of the participating team
- methodologies that were developed and/or used
- the experience of implementing the project, successes as well as challenges encountered, and learning
- research findings, outputs and the value and benefit the project created for you, your organisation and other external stakeholders
- whether the project itself or other post-project activities are still ongoing, the next steps and the potential for future impact

Before we continue, do you have any questions on the study or this interview?

Consent/confidentiality

To confirm, may I request your permission for the following:

We will report this information, such as data, opinions and views expressed, and any analysis we carry out as part of the evaluation study in aggregate to the EPSRC and it will be published in the study report. Where your contribution may be identifiable, we will ask for your permission to include this information in the report. Do you agree to this?

Can I have your permission to audio record the interview? The recording will be only used to ensure that we transcribe details correctly. It will not be provided to anyone outside of Technopolis, and will be destroyed as soon as we have completed analysis of the whole set of interviews.

Thank you, I have now started the recording.

Context and Background

Interviewer: Start by briefly summarising your understanding of the research project or activity based on document review to confirm your understanding and set the scene.

1. Please can you describe your role in the IRC and in this specific activity?
    - Were you also involved in any other notable IRC activity (e.g. Next Step Plus project or other exploratory projects funded by the IRC)

2. How does (or did) this specific research / activity relate to your work within or outside of the IRC?

3. What was the aim of this activity, what was the specific problem it aimed to solve? What did it set out to achieve?

    - E.g., enabling further research through developing tools and methodologies, adapting and scaling up technologies, acquiring new skills and capabilities via training, changing guidelines and policies, solving a specific health problem.
    - What was the situation regarding this problem internationally; who else was working on related solutions?
    - Who were the expected beneficiaries/targets of this project?

4. Who conceived the project idea and designed the project? How did they do this?

Team and Implementation

5. How was the project team created and organised?
    - Who was involved in the project and what roles did they play?

- Which skills, know-how, infrastructure or other resources (e.g., funding, in-kind contributions, networks and collaborations) did each partner bring to the project?
- Were there any changes in the team composition during the project? If yes, what were they and why?
- Did you have any problems attracting individuals with the necessary skills to the team? If yes, what skills were difficult to recruit? Were there any skill gaps in the final team?

6. Thinking back on when the project / activity was implemented, what was your overall experience?
    - Did you encounter any challenges, expected or unexpected? If yes, please describe the challenge(s) and how you were able to overcome this/these.
        - E.g. adjusted project plan, extended timeline, changes in the team, additional resources
    - Were there any notable successes, e.g. steps that went 'better than expected'?
    - In hindsight, is there anything you would change about how the project / activity was designed and conducted?

Outputs, Outcomes and Impacts

7. What **outputs** (immediate results) has the research project / IRC activity led to? What new knowledge / tool was generated?
    - Could you summarise the key outputs of the project/activity to date for me?
        - E.g.:
        - - trained / up-skilled researchers, developed training material (technical, interdisciplinary, translational skills)
        - - established new collaborations, secondments across sectors
        - - led to peer-reviewed publications, international conference presentations, media coverage
        - - created a proof of concept, progressed the technology readiness level of a research asset
        - - developed new datasets, tools and/or methodologies
        - - improved research infrastructure,
        - - contribution to new standards, guidelines and policies / policy briefs
        - - contribution to patents, joint-ventures, spin outs, etc.
        - Please provide specific examples of and references for these outputs.
    - Did the project / activity achieve its intended immediate goals?
    - Were there any unexpected findings / findings not anticipated at the outset?
    - Do you know if these outputs continue to be used by your team or others?

8. What further **outcomes and impact** has the research project / IRC activity led to already? What is it expected to lead to in the future?
    - Could you summarise the key outcomes and impact of the project/activity to date for me?
        - E.g.:
        - - increased the quality of research conducted
        - - opened up a new research field and created research opportunities for our team and others
        - - leveraged additional further research funding
        - - created an interdisciplinary research network
        - - accelerated/improved prediction, detection and monitoring of disease for the UK and LMIC populations
        - - enhanced UK's and global epidemic preparedness
        - - enabled a new (targeted) therapy, lowered the cost of an intervention for the healthcare system, scaled up an intervention, etc.
        - - new or enhanced connections within the wider research and health care ecosystem, e.g. NHS, charities, industry, policy makers
        - - wider impacts on the research community, healthcare sector and society, decision makers and patients
        - - environmental benefits
        - - any other

        - Please provide documents and links with references to these outcomes after the interview, where available.

    - Given progress to date, are there outcomes and impact of the project / activity you <u>anticipate for the future</u>? Please describe these, and why you think these are likely to arise.
    - *If research project*: How did this project / activity link the implementation and outputs with wider stakeholders and the ultimate users?
        - Did you encounter challenges to engagement, did you identify enablers of engagement?

9. In your view, how has this project supported (or will support) the innovative potential, capabilities, and economic growth of the UK private sector?
    - Could you summarise the key support pathways for me?
        - E.g.:
        - - provided/increased skilled workforce in healthcare technologies
        - - de-risked private investment into further innovation
        - - accelerated translation to new product/service development and manufacture
        - - provided essential (reproducible) data to industry
        - - contributed to market knowledge

- - diversified adoption routes
- - contributed to brand and UK leadership in the IRC's technological area of focus
- - any other

- Did any of the effects fall outside of the healthcare technologies areas?
- Could you provide examples or explain how in your view your project / activity / IRC contributed to catalysing growth through cost savings or increased turnover for businesses and local economies?

10. What was the benefit and value of this project a) to you personally; b) to your organisation?
    - Could you summarise the key benefit and value for me?
        - E.g.:
        - - increased skills / knowledge in translational healthcare technologies
        - - increased reputation, career development
        - - enhanced partnering opportunities
        - - further research funding
        - - enhanced leadership / brand
        - - other
        -
    - Did you participate in any exchange programme, or visit other research groups organised or enabled by the IRC? If yes, did this have an effect on your career development?

11. Are there any next steps planned for this project / activity? If yes, what are the aims of the further activity, and what outputs, outcomes and impacts might these lead to?

Programme design

12. What has been the main value of the IRC partnership to you and your research/research group?
    - How did (or does) being part of the IRC enable you and your project / activity to succeed?
    - What is working/has worked particularly well in your IRC and why?
    - What is/has been the main challenge you encountered in your IRC?
    - [*May have been covered above*:] Were you able to build linkages between your research project and other programmes/stakeholders within and outside the UK (e.g. NHS, charities, industry, policy makers) as a result of being part of the IRC?
    - In hindsight, what could be done differently in the way the IRC is organised and run that would make it more efficient and enhance its impact?

13. In your view, how did (or does) the EPSRC programme management help the IRC to achieve its objectives?
    - In hindsight, what could be done differently in the way the EPSRC manages the programme that would make the interactions more efficient and enhance the IRCs' impact?

14. How did COVID-19 pandemic influence the (potential for) impact for the project / research activity / IRC overall?
    - Please describe both negative and positive effects of the pandemic (if any).

15. [*If research project*:] What would you have done with the specific research idea if the IRC had not been funded? Did you have an alternative?
    - E.g., would you have:
        - - conducted the same research from other funding sources. If yes, what were the alternatives?
        - - altered the research objectives and design to fit another funders remit. If yes, what were the alternatives?
        - - not been able to conduct the research

16. In your view, has the IRC achieved (or is on the path to achieve) long-term financial sustainability as a result of the EPSRC funding?
    - If yes, how was this / will this be achieved? What are current follow-on funding sources? Where will the future funding come from?

17. Programme design: Overall, in your view, what are the pros and cons of selecting a few long-term, large-scale funding programmes (such as the IRC), compared to funding a larger number of direct project grants?
    - What were the benefits and challenges of creating Next Step Plus projects (smaller projects funded by the EPSRC to build on findings from the IRC) and other exploratory risk projects funded directly by the IRC.
    - Are you aware of alternative programme designs that UKRI/EPSRC could also adopt or learn from, with relevance to the IRC programme?

Conclusions

18. Do you have any other thoughts, views or lessons learnt regarding the IRC? Or do you have further suggestions for the EPSRC relating to the IRC programme?

Thank you very much for your time and insights; this is extremely helpful to inform the study.

If there are any clarification questions or additional aspects to check with you, may I contact you again? I will make sure to keep any questions as brief as possible.

Appendix E Economic analysis

E.1 Economic benefit from IRC spinouts

The EPSRC Healthcare Technologies Interdisciplinary Research Collaborations (IRC) have been successful in generating economic output through the creation of six spin-outs. Table 23 provides descriptive statistics for these spin-outs in terms of age, region, and industry.

Table 23 Descriptive statistics on spinouts

IRC	Company name	Description	Age (Years)	Region	Industry
Proteus	BioCaptiva	University of Edinburgh spin-out that has developed a novel medical device for the application of liquid biopsy to diagnose and monitor difficult-to-detect cancers.	5	Scotland	Biotechnology and Life Sciences
Proteus	Prothea Technologies	The mission of the company is to provide a combined endoscopic imaging and biopsy tool for the distal lung to diagnose lung cancer, reducing time-to-treat from weeks to minutes; relieving hospital pressures, and improving patient outcomes.	3	Scotland	Biotechnology and Life Sciences
Proteus	Singular Photonics	An engineering spin-out aimed at developing high-performance camera modules based on sensitive light detectors, with applications in spectroscopy, microscopy, and medical imaging.	0*	Scotland	Industrial, Electric & Electronic Machinery
i-sense	Signatur Biosciences	A spin-out providing smart PCR kits that can detect complex diseases.	2	London	Diagnostic equipment
i-sense	Zyme Dx	A spin-out from Imperial College offering rapid diagnostic tests aimed at achieving earlier diagnoses.	2	London	Biotechnology and Life Sciences
TeDDy	Vector Bioscience Cambridge	University of Cambridge spin-out that has developed a tailored platform technology based on specific porous	3	East of England	Biotechnology research

		materials (known as meta-organic frameworks) that improve cancer drugs' efficacy and safety.			

Source: FAME and manual online searches. Note: *Singular Photonics has been incorporated on 2 February 2024.

E.1.1 Further funding raised by spin-outs

All six spin-outs have secured further funding according to data linking with secondary data sources (such as Crunchbase), interview consultations with programme participants, and manual online searches of investment deals. Collectively, the **spin-outs have secured 12 deals worth more than £18 million in total**. The figures present a conservative estimate, primarily attributed to challenges in acquiring data regarding deal values and the confidential nature of such information. Table 24 provides further details on the type and value of each investment deal raised by spin-outs.

Table 24 Further funding raised by IRC spin-outs

IRC: Company name	Type of deals	Year	Value of deals
Proteus: **BioCaptiva**	Seed funding from Edinburgh-based business angel investment syndicate, Archangels, and Scottish Enterprise, to help develop the technology[51].	2021	£1m
	Joined funding from Archangels, Scottish Enterprise, Cancer Research Horizons, and Old College Capital which is the University of Edinburgh's in-house venture investment fund. The investment will be used to fund the company through the first in human trials, and to prepare for regulatory trials.[52]	2022	£2.1m
Proteus: **Prothea Technologies**	Unspecified investors.[53]	2024	£12m
Proteus: **Singular Photonics**	Funding from Scottish Enterprise to conduct a feasibility study on the commercialisation of the technologies	2020	£60k
	Funding from Scottish Enterprise for the development of a business case for a spinout company, Singular Photonics.	2022	£75k

[51] BioCaptiva secures £1m seed investment from Archangels and Scottish Enterprise, April 2021 https://www.privateequitywire.co.uk/biocapitiva-secures-gbp1m-seed-investment-archangels-and-scottish-enterprise/

[52] BioCaptiva announces oversubscribed £2.1m additional seed financing to complete first in human trial with the BioCaptis, https://www.cancerresearchhorizons.com/news/biocaptiva-announces-oversubscribed-ps21-million-additional-seed-financing-complete-first

[53] EPSRC Impact Acceleration Account (IAA) Project Update – June 2022, https://researchportal.bath.ac.uk/files/292315113/IAA439_Stone_End_of_Project_Report_Sept_22.docx

	Funding from Scottish Enterprise for creating the company Singular Photonics. The funding was used for prototypes, software, and firmware.	2022	£199k
i-sense: **Signatur Biosciences**	Venture round raised by Riceberg Ventures and Y Combinator[54].	2022	Not available
i-sense: **Zyme Dx**	Funding from the National Institute for Health and Care Research (NIHR) through its Invention for Innovation (i4i) programme to gather additional data for its business case and tailor the device for use in an NHS setting.[55]		£150k
	Grants from non-profit organisations to support further development of the technology for use across a range of diseases.		Not available
TeDDy: **Vector Bioscience**	Grant funding from IUK Fast Start programme.	2022	£50k
	Grant funding from IUK Biomedical Catalyst.	2022	£450k
	Non-dilutive investment from the European Innovation Council's 'Transition Challenge' programme to develop drug delivery platforms for RNA cancer therapies.[56]	2023	£2.2m

Source: Crunchbase, online searches, and interviews. Publicly available data on investment deals is referenced where possible. All other information on investment deals comes from interview consultations.

E.1.2 Gross value added (GVA) derived from IRCs spin-outs

The evaluation aims to estimate the economic contribution of the IRC funding, in particular in terms of employment creation and GVA.

Collectively, **IRC spin-outs have generated 28 new jobs in total, or five jobs per spin-out on average.** Based on interview consultations with spin-outs, we note that all these ventures are in the pre-commercial stages and have yet to report any revenue. As such, we estimated the economic benefit from these spin-outs by multiplying each company's employment figures by the industry specific GVA per unit of employment ratios.[57] By using this approach, **we estimated that the 2022 GVA of the spin-outs is around £1.3 million. If employment growth is in line with expectations over the next two years, the GVA derived from IRC spin-outs will grow to £3.4 million.**

[54] Source: Crunchbase

[55] https://fundingawards.nihr.ac.uk/award/NIHR205784

[56] Cambridge spin-out receives £2.2 million to help improve cancer treatments, March 2023, https://www.cam.ac.uk/news/cambridge-spin-out-receives-ps2-2-million-to-help-improve-cancer-treatments

[57] Regional gross value added (balanced) by industry , April 2023. Available at: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry

Table 25 GVA estimates of IRC spin-outs

IRC	Company name	Employment in 2022 *	Projected employment in 2025 **	GVA per workforce job	Estimated GVA in 2022	Projected GVA in 2025
Proteus	BioCaptiva	7	14	£42,316	£296,212	£592,424
Proteus	Prothea Technologies	2	12	£42,316	£84,632	£507,792
Proteus	Singular Photonics	3	12	£42,316	£126,948	£507,792
i-sense	Signatur Biosciences	7	14	£64,635	£452,445	£904,890
i-sense	Zyme Dx	4	8	£64,635	£258,540	£517,080
TeDDy	Vector Bioscience	5	10	£33,992	£101,976	£339,920
Total		**28**	**70**		**£1.3m**	**£3.4m**

Source: FAME and manual online searches. Note: Regional GVA per workforce job in the professional, scientific and technical activities sector; chained volume measures in 2019 money value; and GBP in 2021. * Employment figures that company representatives disclosed or available publicly. ** Projections are from expectations disclosed by interviewees, or estimates based on average anticipated growth.

Estimating the GVA from spin-outs faces the challenge of considering inherent time lag for these ventures to commercialise products and contribute to economic growth. Spin-outs undergo a prolonged development phase from research to market, and their employment growth may materialise over the long run. Attributing the economic impact associated with IRC funding is also challenging as researchers receive funding from multiple sources for multiple synergistic research projects that may contribute to developing the technology over many years. It is therefore often not possible to isolate and quantify the exclusive contribution of a particular funding program. Nevertheless, given the fundamental role that the EPSRC funding played in the development of the relevant technologies and thus the early establishment of these spin-outs, we have assumed high additionality of the IRC funding. Without such public support, it is unlikely that the ensuing economic activity associated with these spin-outs would have happened to the same scale, within the same timeline, or with the same scope of applications.

E.2 Overview of key industry partners

One of the key benefits of the EPSRC's IRC investment includes the establishment of new partnerships with a range of industry partners to complement the expertise of academics and improve the translational impact of research. **Ten key industry partners collaborated with IRCs,**

including multinational and national businesses. Table 26 provides descriptive characteristics of these industry partners in terms of age, location, and industry sector.

Examining industry partners provides insight into the programme's ability to attract established corporations such as Toshiba, Microsoft and AstraZeneca, leveraging the wealth of experience and resources these companies can provide. In terms of geographical location, industry partners are spread across different regions, with the majority concentrated in the South East (4) and East of England (4).

Table 26 Descriptive characteristics on key industry partners

IRC	Company name	Age (years)	Region	Industry
i-sense	Cambridge Life Sciences	20	East of England	Chemicals, Petroleum, Rubber & Plastic
i-sense	Google UK / Diagonal Works	4	South East	Computer Software
i-sense	Microsoft Research	26	East of England	Business Services
i-sense	O2 Telefonica Europe plc	19	South East	Communications
Proteus	ST Microelectronics Limited (UK)	61	South East	Manufacture of electronic components
Proteus	Mauna Kea Technologies (MKT)	23	USA, France	Diagnostic equipment
SPHERE	Toshiba Research Europe Ltd	33	South East	Biotechnology and Life Sciences
TeDDy	Aqdot	11	East of England	Chemicals, Petroleum, Rubber & Plastic
TeDDy	AstraZeneca plc	31	East of England	Chemicals, Petroleum, Rubber & Plastic
TeDDy	Pragmatic Semiconductor	13	North East	Industrial, Electric & Electronic Machinery

Source: FAME and manual online searches.

Appendix F IRC monitoring documents

EPSRC has made available for the evaluation team the following documentation monitoring information for each Interdisciplinary Research Collaboration (IRC) and their Next Step Plus projects.

Table 27 Available documents for the IRCs

Type of document	Document year	IRC SPHERE and OPERA	IRC Proteus and PPT	IRC i-sense and u-sense & Smartphone mRNA	IRC TeDDy
Proposal forms	2013	✓	✓	✓	N/A
	2018/19	✓	✓	✓	✓
Case for Support	2013	✓	✓	✓	N/A
	2018/19	✓	✓	✓	✓
ResearchFish Outputs	2023	✓	✓	✓	✓
Funding call text	2012	✓	✓	✓	N/A
	2017	✓	✓	✓	✓
Steering Committee Meeting Notes	2023				✓
Mid-term report (panel feedback)	2015/16	✓	✓	✓	N/A
	2022	N/A			✓
Mid-term report (self-collected data)	2021		✓		
Advisory board presentations/progress report	2022	✓	✓		
Advisory board Meeting Notes	2022			✓	
Advisory board slides	2022		✓		
Presentation slides	2022		✓	✓	
Conferences Summary	2019-2022		✓		
Annual reports	2014 to 2021			✓	

Appendix G Workshops and training activities by IRC

A summary of workshops and training activities organised by IRCs are available in the table below. Note that this list is based on data made available via interviews, email exchanges and project documentation, and thus may not be exhaustive.

Table 28 Workshops and training activities by IRC

IRC	Type of activity	Themes
i-sense	Career development events	• Structured career development action plans and regular mentorship • Careers Day: Learning from i-sense alumni: 3 funder talks, 7 alumni talk, 42 attendees • Q&A with experts • Virtual career workshops facilitated by coaching expert
	Conferences	• The Future of Healthcare Technology • Future of Diseases Diagnostics: 10-year anniversary • LMIC diagnostics conference (joint with Oxford University) • Biannual meetings with all members and partners
	Workshops & training	• Enterprise, innovation & commercialisation • Annual event on networking and communication skills • Diagnostics development, evaluation, policy development and implementation • Preparing for global health response • Designing trials of diagnostic test accuracy • Data visualisation masterclass • Infographics workshop • Mobility Fellowships
Proteus	Career development events	• Line management for academic mentoring of early career researchers • Regular peer-to-peer support
	Workshops & training	• Public engagement and presentation skills • Grant writing • Intellectual property protection & commercialisation • Project management • Good manufacturing practice • Good clinical practice • Medical device / pharmaceutical assurance training
SPHERE	Workshops & training	• Communication skills • Research ethics • Lecturing skills • Intellectual property protection • Good clinical practice • Working with children • Scenario-based workshops for technical staff working inside private homes
TeDDy	Career development events	• Mentoring breakfast with senior academics • Careers mentoring sessions • Careers talk: Pharmaceutical R&D; Founding a start-up; Becoming an independent academic
	Conferences	• Annual meetings with all IRC members
	Workshops & training	• Intellectual property protection • Nanomaterials in therapeutics • Cancer therapies • Novel drug delivery vehicles • Medical devices innovation

Appendix H Additional data tables

Table 29 Number and type of organisations involved in the IRC programme

Type of organisation	Number of organisations in Phase 1 (2013-2018)	Number of organisations in Phase 2 (2018-2024) retained from first phase	Number of new organisations in Phase 2 (2018-2024)	Total unique organisations involved with the IRC (2013-2024)
University	12	9	27	**39**
Research Institution	2	0	11	**13**
Company	12	6	9	**21***
Healthcare provider	1	0	4	**5**
Charity / non-profit	2	0	2	**4**
Government	0	0	1	**1**
Local authority	1	1	0	**1**
Professional body	0	0	1	**1**
R&D Centre	0	0	2	**2**
Total	**30**	**16**	**57**	**87**

Source: Desk review of IRC documentation and project management information obtained from individual IRCs. Note that while 21 companies were listed in various IRC documentation, upon consultation with IRCs only 10 companies were considered to be relevant 'key industry partners' that engaged with the projects.

Table 30 Number of researchers and students involved in the IRC programme

Role	i-sense	Proteus	SPHERE	TeDDy	Total
Principal Investigator	1	1	1	1	4
Co-Investigator	25	25	41	15	106
Research associates/early career/students	86	40	3*	34	163
Total	**112**	**59**	**45**	**50**	**266**

Source: Desk review of IRC documentation and project management information obtained from individual IRCs. Note that we were unable to obtain information on the total number of students trained in IRC SPHERE and thus the total number of early-career and mid-career IRC researchers represents an underestimate.

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