

Annex I

Report on UK heritage science research capabilities

carried out for the UK Research Infrastructure for Heritage Science

Caroline Peach, Preservation Matters Ltd
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1 Executive Summary

1.1 The European Research Infrastructure for Heritage Science (E-RIHS) is an international Research Infrastructure initiative with a vision to transform research into heritage interpretation and management. E-RIHS aims to provide advanced services to the heritage and scientific community through bringing together cutting-edge tools and expertise.

1.2 The Infrastructure and Access Working Group of UK-RIHS (the UK national hub of E-RIHS) commissioned Preservation Matters Ltd to research current UK heritage science capabilities, to ascertain current and future community needs and to identify key gaps. Data collection was carried out by survey, (with telephone support available) and was complemented by a review of select secondary sources. The research forms part of E-RIHS preparatory phase activities towards the establishment of E-RIHS as a European Research Infrastructure Consortium.

1.3 Twenty-six organisations contributed to this initial landscape analysis of heritage science research capabilities. Between them, 25 of the organisations provided information on 55 research facilities. These facilities have been mapped to show their distribution across the UK. The other organisation provided information on access needs only.

1.4 Twenty-three of the 25 organisations are eligible for UKRI funding and two are not. Of the 23 eligible organisations 14 have IRO (Independent Research Organisation) status, 7 are HEIs (Higher Education Institutions), 1 is part of UKRI and 1 has indicated it is eligible but is neither an IRO or HEI. Thirteen of the 25 organisations may be classified as 'public sector' (in the sense that they are publicly funded), 9 as 'higher education', 2 as 'heritage' (non-publicly funded) and 1 as commercial.

1.5 The survey responses show that the UK infrastructure for heritage science is a distributed infrastructure that encompasses specialised large-scale equipment; a wide range of commercially produced equipment and custom-made instrumentation; significant reference collections; both mature and developing digital collections and systems; and world-leading expertise.

1.6 Applications of the facilities include (but are not limited to):

- Understanding materials and their degradation
- Understanding the effects of exposure to the environment and use
- Understanding the impact of climate change and strategies for adaptation
- Understanding relationships with society
- Sophisticated imaging
- Development of innovative new techniques and systems to support discovery and preservation

1.7 An appendix to this report provides a brief description of each of the 55 facilities including equipment, techniques and expertise. This provides an insight into the current state-of-the-art. More detailed information is available in the full report and data sheet submitted to the UK-RIHS Infrastructure and Access Working Group.

1.8 The overall picture is of numerous organisations that are active in the field of heritage science research hosting facilities with equipment to support materials analysis and identification, monitoring and prediction of deterioration and responses to external change,

the development of techniques for preservation management of heritage as well as techniques for visualization and improved access to heritage assets and associated data. These facilities are staffed by expert teams with high calibre track records. Particular centres of expertise include:

- Advanced imaging and sensing instrumentation and techniques
- Analysis of ancient biomolecules
- Digital data documentation, curation and preservation
- Digital research
- Environmental studies (and reference collections)
- Geophysical survey and geospatial analysis
- Historic iron
- Mobile laboratory facilities
- Modern materials
- Natural collections digitization
- Radiocarbon dating and isotope analysis
- Reference collections (samples, artists' paints, analytical techniques)
- Weathering and rock breakdown

1.9 Total capital investment (not including buildings or running costs) for the thirty-six facilities that provided information exceeds £114 million.

1.10 Figures on annual running costs were provided by 24 facilities. Although there is inconsistency in the way these have been provided, annual running costs for 24 facilities exceeds £4.6 million.

1.11 Limited information has been provided on the costs of providing access (from 22 of the 55 facilities). The variety of formats in which the information was reported and the fact that many services are provided (and costed) on a bespoke basis means it has not been possible to make generalisations about the cost of providing access. It should be noted that where costs have been provided, they are reported as 'cost to user' (which may not always be the same as the cost to provide access).

1.12 A limited number (11) of the responding facilities provide regular access to the wider research community (outside of research collaborations or funded projects). Of these, several have a funded remit to provide access and therefore have the necessary resource to support the provision of external access. There are a number of other facilities that could provide wider access with relative ease if additional resource (notably staffing) were available to support access provision.

1.13 Most facilities have purchased their equipment within the last 5 or 10 years; and most expect to depreciate within a 10 year period (5 years for smaller pieces of equipment or those that are heavily dependent on technology). The larger facilities appear to have established and resourced rolling programmes of equipment maintenance, upgrade and replacement.

1.14 The future investment needs of 23 (of the 55 facilities) comes to more than £51 million over 5 years. Investment covers plans for maintenance and upgrades, replacing existing equipment and developing new research capabilities. A further 20 facilities have provided information on research capability they would like to develop but have not provided any associated estimate of the financial investment required.

1.15 The sector demonstrates strong collaborative working practices and regular engagement with the wider UK heritage science research infrastructure. Fifty-one out of 55 facilities have provided information on the other facilities with which they regularly engage. The additional facilities have been added to the mapping in this report.

1.16 Respondents have provided detailed information on research capability that they would like to access, and that they find difficult or impossible to access in the UK. An initial categorization into 'equipment or techniques', 'expertise or knowledge-base' and 'strategic' access needs has been carried out as part of this report. These responses would benefit from more informed analysis to build a detailed picture of future community needs and where there is most potential to enhance connectivity between research facilities.

1.17 The landscape analysis reveals a distribution of centres of national and international excellence in heritage science research and innovation with some facilities operating as recognisable research infrastructure providers and others currently only able to provide access to facilities as part of funded projects. This distributed network needs investment to mature into an integrated research infrastructure accessible to the wider research community.

1.18 Conclusions focus on four key areas of opportunity for development of the UK heritage science infrastructure:

- Coordination is needed to clarify complementarity and interoperability between research facilities and effect a change from a network of distributed research centres to effective operation as an infrastructure, by building the connections between research capabilities and making the infrastructure as a whole more visible and accessible to researchers.
- Investment in staffing is critical to opening up access to facilities. This is not only staffing for the technical/research services but also for the administrative functions associated with access services.
- Individual facilities have identified investment needs that will result in developed research capability, but infrastructure investment should also be directed towards facilitating greater community access to the large national facilities (which is reported as difficult to obtain).
- ARCHLAB/DIGILAB resources are the least well developed and are ripe for transformation. The UK has particular strengths in reference resources. Virtual provision to these resources would be of benefit to the international research community and investment in digital infrastructure to enable this, (with regard to FAIR principles so that access is sustainable and long-term preservation of data is ensured), should be considered as a priority.

2 Introduction

2.1 The brief

The Infrastructure and Access Working Group of the UK national hub of the European Research Infrastructure for Heritage Science (www.e-rihs.ac.uk) was established to support the development of UK-RIHS by setting out a plan for heritage science research infrastructure in the UK.

The European Research Infrastructure for Heritage Science (E-RIHS) is an international Research Infrastructure initiative with a vision to transform research into heritage interpretation and management. E-RIHS aims to provide advanced services to the scientific and heritage communities through bringing together cutting-edge tools and expertise.

The key research communities served by E-RIHS are heritage science researchers in the heritage industry and the research sector. They encompass a broad range of cross-disciplinary researchers and practitioners, from engineering and physical sciences to digital humanities, conservation and curation. E-RIHS is currently in its preparatory phase with a projected implementation phase to commence in 2021.

During the preparatory phase, the mission of the UK Infrastructure and Access Working Group is to develop an understanding of the needs and requirements of the UK communities, to explore the current provision of services and to estimate the future need and scope of infrastructure investments. The activities of the working group will therefore explore the current state-of-the-art and facilitate the development of the national heritage science capabilities with a range of research and heritage practitioners, both as users and providers of access to research infrastructure in mind.

2.2 Scope of work

Research was commissioned from Preservation Matters Ltd to understand the current UK heritage science capabilities, to ascertain current and future community needs and to identify key gaps.

The scope of the work was to:

- Conduct quantitative (mixed-method) research on current provision of access services and future research needs.
- Provide an analysis of the current state-of-the-art within the heritage science sector.
- Prepare a report based on research data and secondary sources outlining the current state-of-the-art and key areas of opportunity for the UK heritage science infrastructure development.

The research was undertaken with guidance from the UK-RIHS Infrastructure and Access Working Group.

2.3 How the report will be used

The UK-RIHS Infrastructure and Access Working Group will, on the basis of this research report, prepare a document for consideration by the UK-RIHS Steering Committee.

The research is intended to inform the following key areas of the work of UK-RIHS:

- What could be the priority areas/core features of the future research infrastructure investments?
- What level of investment is necessary for E UK-RIHS in the future?

The project is part of the Horizon 2020-supported E-RIHS Preparatory Phase (PP) project and will allow the UK partners to inform access strategy development on the EU level.

3 Context

3.1 Europe

The European Research Infrastructure for Heritage Science (E-RIHS) is an international Research Infrastructure initiative with a vision to transform research into heritage interpretation and management¹. E-RIHS aims to connect researchers in the humanities and natural sciences to foster scientific excellence and innovation, build connected research capabilities, and pioneer interdisciplinarity, co-creation and research excellence. It builds on previous European projects that include IPERION CH², ARIADNE³ and PARTHENOS⁴.

E-RIHS was included in the ESFRI (European Strategy for Research Infrastructures) Roadmap in 2016. It was the only Research Infrastructure Project in the Social and Cultural Innovation domain until the European Holocaust Research Infrastructure joined the Roadmap in 2018⁵. E-RIHS is currently in its Preparatory Phase with the goal of being established as an ERIC (European Research Infrastructure Consortium) in 2020. The preparatory phase partnership brings together 16 countries (15 EU member states plus Israel). National hubs sharing the objectives of E-RIHS are active in Cyprus, France, Germany, Hungary, Italy, Poland, Portugal, Spain, Slovenia and the United Kingdom.

The national hub in the United Kingdom is UK-RIHS (www.e-rihs.ac.uk). Part of its work in the preparatory phase is to develop a coherent strategy for a fully integrated Research Infrastructure by identifying complementarity, interoperability, competencies and expertise across the Research Infrastructures taking into account both instrumentation and expertise.

The Infrastructure and Access working group of UK-RIHS is generating an understanding of current UK heritage science research capability as a step towards the integration of national facilities in the wider European Research Infrastructure. E-RIHS uses a four-platform typology to categorise different types of heritage science research capability, or 'facility'. The collection of these capabilities, spread across the four integrated platforms (or 'LABs'), makes up the infrastructure which can include major research equipment (or sets of instruments) (FIXLAB or MOLAB), knowledge-based resources such as reference collections, archives and data (ARCHLAB), and e-infrastructures or virtual facilities (DIGILAB).

¹ Further information on E-RIHS is available at: <http://www.e-rihs.eu/>. Accessed 07/01/2019.

² IPERION CH - Integrated Platform for the European Infrastructure ON Cultural Heritage <http://www.e-rihs.eu/>. Accessed 07/01/2019.

³ ARIADNE – a programme to integrate existing archaeological infrastructure across Europe. <https://www.ariadne-eu.org/>. Accessed 07/01/2019.

⁴ PARTHENOS – Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies <http://www.parthenos-project.eu/>. Accessed 07/01/2019.

⁵ Roadmap and strategy report on research infrastructures, European Strategy Forum on Research Infrastructures, 2018. <https://www.esfri.eu/roadmap-2018> Accessed 07/01/2019.

⁶ DARIAH (<https://www.dariah.eu/>) and CESSDA (<https://www.cessda.eu/>) exist but already operate as research infrastructure consortia (rather than Projects),

A more detailed explanation of the E-RIHS access platforms is provided as part of the infrastructure survey form in Appendix 1 or at <http://www.e-rihs.eu/access/>. The four platforms have been used in the collection of information about UK capabilities, and are referenced in the landscape analysis, to support future integration with wider European initiatives.

3.2 United Kingdom

In the UK, the launch of UK Research and Innovation (UKRI) in April 2018 and the government's Industrial Strategy are both contributing to a re-definition of the UK research landscape.

The UK government published its Industrial Strategy⁷ in November 2017. The White Paper 'Industrial Strategy: building a Britain fit for the future' sets out a long-term plan to boost the productivity and earnings of people throughout the UK. It is delivered through the Department for Business, Energy and Industrial Strategy (BEIS). Research and Innovation feature strongly in the strategy. Key policy goals are to raise R&D investment to 2.4% of GDP by 2027, invest in programmes to capture the value of innovation through the new Industrial Strategy Challenge Fund, invest in technical skills, and create a new UK Shared Prosperity Fund.

At the same time, there has been considerable change in the research funding landscape and the operation of the Research Councils. UK Research and Innovation was launched as a new body in April 2018 to "work in partnership with universities, research organisations, businesses, charities and government to create the best possible environment for research and industry to flourish"⁸.

UKRI is currently engaged in the development of the first national research and innovation infrastructure for the UK (commissioned by BEIS). An initial analysis of infrastructure questionnaire responses and description of the landscape was published in December 2018⁹. This is intended to spark further discussion with, and contributions from, the UK research community to feed into a final analysis of the landscape in Spring 2019. An online portal is also being developed (due Spring 2019) which will be a searchable tool that identifies and signposts infrastructures available to UK researchers and innovators.

The UK research infrastructure roadmap is seen by government as a key component of the wider work to raise investment in R&D to 2.4% (Industrial Strategy policy goal). In December 2018 over 700 infrastructures that had at least a national significance had been identified through the UKRI infrastructure survey.

Both the European focus on heritage science infrastructure and the UK focus on wider national research and innovation infrastructure provide essential context to this work to understand UK heritage science research capability. They are each important areas of application for the outputs of this research.

⁷ Industrial Strategy: building a Britain fit for the future <https://www.gov.uk/government/topical-events/the-uks-industrial-strategy>. Accessed 07/01/2019.

⁸ UK Research and Innovation <https://www.ukri.org/>. Accessed 07/01/2019.

⁹ UKRI Roadmap. Initial analysis of infrastructure questionnaire responses and description of the landscape <https://www.ukri.org/files/infrastructure/landscape-analysis-2-pdf/>. Accessed 07/01/2019.

4 Approach

The objective of the research project was to understand the current UK heritage science capabilities, to ascertain current and future community needs and to identify key gaps. This was to be achieved by data collection from the UK heritage science community, complemented by a review of select secondary sources.

4.1 Review of secondary sources

An initial review of secondary sources was carried out to provide context to the data collection phase. The review included work by the European Commission on research infrastructures, work to date by the European Research Infrastructure for Heritage Science (E-RIHS) and developments in the UK (led by UK Research and Innovation) to build a UK roadmap for research infrastructure to support delivery of the UK government's Industrial Strategy.

4.2 Data collection

The UK-RIHS Infrastructure and Access working group had drafted a survey to be used to collect information from UK institutions on heritage science research infrastructure capabilities providing shared access in the UK.

The survey was designed to collect information on individual research facilities at institutions. Data collected includes:

- a general description of the facility and provider
- categorization according to the E-RIHS four platform typology
- a summary of potential applications
- a technical description of equipment and techniques
- an estimation of value and of future investment needed in the facility
- conditions of access to the facility
- information on the facility team including key areas of expertise
- project track record including notable publications

Alongside this information about the individual facilities, people were also asked about their current access to heritage science capabilities (the other facilities with which their researchers regularly engage for collaborative research), and the research capabilities or facilities that they would like to have access to.

The survey was finalised with guidance from the working group and was distributed in Word format to enable easy completion by participants. The survey was circulated towards the end of November 2018 with a request for completion by mid-December. A copy of the survey form is available as Appendix 1.

Participation in the survey was by invitation. The UK-RIHS Infrastructure and Access working group identified contacts at key organisations to be invited to contribute to the survey. They included the partners of UK-RIHS, members of the National Heritage Science Forum (NHSF) and other known heritage science research facilities. A list of the research facilities that completed the survey is available as Appendix 2.

Support for completion of the survey was available by telephone from the commissioned consultant and members of the working group.

5 Research infrastructure landscape analysis

In answer to the question, “what is a research infrastructure?” the European Strategy Forum on Research Infrastructures (ESFRI) provides the following definition:

Research infrastructures (RIs) are facilities, resources and services used by the science community to conduct research and foster innovation.

*By **pooling effort** and developing RIs, European countries can achieve **excellence** in highly-demanding scientific fields and simultaneously build the European Research Area (ERA) and Innovation Union.*

They include: major scientific equipment, resources such as collections, archives or scientific data, e-infrastructures such as data and computing systems, and communication networks.

*RIs can be **single-sited** (a single resource at a single location), **distributed** (a network of distributed resources), or **virtual** (the service is provided electronically).^{10 11}*

This landscape analysis is of the research capabilities and facilities that together make up the UK heritage science research infrastructure.

In other mapping of research infrastructures, heritage science is classified as part of the Social Science and Humanities domain¹² but it is worth noting that in an analysis of interdisciplinarity and transformation of the way in which different domains collaborate and interchange between existing infrastructures, the ESFRI 2016 roadmap singles out heritage science as:

“A dramatic example of this hybridation is provided by the ESFRI project E-RIHS which combines material science methods and interpretative schemes of history of art to rejuvenate the field of Heritage Studies”.

The multi-disciplinary and inter-disciplinary nature of heritage science research is reflected in the research infrastructure in which research capabilities are distributed across different types of organisation (including public sector, higher education, heritage, commercial), as well as distributed geographically at numerous centres across the UK.

Twenty-six organisations contributed to this initial landscape analysis of heritage science research capabilities. Between them, twenty-five of the organisations provided information on fifty-five research facilities. The other organisation provided information on access needs only.

5.1 Types of organisation

The twenty-five organisations that are current or potential providers of access to heritage science research infrastructure can be grouped into four broad categories of organisation:

¹⁰ Source: <https://ec.europa.eu/research/infrastructures/index.cfm?pg=about> Accessed 07/01/2019.

¹¹ The UKRI infrastructure roadmap definition of a research infrastructure is slightly different, as follows: *Facilities, resources and services that are used by the research and innovation communities to conduct research and foster innovation in their fields. They include: major scientific equipment (or sets of instruments), knowledge-based resources such as collections, archives and scientific data, e-infrastructures, such as data and computing systems and communication networks and any other tools that are essential to achieve excellence in research and innovation.*

<https://www.ukri.org/files/infrastructure/landscape-analysis-2-pdf/> p.6 Accessed 07/01/2019

¹² For example, the ESFRI 2016 roadmap <https://www.esfri.eu/roadmap-2016>. Accessed 07/01/2019

- Public sector (i.e. those that are publicly funded)
- Higher education
- Heritage (non public sector, non commercial)
- Commercial

There is clear potential for overlap between these groupings (particularly categorisation as ‘public sector’ or ‘heritage’, so for clarity the mapping of organisations to these groupings is shown below.

| Public sector | Higher education |
|--|---------------------------------------|
| Amgueddfa Cymru – National Museum Wales | Cardiff University |
| British Library | Nottingham Trent University |
| English Heritage | Science & Technology Facility Council |
| Historic England | UCL |
| Historic Environment Scotland | Universities of Glasgow |
| Imperial War Museums | University of Bristol |
| National Gallery | University of Cambridge |
| National Museums Scotland | University of Oxford |
| Natural History Museum | University of York |
| Tate | |
| The British Museum | |
| The National Archives | |
| Victoria and Albert Museum | |
| Heritage | Commercial |
| Historic Royal Palaces | York Archaeological Trust |
| National Trust for England, Wales & Northern Ireland | |

In terms of eligibility for UKRI funding, twenty-three of the twenty-five organisations are eligible and two are not. Of the 23 eligible organisations 14 have IRO (Independent Research Organisation) status¹³, 7 are HEIs (Higher Education Institutions), 1 is part of UKRI and 1 has indicated it is eligible but is neither an IRO or HEI.

5.2 Geographical distribution of facilities

Just under half of the organisations (12 out of 25) provided information on a single facility. Five provided information on two facilities, four provided information on three facilities, one provided information on four facilities, one on five facilities, one on six facilities and one on seven facilities.

The map (figure 1) gives a sense of the distribution of the 55 facilities that responded to the survey across the UK (shown by red markers). Most of the facilities are located in urban centres; there is a concentration of organisations and facilities in the London area. The low (visible) number of markers on the map below indicates both a clustering of facilities (e.g. in urban areas) but also reflects the provision of multiple facilities by single institutions showing as stacked markers. The map can be viewed online via [GoogleMaps](#) to enable zooming and a more detailed insight into geographical distribution.

¹³ One is also a PSRE – Public Sector Research Establishment

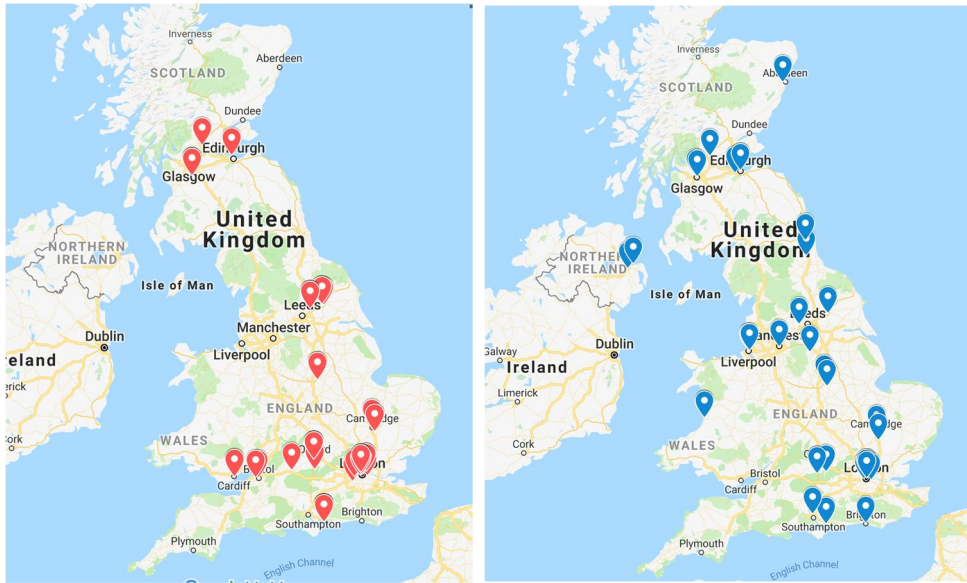


Figure 1. Map of locations of heritage science research facilities that completed the survey (red) and other potential facilities (blue)

A list of the research facilities that took part in the survey is given in Appendix 2. The list does not represent all heritage research facilities in the UK. There are several important facilities that have not yet contributed to the landscape analysis (including some partners of UK-RIHS and members of the National Heritage Science Forum (NHSF)). The short timescale for this research and its timing at the end of the calendar year had a negative impact on some people's ability to complete the survey.

The location of a further 40 organisations that are thought to offer heritage science research capability, but which have not contributed to the survey are shown in blue on the map in Figure 1 (and listed in Appendix 3).

5.3 Current state-of-the-art (equipment, techniques and expertise)

5.3.1 Overview

The UK heritage science landscape encompasses facilities with specialised large-scale equipment; a wide range of commercially produced equipment and custom-made instrumentation; significant reference collections; mature and developing digital collections and systems; and world-leading expertise.

Much of the equipment is located in laboratories but many facilities (particularly those in organisations with responsibility for the long-term custodianship of buildings, sites or collections) also hold an array of mobile or portable instruments. For organisations such as English Heritage, Historic Royal Palaces and the National Trust, the portability of equipment is vital as it is used frequently at their numerous geographically dispersed sites.

In addition to this, four facilities are primarily 'mobile'. Two of these are mobile laboratories through which facilities and services that might otherwise only be available in a fixed laboratory can be transported on site. The other two are mobile applications - Geophysics and Geospatial imaging.

5.3.2 Individual heritage science research capabilities/facilities

The survey generated information on fifty-five facilities, with each providing data that included:

- a general description of the facility and provider
- a summary of potential applications
- a technical description of equipment and techniques
- an estimation of value and of future investment needed in the facility
- conditions of access to the facility
- information on the facility team including key areas of expertise
- project track record including notable publications

The mapping of heritage science research capability reveals strengths in equipment and techniques, knowledge and expertise and e-infrastructure. Notable amongst the listed facilities are centres of excellence in:

- Advanced imaging and sensing instrumentation and techniques (Nottingham Trent University)
- Analysis of ancient biomolecules (University of York)
- Biogeochemistry of contemporary and ancient environments (University of Bristol)
- Chiral amino acid analysis (University of York)
- Digital data curation and preservation (Archaeology Data Service, University of York; British Library)
- Digital documentation (Historic Environment Scotland)
- Digital research (British Library)
- Environmental studies – including national reference collections (Historic England)
- Full scale environmental and mechanical testing for the historic built environment (UCL)
- Geophysical survey and geospatial analysis (Historic England)
- Historical iron (Cardiff University)
- Mobile heritage laboratory and citizen science (UCL)
- Modern materials (particularly paints) (Tate)
- Natural collections digitization, imaging and sample analysis (Natural History Museum)
- Radiocarbon dating and isotope analysis (SUERC-Universities of Glasgow, and University of Oxford)
- Reference collection for comparative analysis (British Museum)
- Reference collections for paints and artists' materials (National Gallery, University of Cambridge)
- Weathering and rock breakdown (University of Oxford)

Many of the facilities are producers of standards and guidance in their field (national and international).

For each facility a high-level general description has been provided in Appendix 4¹⁴.

¹⁴ The full report to the UK-RIHS Infrastructure and Access working group also includes information on key techniques and expertise. More detailed information was provided in the original submission from each facility which is able as background data to the UK-RIHS Infrastructure and Access working group.

5.3.3 Applications

The UK's heritage science research landscape is of national and international significance. Combined, these facilities (including expertise) support an astonishing array of applications that address fundamental questions about cultural and natural heritage such as:

- What is it?
- How was it made/did it evolve?
- What does it tell us (about society or the world around us)?
- What will happen to it in the future?
- How can we extend its (useful) life?
- What impact can techniques and knowledge generated in the heritage domain have on other sectors and for industry?

Applications described by the facilities that responded to the survey include:

- Analysis and identification of a wide range of materials, including archaeological, geological and paleontological materials; built and marine environment materials; objects and collections including ancient and modern materials – both materials of fabrication and decay products.
- A range of dating techniques.
- Study of ancient and modern DNA; technical advances in amino acids research; understanding of the depositional history of sediments.
- Understanding the production, provenance and past use of heritage assets.
- For the authentication of heritage assets.
- Insights into past societies, environments, disease; art history and technical art history including the evolution of artists' materials and their application.
- Monitoring the effects of exposure and use of heritage to understand decay and inform the development of new materials, techniques and strategies for preservation.
- Testing and modeling new materials and techniques; understanding their performance over time, and their sustainability and environmental impact.
- Assessing the response of heritage structures and artefacts to natural hazards and environmental conditions; understanding the performance of historic buildings particularly with respect to climate change.
- Design, installation and use of modern building services in historic buildings; options for retrofitting and re-use of the historic built environment.
- Revealing information that can't be seen with the naked eye, for example mapping subsurface archaeology, analyzing building structures, imaging 'hidden' text and drawings, analyzing subsurface microstructures to better understand painting techniques, revealing internal structures of objects generating knowledge of how they are made.
- Development of new imaging techniques or methods of digitisation that will enable researchers and the public to view and access heritage in new ways and remotely.
- Development of e-infrastructure, increasing access to Open Data, new ways of using data (particularly at scale) and digital preservation.
- Production of a wide range of good practice guidance.

5.3.4 E-RIHS access platforms

Respondents to the survey were encouraged to identify which of the four E-RIHS access platforms the research capability they were providing information about aligns to. This is to inform future work to further connect research competencies and strengthen operation as an integrated research infrastructure.

E-RIHS access platforms

(i) E-RIHS ARCHLAB

An ARCHLAB provides access to physical collections, such as objects, technical images, samples and reference materials, analytical data and conservation documentation, as stored in museums, galleries and research institutions.

(ii) E-RIHS DIGILAB

A DIGILAB provides online access to digital tools concerning heritage and data, with the aim of making it FAIR (Findable, Accessible, Interoperable and Re-usable). This includes and enables access to searchable registries of datasets, reference collections, thesauri, ontologies etc., and supports data interoperability through the creation of shared knowledge organization systems. It can include online data processing software.

(iii) E-RIHS FIXLAB

FIXLAB describes large-scale and medium-scale fixed facilities – e.g. particle accelerators, neutron and laser sources and other essentially immovable research facilities including the associated unique expertise.

(iv) E-RIHS MOLAB

MOLAB is access to a comprehensive selection of mobile analytical instrumentation for non-invasive measurements on objects, buildings, and sites, allowing the implementation of complex multi-technique diagnostic projects for in situ investigations. It describes the totality of the facility (i.e. it includes the mobile equipment, transport, unique expertise and fixed facility (lab) that supports the maintenance of the equipment) as one entity.

<http://www.e-rihs.eu/access/>

It is clear from the completed survey forms that people often found it difficult to place a facility in a single E-RIHS access platform. Facilities are frequently categorized as both FIXLAB and MOLAB, perhaps reflecting the type of equipment more than the projected access service. There is also overlap between the ARCHLAB and DIGILAB categories. This is sometimes a result of facilities being in the process of digitising archives or having archives (or knowledge-base) that span both physical and digital formats.

Furthermore, it is likely that the ARCHLAB category in particular is under-reported. It is suspected that many of the organisations that hold collections could provide access to an ARCHLAB in the sense of the E-RIHS definition above.

Although the 2016 ESFRI research infrastructure roadmap makes reference to heritage collections themselves as infrastructure:

“Research infrastructures that support research across and within the Social Sciences and Humanities are among the first known infrastructures: libraries, museums and archives are the most obvious examples of this legacy”¹⁵

and the 2018 UKRI Infrastructure Roadmap initial analysis identifies:

¹⁵ ESFRI 2016 roadmap – Landscape analysis section on social and cultural innovation, <https://www.esfri.eu/roadmap-2016> Accessed 07/01/2019.

“a large group [of infrastructures] concerned with allowing access to research objects – physical or digitised versions”

in its analysis of infrastructures in the social sciences, arts and humanities sector¹⁶, the distinction for the purpose of this study is that an ARCHLAB is the reference collection used to support research and innovation (rather than the collection of materials upon which scientific study takes place); aggregated catalogues for the latter are already in place in some instances¹⁷.

It would not be unreasonable to assume that most of the organisations that hold collections and other heritage assets will have records of conservation documentation, technical images and analytical data and this could form a distributed UK ARCHLAB of national and international significance for heritage science research.

5.4 Analysis of investment, running costs, projected costs

5.4.1 Estimate of total capital investment

Survey participants were asked to estimate the total value of the equipment on offer as part of the facility. This estimate should not include building, building management or running costs.

Thirty-six (of the fifty-five) facilities were able to provide an estimate of total capital cost. The total capital investment in these facilities (not including buildings) is approximately £114 million.

Some sizeable facilities were not able to provide data on capital investment within the timescale of the survey and so the total of £114 million **does not include** the capital costs of the following facilities:

- Ashmolean Museum, University of Oxford
- Bodleian Libraries, University of Oxford
- Conservation Archive, Tate
- Hamilton Kerr Institute, University of Cambridge
- Historic England Archive
- ISIS Neutron and Muon Source
- National Gallery Scientific Department (Archive)
- RLAHA (Research Laboratory for Archaeology and History of Art), University of Oxford
- SUERC Radiogenic Isotope Laboratory and Luminescence Laboratory, Universities of Glasgow
- The British Library (ARCHLAB, Collection Care, Digitisation Studio, Datasets, DataCite, Shared Open Heritage Repository)
- York Archaeological Trust

¹⁶ UKRI Infrastructure Roadmap. Initial analysis of infrastructure questionnaire responses and description of the landscape (December 2018), p. 54 <https://www.ukri.org/files/infrastructure/landscape-analysis-2-pdf/>. Accessed 07/01/2019.

¹⁷ Aggregated catalogues of museum and archive collections exist such as Discovery, which holds more than 32 million descriptions of records held by The National Archives and more than 2,500 archives across the country, <https://discovery.nationalarchives.gov.uk/> or the Europeana collections portal, <https://www.europeana.eu/portal/en>. Accessed 07/01/2019.

5.4.2 Estimate of annual running costs

Of the fifty-five facilities covered by the survey, twenty-four were able to provide information on typical annual running costs within the timeframe for responses.

There was considerable variation in what was included in the annual running costs. Some organisations included staff costs, whilst others only reported consumables and maintenance costs.

With this caveat in mind, the total annual running costs for the 24 facilities that reported information comes to over £4.6 million.

The facilities for which annual running costs are **not included** in the figure of £4.6 million are listed below:

- XPS facility at Cardiff University (other facilities are included in running costs)
- Conservation Research Lab, English Heritage
- FIXLAB Environmental Studies, Historic England
- ARCHLAB Environmental Studies, Historic England
- FIXLAB Material Science, Historic England
- FIXLAB Conservation, Historic England
- Geospatial Imaging, Historic England
- Historic England Archive
- Imperial War Museums (both facilities)
- National Gallery Scientific Department (archive)
- ISAAC, Nottingham Trent University (both facilities)
- ISIS Neutron and Muon Source
- Fitzwilliam Museum, University of Cambridge
- Hamilton Kerr Institute, University of Cambridge
- School of Geography and the Environment, University of Oxford
- RLAHA (Research Laboratory for Archaeology and History of Art), University of Oxford
- Bodleian Libraries, University of Oxford
- Ashmolean Museum, University of Oxford
- SUERC Radiocarbon and Stable Isotope Laboratory, Universities of Glasgow
- SUERC Radiogenic Isotope Laboratory, Universities of Glasgow
- Luminescence Laboratory, Universities of Glasgow
- Conservation Archive, Tate
- The British Library (ARCHLAB, Collection Care, Digitisation Studio, Datasets, DataCite, Shared Open Heritage Repository)
- Collection Care Department Analytical Lab, The National Archives
- York Archaeological Trust

5.4.3 Estimate of cost of providing access

Organisations were asked to provide an estimate of the cost of providing access. For example, the cost per sample (including all preparation and data interpretation activities).

Just under half of the facilities (22) were able to provide this information and the way in which it was provided was so varied that it is not possible to provide any overall indicative cost per unit or even range of costs. For example, costs are provided per unit (which can range from a single sample to an entire experiment), as a day rate, or as a proportion of

client day rates. Furthermore, many costings are provided ‘on application’ because they are determined by the specifics of the service or project and are therefore established on a case-by-case basis.

For the most part, the information on costs that has been provided appears to be the **cost to the user** (which is not necessarily the same as the cost to provide access).

5.4.4 Conditions of access

The survey asks about conditions of access to the facility as a whole, and to specify if there are requirements that relate to particular pieces of equipment.

Access to facilities is influenced by:

- Charging policies
- Staffing levels at facilities (for supervision, conducting analysis or providing training)
- Availability of equipment (times at which it is not in use by host institution)
- Security and insurance costs
- Safety considerations during use of equipment (particularly XRF techniques)
- Transportation (of objects/samples or of equipment)
- Access policies (who can use the services, e.g. public; researchers)

Some facilities already provide regular access to the wider research community; of these, some are specifically funded by UK Research Councils to provide this function (e.g. RLHA and SUERC).

Facilities that provide regular access to the wider research community are:

| Facility | Access to wider research community |
|---|---|
| XRD laboratory AC-NMW (FIXLAB) | A relatively open policy of access to the equipment. Used daily to support identification of material brought in by the general public and staff also support analysis of one-off items from researchers. |
| Historic England Archive (ARCHLAB) | Free online access to the Historic England Archive catalogue and other resources such as England’s Places and Britain from Above. The library catalogue can be searched online via COPAC. The Archive Services team offer free searches for holdings on single buildings and small sites on a first come first served basis. Charges are made for copies and expedited searches, or where the research requested is large or complex. The Public Search Room and Library are open four days a week. |
| Historic England: Environmental Studies (FIXLAB) | Access is provided to researchers and members of the public free of charge. A charge is made to commercial organisations. Training on most pieces of equipment can be provided by staff. Individuals wishing to make use of chemical preparation laboratories must be training prior to arrival. |
| ISIS Neutron and Muon Source (FIXLAB) | Training to use the available equipment of the scientist performing an experiment is provided by the relevant instrument scientist (local contact), who will assist the users during the experiments and data analysis. If the use of equipment of the ancillary Research Complex is required, basic training can be provided, but there is not a full assistance during the measurements like on the ISIS instruments. |

| | |
|---|---|
| | Data analysis is usually a complex task, therefore it is advisable that in the experimental team there is expertise to perform it. Instrument scientists are available to discuss and assist in all the data processing but cannot usually perform a full data analysis for the users, unless agreed before the experiment. |
| National Gallery Scientific Department (archive) (ARCHLAB) | Access to Gallery history records via the Research Centre. Access to scientific records via the IPERION-CH ARCHLAB transnational programme. |
| Natural History Museum – Digital Collections Programme (DIGILAB) | Digital access is provided through the Natural History Museum data portal. Data can be accessed through the web interface, downloaded or via the Portal API. The digital collection is openly accessible under a series of Creative Commons wavers and licences. |
| The British Library | Collections access in reading rooms or online. Commercial digitization services. Supported access to datasets via BL Labs Open access to Shared Open Repository for Heritage. |
| RLAHA, University of Oxford (FIXLAB) | Services to analyse samples are available and information about sampling for various applications is provided through the facilities' website (https://www.arch.ox.ac.uk/facilities-and-services) |
| Scottish Universities Environmental Research Centre (SUERC), Radiocarbon and Stable Isotope Laboratory, Universities of Glasgow (FIXLAB) | Facility access is simple and done by filling out a spreadsheet to submit electronically in advance of posting the samples. The Radiocarbon Laboratory also welcomes visitors and has taken in students for extended training programmes in pretreatment, measurement, and interpretation of results. |
| UCL Mobile Heritage Lab (MOLAB) | Online application form. Access would need to include: - Technical support - Driver (either the lab technician or an externally hired driver that has been approved and insured). - Expert support (PDRA level or higher) - Training - Insurance |
| Archaeology Data Service (ADS), University of York (DIGILAB) | ADS is able to offer unlimited Open Access to data for all E-RHIS users. Preservation services would be subject to ADS Charging Policy and costing calculator. |

There are a number of other surveyed facilities that already provide access to the wider community through other means (such as through funded research projects and collaborations). These facilities have the potential to provide access to the wider research community (particularly to equipment and techniques) as part of a distributed heritage science infrastructure if additional resource is available, or under particular conditions (e.g. subject to an application process).

This list includes:

- Department of Scientific Research, British Museum (FIXLAB)
- Cardiff University Conservation Laboratories (FIXLAB)
- ARCHLAB Environmental Studies, Historic England
- FIXLAB Conservation, Historic England
- FIXLAB/MOLAB Material Science, Historic England
- ISAAC, Nottingham Trent University (MOLAB and FIXLAB)
- The Engine Shed, Historic Environment Scotland (ARCHLAB, DIGILAB, FIXLAB)
- National Gallery (ARCHLAB)

- National Museums Scotland Collection Centre (FIXLAB)
- Conservation Archive, Tate (ARCHLAB)
- The British Library – DataCite (DIGILAB)
- UCL Collections ARCHLAB
- UCL E&MC² Environmental Chambers and Mechanical testing frame (FIXLAB)
- UCL Heritage Imaging Facility (FIXLAB)
- UCL Preventive Conservation Lab (FIXLAB)
- Bristol Radiocarbon Accelerator Mass Spectrometry Facility, University of Bristol (FIXLAB)
- Organic Geochemistry Unit, University of Bristol (FIXLAB)
- BioArCh, University of York (FIXLAB)
- NEaar, University of York (FIXLAB)

Most of these facilities identify investment in additional staffing as critical to the provision of access services to a wider research community, (beyond any current access provided through funded research projects or collaborations).

5.4.5 Future investment

To gauge future investment required in the facilities, the survey asked about the age of current equipment and its expected useful lifetime. It also asked for an estimate of financial investment required over the next five years, together with a description of why the investment is necessary (e.g. development of new methods, maintenance, innovation, prototype instrumentation). Finally, the survey asked what capabilities (infrastructure and/or expertise) facilities would like to develop in the next five years.

Age of current equipment and useful lifetime

Facilities have invested in equipment over a number of years. Consequently, the age of current equipment that is in use varies considerably (particularly when considering that most facilities use several pieces of equipment and have provided a general range for the age of that equipment).

The dates of equipment purchases have been mapped to 5 ‘age ranges’ to give an indication of the age profile of equipment that makes up the UK heritage science research infrastructure. Some of the mapping is subjective given the range of ages of pieces of equipment that have been given in a single response. In these cases, the age band selected reflects the band that applies to the majority of the equipment mentioned by the facility.

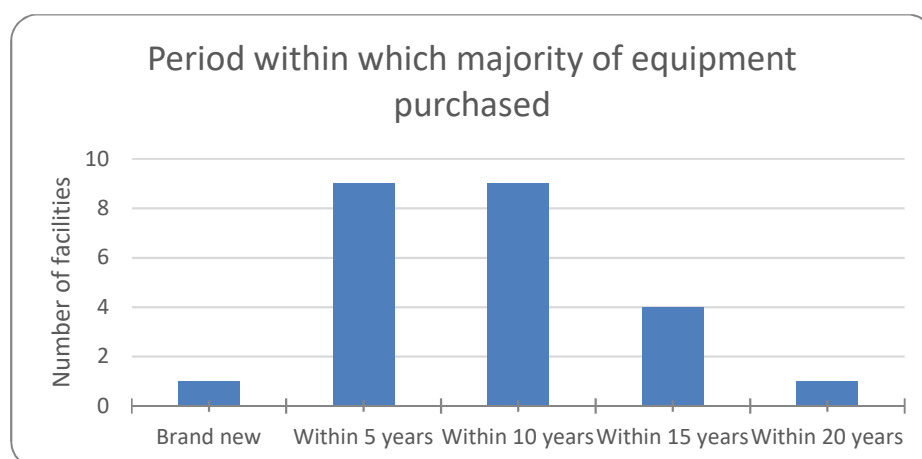


Figure 2. Period within which majority of equipment purchased

Twenty-four facilities provided information on the age of equipment and most of these have purchased the majority of their equipment within the last five or ten years.

Useful life of equipment

The age of equipment is not necessarily the best guide to when it needs to be upgraded or replaced. For example, equipment that is highly dependent on fast-developing technology or smaller pieces of equipment that are heavily used may need to be replaced more frequently than larger pieces of equipment. For this reason, people were asked about the 'useful lifetime' of equipment at the facility.

Seventeen of the 55 facilities provided information on 'useful lifetime'. Most gave a depreciation period of ten years; though ranges commonly spanned five to fifteen years with shorter 'useful lifetimes' often relating to technological infrastructure. Some facilities specifically identified that their strategy is to invest in maintenance contracts and software updates/renewal in order to prolong the useful lifetime of associated hardware. Many facilities aim to operate a rolling replacement schedule over a period of up to 10 years (up to five years for smaller pieces of equipment).

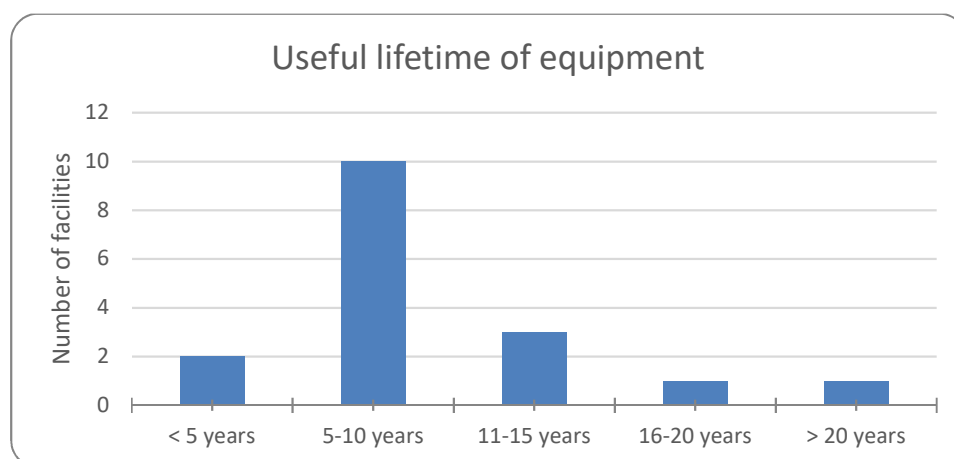


Figure 3. Useful lifetime of equipment

Financial estimate of future investment needed over five years

Twenty-three of the 55 facilities responding to the survey provided financial estimates of future investment needed over the next five years. That investment is in the region of £50.6 million. Two organisations identified investment 'in the hundreds of thousands' so it can confidently be said that this portion of the heritage science research infrastructure has identified investment needs in excess of £51 million within the next five years.

Of the other 32 facilities, five stated no investment needs (or planned investment); twenty have identified investment needs in terms of equipment/capability development but have not given a financial estimate; the remaining seven facilities have not provided information on future investment needs.

Reasons for investment

In addition to estimating the financial investment needed over the next five years, the survey asked for a description of what the investment was needed for. Three broad areas of investment can be identified from the responses (respondents could choose more than one area): maintenance and upgrades, replacing existing equipment, and development of new capabilities.

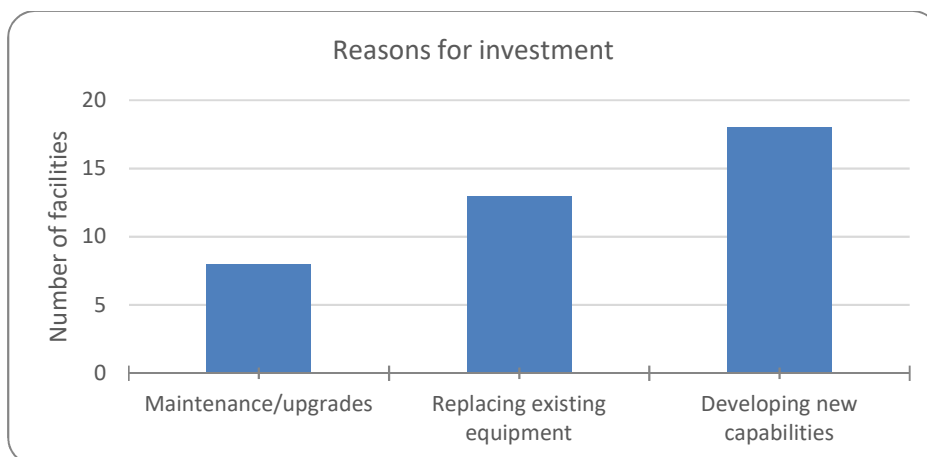


Figure 4. Reasons for investment

Amongst the new capabilities that facilities would like to develop there are repeated requirements for:

- Portable instrumentation
- Improvements in / new equipment for non-destructive analysis
- Spectroscopy equipment
- Micro-fading equipment
- Raman (especially portable)
- Imaging and data analysis infrastructure
- Improvements to digital recording and storage capability
- Supporting e-infrastructures (for storage and access)
- Digital preservation of emerging formats
- Data-driven research, AI and machine learning

In broad terms, it appears that heritage organisations have the greatest need for investment in replacement of (relatively small pieces of) equipment; facilities operating from publicly funded organisations want to address their capability to generate, manage and provide access to data; and higher education institutions are seeking to investment in capability to develop new techniques, improve workflows and expand their investigative research capability.

Several facilities also identified investment in expertise as part of capability development; this included investing in staff with knowledge of particular analytical techniques (most often to complement existing research strengths), or investment in technicians to support operations and facilitate the development of access and commercial services.

5.5 Access to other heritage science capabilities

In order to build up a picture of current and future community access needs, survey respondents were asked to provide information about the heritage science capabilities that they access elsewhere.

5.5.1 Facilities regularly engaged with for collaborative research

In the first instance, they were asked what facilities their researchers regularly engage with for collaborative research (both within their own institution and external to it).

All but four of the fifty-five facilities provided information on the other facilities that they engage with. In some cases, just the name of the organisation/facility has been provided but most people have also provided a description of the techniques or expertise that they access.

The type of facility (or service) that people are accessing externally is influenced by what they already have access to in their own facility, so it is difficult to present a succinct picture of who uses what and where. Repeated mention is made of access to large-scale facilities such as ISIS and Diamond Light Source, as is access to mass spectrometers (located at a variety of facilities).

UK organisations with which respondents regularly engage have been included in Appendix 3 (and mapping in figure 1) of organisations with heritage science research capability that did not complete the survey. It is clear from the responses that people are using the wider research infrastructure and regularly accessing equipment and expertise outside of their own facility.

Facilities also made reference to use of networks and organisations that facilitate collaboration including:

- ColArt
- Consortium of European Taxonomic Facilities (CETAF)
- G12 Group of leading natural history museums
- Independent Research Organisation Consortium
- National Heritage Science Forum
- SYNTHESYS (EU-funded initiative)
- UCL Centre for Science & Engineering in Art, Heritage and Archaeology (SEAHA)

Although this study focuses on infrastructure in the UK, responses to the survey also give an insight into some of the international collaboration that benefits the sector. The strength of international collaboration is particularly apparent when reviewing the project track record raw data.

5.5.2 Research capability/facility access needs

Complementing the question about facilities with which researchers regularly engage for collaborative research, the community was also asked to identify the research capabilities/facilities it would like to have access to and, considering the research regularly undertaken within the facility itself, what research facilities or capabilities it struggles, or finds impossible, to access in the UK.

Access needs were identified that relate to equipment and techniques, to knowledge and expertise, as well as what might best be described as a number of strategic access needs.

Equipment and techniques

Large-scale facilities

Easier access to Electron microprobe mineral analysis

Wider access to ICPMS and GC-C-IRMS

PIXIE

Access to micro X-Ray Diffraction at a synchrotron facility (e.g. Diamond)

Synchrotron and dating facility

Synchrotron

IR and other beamlines suited to collection sample types

More regular beamline access (Diamond is hard to get in to)

Access to Prompt Gamma Activation Analysis (Neutron Reactor) – previously accessed at the Budapest Neutron Centre via CHARISMA, but access is dependent on success of grant application which makes planning of research challenging.

Industrial CT scanning

CT

X-ray scattering

Portable instruments

MicroCT

Mobile X-Ray facilities

Portable radiography

Portable XRD

Spectroscopy

SEM facilities that can be used on live specimens

Difficult to access GC-MS, HPLC-MS and some spectroscopic methods (as these tend to require significant background knowledge and infrastructure)

Laser-induced breakdown spectroscopy (LIBS)

Separation techniques (HPLC/GCMS etc.) for dye analysis and related analyses

Advanced mass spectrometry techniques, e.g. proteomics

Microfading

Microfader accelerated method

Microfading facilities

Imaging

High resolution laser scanning

Combined imaging and chemical/physical analysis (IR-AFM etc.)

IR mapping imaging; multispectral imaging, XRF mapping

Scanning, imaging as well as facilities to store, manipulate, reinterpret and reuse digital collections.

Hyper spectral imaging/ multi spectral imaging

Diffusion and surface science techniques

Other

Trace analysis for organic molecules

DNA sequencing

Better accelerated ageing facilities

Increase facilities for radiocarbon dating including radiocarbon dating of single compounds.

Instrumental methods for masonry moisture monitoring

Visible light emission measurement facility for light sources assessment

Display case volatile acids and aldehydes monitoring services

Nanoindentation and mechanical/thermal techniques

Knowledge and expertise

Expertise

Expertise to support our work including knowledge exchange

High specificity mass spectrometry and chemometrics experts
Access to raw materials included in art (e.g. additives in paints, plastics, industrial products)
Product development expertise

Access to knowledge-bases

Access to various ARCHLAB facilities
Easier access to the Hamilton Kerr Institute paint manufacturer archives (which needs considerable investment to make it more widely accessible)
MuSIS (Historic Environment Scotland)
Extensive access to ARCHLAB facilities in the UK, ranging from historic buildings to archives.
Access to ARCHLAB facilities to carry out imaging on real objects and samples for scientific research.
Access to samples held in archaeological repositories and museums.
Online access to technical scientific literature
Access to DIGILAB facilities to store, manage and reuse heritage science data.
Access to DIGILAB facilities for the purpose of storage, reuse and repurposing of imaging

Capacity

Qualified UK candidates for PhD positions
More positions for 5 years, and permanent Heritage Scientist posts

Strategic

Analysis of large multi-dimensional datasets generated by our facilities could be aided by access to high performance computing facilities.
Access to a pool of digital tools, e.g. for advanced processing of scientific data or better documentation.
Digital and genetic access to natural science collections (currently being developed within Europe as part of the Natural History Museum's participation in DiSSCo (Distributed System of Scientific Collections)¹⁸.
Funding for digitization (many funders support the development of associated infrastructure, but funding actual digitization is a significant limiting factor).
Facilities that link to the Industrial Strategy, Innovate UK and Knowledge Transfer Network.
Links with the new Geospatial Commission.

5.6 Infrastructure development

Whilst some of the facilities that have responded to this enquiry on UK heritage science research capability are recognisable as infrastructure providers to a wider research community, others will require investment to develop the access potential of their facilities in order to regularly serve a wider research community beyond current engagement through collaborative projects. The UKRI landscape analysis (2018) identifies three requirements as part of its definition of a research and innovation infrastructure¹⁹:

¹⁸ DiSSCo (Distributed System of Scientific Collections) <https://dissco.eu/>. Accessed 07/01/2019
DiSSCo will provide comprehensive services for unified digital, physical and remote access to all major European collections; training and support covering formal and professional training activities, tooling them up to effectively navigate big-data generated through bio- and geo-diversity research; joint research programming supporting innovation-led joint science programmes, building on the combined capacity of hundreds of European institutions; and policy harmonization to provide an integrated and simplified policy framework for digitization, access and training.

¹⁹ UKRI Infrastructure roadmap: initial analysis of infrastructure questionnaire responses and description of the landscape (2018), <https://www.ukri.org/files/infrastructure/landscape-analysis-2-pdf/> Accessed 07/01/2019.

Requirement 1: purpose

An infrastructure must provide an essential platform to conduct or facilitate excellent research and innovation that benefits the UK as demonstrated by independent assessment such as peer review. This could be through provision of equipment, facilities, analytical services, data and underpinning infrastructure. This might be encapsulated within a facility R&I organisation or part of an organisation.

The infrastructure should be regarded and operated as a strategic capability enabling collaboration, supporting provision of specialist and technical needs and providing innovation in service support (e.g. regulatory compliance) which leads to efficiency of operation and reduced duplication (e.g. unique critical mass, coordination, scheduling).

Requirement 2: accessibility

An infrastructure must provide access, resources or related services to the wider, UK research and innovation community outside the infrastructure institution itself.

Requirement 3: scale and longevity

An infrastructure must have some degree of strategic, international or national importance. Some infrastructures which are currently regionally important but in key areas of emerging capability might also be captured.

- Assessed as critical for UK research and innovation excellence in one or more sectors (considered at frontier of knowledge, addressing the most pressing challenges, demonstrable UK leadership, cutting-edge quality, importance and relevance to one or more fields)
- Assessed as beneficial for UK research and innovation impact: This would include relevance and alignment with HMG economic and societal challenges and priorities. Evidence of importance to user community through a range of pathways including leverage of co-funding, role an infrastructure plays both within the local economy and at a national level

In addition there is an implicit expectation that short term, focused projects without long term sustainability (existing or planned and relative to asset and technology life-cycles) would not be within scope.

Analysis of the facilities that completed the survey against these three requirements shows that there is a relatively small number that can be considered infrastructure providers, these are:

- Historic England Archive (ARCHLAB)
- ISIS Neutron and Muon Source (FIXLAB)
- UCL Mobile Heritage Lab (MOLAB)
- SUERC Radiocarbon and Stable Isotope Laboratory (FIXLAB)
- RLAHA, University of Oxford (FIXLAB)
- Archaeology Data Service, University of York (DIGILAB)
- The British Library (ARCHLAB, DIGILAB)

In addition the following facilities, (identified through secondary research but which did not contribute to the survey) could be considered as infrastructure providers within the heritage science domain:

- [Diamond Light Source Ltd](#) (FIXLAB)
- [Museum of London Archaeological Archive](#) (ARCHLAB)
- [Centre for Human Bioarchaeology](#) (ARCHLAB) – including the Wellcome Osteological Research Database
- [Sheffield Centre for Archaeobotany and ancient Land-use, University of Sheffield](#) (ARCHLAB)
- Facilities listed as being part of the [National Zooarchaeological Reference Resource](#) (ARCHLAB) (see <https://doi.org/10.5284/1043267>)

Of the 23 facilities that were identified in section 5.4.4 as having the potential to provide sustained access to external researchers, (subject to investment), 12 are within publicly funded (heritage) organisations and 11 are within higher education institutions; 15 broadly fit under the 'FIXLAB' platform, five under the 'ARCHLAB' platform, two under 'DIGILAB' and one has the potential to provide access services through all four E-RIHS platforms.

6 Conclusions

The landscape analysis reveals numerous centres of national and international excellence in heritage science research and innovation. UK heritage science research capabilities are diverse in geographical distribution, in the types of organisation that host facilities and in the broad range of equipment, techniques and expertise that is used together to better understand, preserve and provide access to heritage.

The infrastructure is immature but has potential for development, particularly in terms of opportunities to engage a much wider research community in inter-disciplinary heritage-based research. It currently operates as a distributed network made up of providers of recognisable infrastructure services, centres of high calibre research (many of which already provide access to their facilities when funded), and heritage organisations (some of which have the potential to provide services as part of a wider infrastructure and others that are more likely to participate as users of infrastructure).

The research has identified four key areas of opportunity for infrastructure development.

1. *Coordination is necessary to maximize the operation of facilities as an integrated infrastructure*

Coordination is needed to effect a change from a network of distributed research centres to effective operation as an infrastructure by building the connections between research capabilities and making the infrastructure as a whole more visible.

Collaboration is a feature of the heritage science research landscape and there is clear evidence of researchers accessing equipment, techniques and expertise from across a distributed research infrastructure. However, that infrastructure is not particularly well defined nor accessible at present. Investment in coordination of the infrastructure to clarify the complementarity and interoperability between research facilities would strengthen the infrastructure as a whole and enable better information on access facilities, services and potential applications to be provided to the wider research community.

2. Investment in staffing will be critical to opening up access to facilities (particularly FIXLAB and MOLAB facilities)

At present the research capabilities of many organisations (particularly heritage organisations, whether publicly funded or not) are operating at full capacity, in that they are entirely devoted towards research and heritage science activities within the facility's institution, limiting their potential as part of a wider infrastructure. For example, some organisations used the 'ARCHLAB' category to describe the access facility they can provide, although it is evident that other capability exists (e.g. FIXLAB, MOLAB) to support internal institutional research needs. For these organisations external access to facilities appears to be dictated by funded research projects and there is currently little capacity to engage in the provision of unresourced access services even at a low level.

Investment in staff (to provide the training, supervision, administration associated with the operation of an access platform that is available to the wider research community) is likely to be the greatest need to bring existing FIXLAB and MOLAB facilities into a shared infrastructure. Not only will there be a need for an increase in technical staff to operate the access services but there will also be a need for facilities to develop a good understanding of the cost of provision of services and in some cases, a more structured approach to the maintenance and renewal of equipment (especially if there is the potential for it to be used more intensively if offered as part of an access facility). Data on costs of access was only provided by about half of the respondents to this survey. This could be a consequence of the time of year at which the survey was carried out (limiting respondents' time available to work the figures out) but it seems likely that in many cases the information will not exist because services have not previously been provided to the wider research community.

3. Investment is needed to support the development of individual facilities, but it should also be directed towards facilitating greater access to large national facilities

Individual facilities have identified a variety of investment needs to improve the way they operate and to support future innovation and development of research capabilities. With support, such facilities could of course be accessible as part of the shared infrastructure. In terms of cross-community infrastructure needs, greater ease of access to the very large facilities such as ISIS and Diamond Light Source has been identified. There are also widespread requirements for access to portable instrumentation, imaging and spectroscopy equipment.

4. ARCHLAB/DIGILAB resources are least well developed and are ripe for transformation

The greatest overall community need relates to the development of, and access to, ARCHLAB/DIGILAB facilities. Access to ARCHLAB facilities is mentioned frequently in response to the question about capabilities that people would like to have access to, but currently struggle or find impossible to access in the UK.

It is thought that the existence of ARCHLAB facilities is under-reported in this landscape analysis. Where such facilities have been reported, the need for investment in digital infrastructure has also been identified to support increased access. Development of ARCHLAB/DIGILAB facilities (i.e. virtual provision to reference resources - but also potentially to support knowledge transfer and virtual access to the world-class expertise that exists in the UK) should be a priority area for development as part of the UK's heritage science research infrastructure. The creation of additional digital infrastructure needs to be done with regard to the FAIR principles²⁰, so that investment in digitization and digital access is sustainable, and the long-term preservation of data is ensured.

²⁰ FAIR principles: Findable, Accessible, Interoperable and Re-usable

Appendix 1 UK Heritage Science Infrastructure Capabilities Survey

Aims

This survey aims to understand current heritage science research infrastructure capabilities providing shared access in the UK, to ascertain current and future community needs and to identify key gaps. It is being carried out on behalf of the UK Infrastructure and Access Working Group of UK-RIHS.

We want to understand

- State-of-the-art - what research capabilities are currently available?
- Gaps - what research capabilities are needed now? What is missing from the current heritage science provision?
- Future investment and infrastructure development - what research capabilities are necessary in the future?

We therefore seek your input to this survey of UK heritage science infrastructure through provision of information on the facilities (equipment, tools and expertise) within your institution that are available for use by the wider research community.

Research Capabilities – introducing the four-platform typology

The European Research Infrastructure for Heritage Science (E-RIHS) is an international Research Infrastructure initiative with a vision to transform research on heritage interpretation and management. E-RIHS aims to connect researchers in the humanities and natural sciences to foster scientific excellence and innovation, build connected research capabilities, and pioneer interdisciplinarity, co-creation and research excellence.

E-RIHS uses a four-platform typology to categorise different types of research capability, or 'facility'. The collection of these capabilities, spread across the four integrated platforms (or 'LABs'), makes up the infrastructure which can include major research equipment (or sets of instruments), knowledge-based resources such as reference collections, archives and data, and e-infrastructures. A single institution may have several research capabilities across one or more of the following platforms relevant to heritage science research.

(i) E-RIHS **ARCHLAB**

An ARCHLAB provides access to physical collections, such as objects, technical images, samples and reference materials, analytical data and conservation documentation, as stored in museums, galleries and research institutions.

(ii) E-RIHS **DIGILAB**

A DIGILAB provides online access to digital tools concerning heritage and data, with the aim of making it FAIR (Findable, Accessible, Interoperable and Re-usable). This includes and enables access to searchable registries of datasets, reference collections, thesauri, ontologies etc., and supports data interoperability through the creation of shared knowledge organization systems. It can include online data processing software.

(iii) E-RIHS **FIXLAB**

FIXLAB describes large-scale and medium-scale fixed facilities – e.g. particle accelerators, neutron and laser sources and other essentially immovable research facilities including the associated unique expertise.

(iv) E-RIHS **MOLAB**

MOLAB is access to a comprehensive selection of mobile analytical instrumentation for non-invasive measurements on objects, buildings, and sites, allowing the implementation of complex multi-technique diagnostic projects for in situ investigations. It describes the totality of the facility (i.e. it includes the mobile equipment, transport, unique expertise and fixed facility (lab) that supports the maintenance of the equipment) as one entity.

When thinking about what constitutes a 'facility' respondents should consider how the wider research community uses it; this will help to define the package of equipment, techniques, or expertise that is available from the facility.

You may find the information provided by ORCID about research resources helpful in terms of definitions <https://orcid.org/organizations/research-orgs/resources>. Alternatively we would be happy to put you in touch with a member of the working group to discuss your institution's research capabilities and how they align to the E-RIHS typology.

Background – why this information is being collected and how it will be used

The Infrastructure and Access Working Group of the UK national hub of the European Research Infrastructure for Heritage Science (www.e-rihs.ac.uk) was established to support the development of E-RIHS.uk by **setting out a plan for heritage science research infrastructure in the UK**.

The information collected through this survey will be used to inform that plan, which will:

- Show what research capabilities are currently available (see the explanation of the four platforms above)
- Show where there are gaps in research capabilities
- Build an understanding of investment and infrastructure development needs to support future research capabilities.

The data is being collected over a short time period (November-December 2018) to inform a report by the Working Group to the UK-RIHS steering group early in January 2019.

UK partners of E-RIHS:

The British Library
The British Museum
Cardiff University
Diamond Light Source
Historic England
Historic Environment Scotland
ISIS Neutron and Muon Source
The National Gallery
Nottingham Trent University
Scottish Universities Environmental Research Centre
UCL (University College London)
University of Bradford
University of Brighton
University of York

Data protection and further information

The data submitted will be used to understand the current UK heritage science capabilities, to ascertain current and future community needs and to identify key gaps. Data will be processed by Preservation Matters Ltd until 10 January 2019 to understand the current provision of access services and future research needs; provide an analysis of the current state-of-the-art within the heritage science sector; and prepare a report based on the research data collected and secondary sources.

The research data will be made available to the E-RIHS Infrastructure & Access Working Group members for the purposes of analysis until the end of E-RIHS Preparatory Phase (January 2020).

Personal data collected through this survey includes the name of the person completing the survey and their work contact information (address, email address, telephone number).

Completing this form and contact details

This form is distributed as a Word document for ease of completion. Please fill in as much of it as you can by the date given in the covering email. We have given guidelines on the amount of content to include.

Some institutions may have several facilities. If this is the case, you can either distribute the form within your organisation for completion by the most appropriate individual. Or you can copy/paste sections 2/3 of the form and provide a collation of information on the facilities available within a single form.

If you would like help completing the form, or to discuss answers, please email Caroline Peach caroline.peach@preservationmatters.co.uk. We would be happy to make an appointment to talk you through the completion of the form.

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| SECTION 1 - GENERAL INFORMATION |
| Facility name <i>This is the name of the research centre, collection or equipment you will be providing information about. (If you will be entering multiple facilities, please list all facility names here.)</i> |
| Institution <i>Please enter name of institution</i> |
| Contact details <i>For the person completing this form The contact details given here may be used to clarify information submitted in this form.</i> |
| <i>Contact person: Work e-mail: Work phone number:</i> |
| Location <i>Please provide information about the locations of facility (and first half of postcode)</i> |
| Eligibility for UKRI funding <i>Please indicate yes or no (eligibility) and specify if not an HEI or IRO</i> |
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| SECTION 2 - ABOUT THE FACILITY |
| <i>Please only provide information about one facility in this section. If you would like to submit information on several facilities, please copy/paste the blue section of this form (section 2) so that you can complete a separate 'section 2' for each facility.</i> |
| Facility name |
| |
| Access platform <i>Please specify if the facility provides access within MOLAB, FIXLAB, DIGILAB and/or ARCHLAB (see page 1-2 for definitions of the 4 platforms)</i> |
| |
| General description of facility and provider |

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| <p><i>Please provide a short description (up to 10 lines of text) of the key capabilities of the facility. What are its main points of excellence and why (e.g. standards met, areas of national/international importance)?</i></p> <p><i>What equipment, infrastructure, and expertise does the facility consist of, in non-technical language?</i></p> |
| <p style="text-align: center;">Summary of potential applications</p> <p><i>Please list the key research applications of the facility (up to 10 lines of text). Please specify what kind of heritage science research is possible using the facility.</i></p> |
| <p style="text-align: center;">Technical description</p> <p><i>What individual pieces of equipment does the facility consist of? Is the equipment, as part of the facility, a custom-made prototype? If not entirely, estimate the extent to which it is custom-made.</i></p> <p><i>Please provide more detail about techniques and their related applications for the separate pieces of equipment (if necessary). Please provide information on typical experimental setup e.g. sample requirements, environmental and geometrical constraints, accuracy and other metrological details. Please provide information on the typical duration of an experiment.</i></p> |
| <p style="text-align: center;">Value</p> <p><i>Please estimate the total value of the equipment on offer as part of the facility, (this should not include building/ building management/running costs). Please provide information about the capital investment, running costs (annual) and typical unit cost. Please estimate the cost of providing access (e.g. cost per sample including all preparation and data interpretation activities).</i></p> |
| <p style="text-align: center;">Future investment needed</p> <p><i>Please state when the equipment was purchased and its useful lifetime. Please provide information about the financial estimate for future investment (cost over 5 years). Please specify why this investment is necessary (e.g. development of new methods, maintenance, innovation, prototype instrumentation). What capabilities (infrastructure and/or expertise) would you like to develop in the next 5 years?</i></p> |
| <p style="text-align: center;">Conditions of access</p> <p><i>e.g. transportation, insurance, training, safety and other requirements. Please focus your answer on the facility as a whole, and specify if other/specific requirements relate to particular pieces of equipment.</i></p> |

[PLEASE COPY/PASTE SECTION 2 AS MANY TIMES AS NECESSARY TO PROVIDE INFORMATION ON DIFFERENT FACILITIES AVAILABLE AT YOUR INSTITUTION]

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| SECTION 3 - ABOUT THE TEAM |
| <i>Please only provide information about one facility's team in each box. If you have provided information about multiple facilities under section 2, please copy/paste and fill out a new 'Section 3 - About the Team' table for each facility.</i> |
| <p style="text-align: center;">Facility team</p> <p><i>Please provide a short description (up to 10 lines of text) of key roles and brief team profiles. Please include information on key individuals. If you are providing information on more than one facility, please state which facility the team relates to.</i></p> |
| |
| <p style="text-align: center;">Highlight expertise</p> <p><i>What is the facility's specific expertise? What are the key capabilities? (up to 10 lines of text)</i></p> |
| |
| <p style="text-align: center;">Project track record</p> <p><i>Please list projects specific to the facility, as well as how they were funded, e.g. AHRC/EPSRC/H2020 etc. Please give a selection of relevant publications.</i></p> |
| |
| <p style="text-align: center;">Other comments</p> |
| |

[IF YOU HAVE PROVIDED INFORMATION ON MORE THAN ONE FACILITY, AND THERE ARE DIFFERENT TEAMS ASSOCIATED WITH EACH FACILITY, PLEASE COPY/PASTE SECTION 3 AS MANY TIMES AS NECESSARY TO PROVIDE INFORMATION ON THE DIFFERENT TEAMS]

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| SECTION 4 - ACCESS TO HERITAGE SCIENCE CAPABILITIES |
| <p style="text-align: center;">Current access to heritage science capabilities</p> <p><i>What facilities do your researchers regularly engage with for collaborative research (both within your institution and external to it)?</i></p> |
| |
| <p style="text-align: center;">Access needed</p> <p><i>What research capabilities/ facilities would you like to have access to? Considering the research regularly undertaken within your facility, what research facilities or capabilities do you struggle or find impossible to access in the UK?</i></p> |
| |

Thank you for completing this form.

If you have any outstanding questions, or have found any sections difficult to complete please email Caroline Peach (caroline.peach@preservationmatters.co.uk) who would be happy to arrange a follow-up telephone call to provide clarification or help you to complete the form.

Please email completed forms to Caroline Peach, caroline.peach@preservationmatters.co.uk

Appendix 2 List of heritage science research facilities that completed the survey

| Facility name | Institution |
|--|--|
| ACNMW PANalytical X'Pert PRO X-RAY Diffraction unit | Amgueddfa Cymru - National Museum Wales |
| Cardiff University Conservation Laboratories | Cardiff University |
| Conservation Research lab | English Heritage |
| ARCHLAB: Environmental Studies | Historic England |
| FIXLAB: Conservation | Historic England |
| FIXLAB: Environmental Studies | Historic England |
| FIXLAB/MOLAB: Material Science | Historic England |
| Geophysics | Historic England |
| Geospatial Imaging | Historic England |
| Historic England Archive | Historic England |
| The Engine Shed | Historic Environment Scotland |
| Conservation and Collections Care Scientific Laboratory | Historic Royal Palaces |
| Conservation Hangar, Hangar 5, IWM Duxford | Imperial War Museums (IWM) |
| Conservation Studio, Building 6, IWM Duxford | Imperial War Museums (IWM) |
| National Gallery Scientific Department (ARCHLAB) | National Gallery |
| National Gallery Scientific Department (FIXLAB/MOLAB) | National Gallery |
| National Museums Scotland Collections Centre | National Museums Scotland |
| Preventive Conservation | National Trust for England, Wales and Northern Ireland |
| Digital Collections Programme | Natural History Museum (NHM) |
| Imaging and Analysis Centre | Natural History Museum (NHM) |
| The Conservation Centre | Natural History Museum (NHM) |
| Imaging & Sensing for Archaeology, Art History and Conservation (ISAAC) MOLAB | Nottingham Trent University |
| Imaging & Sensing for Archaeology, Art History and Conservation (ISAAC) FIXLAB | Nottingham Trent University |
| ISIS Neutron and Muon Source | Science and Technology Facility Council (STFC) - UKRI |
| Conservation Archive | Tate |
| Conservation Science Labs | Tate |
| The British Library (ARCHLAB) | The British Library |
| The British Library Collection Care | The British Library |
| The British Library Digitisation Studio | The British Library |
| The British Library datasets | The British Library |
| Datacite | The British Library |
| Shared Open Repository for Heritage | The British Library |
| Department of Scientific Research | The British Museum |
| Collection Care Department Analytical Lab | The National Archives |
| <i>UCL Collections ARCHLAB</i> | UCL |
| <i>UCL Heritage Imaging Facility</i> | UCL |
| <i>UCL Mobile Heritage Lab</i> | UCL |
| <i>UCL Preventive Conservation Lab</i> | UCL |

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| E&MC ² Integrated 2 Environmental Chambers with Mechanical Testing Frames | UCL - Department of Civil Environmental Geomatic Engineering |
| Luminescence Laboratory | Universities of Glasgow |
| Radiocarbon and Stable Isotope Laboratory | Universities of Glasgow |
| Radiogenic Isotope Laboratory | Universities of Glasgow |
| Organic Geochemistry Unit | University of Bristol |
| Bristol Radiocarbon Accelerator Mass Spectrometry Facility (BRAMS) | University of Bristol |
| Fitzwilliam Museum | University of Cambridge |
| Hamilton Kerr Institute | University of Cambridge |
| Ashmolean Museum | University of Oxford |
| Bodleian Libraries | University of Oxford |
| RLAHA | University of Oxford |
| SoGE | University of Oxford |
| Archaeology Data Service (ADS) | University of York |
| BioArCh | University of York |
| NEaar (North East Amino Acid Racemisation) | University of York |
| Science Laboratory, V&A | Victoria and Albert Museum |
| Conservation Laboratory | York Archaeological Trust |

Appendix 3 Organisations with heritage science research capability that did not complete the survey

(Figure 1 – mapping of geographical distribution of research capability)

| Institution |
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| Aberystwyth University |
| Birkbeck College, University of London |
| British Bryological Society |
| British Geological Survey |
| Centre for Ecology and Hydrology |
| Centre for Human Bioarchaeology |
| Courtauld Institute of Art |
| Crick Institute |
| Diamond Light Source Ltd |
| Heriot Watt University |
| Imperial College London |
| King's College London (Digital Humanities) |
| Mary Rose Museum |
| Museum of London – Archaeological Archive |
| Museum of London – Collection Care/ Conservation |
| National Galleries of Scotland |
| National Library of Wales |
| National Museums Liverpool |
| National Museums Northern Ireland |
| NERC stable isotope mass spectrometer |
| Queens University Belfast |
| Royal Museums Greenwich |
| Rutherford-Appleton Laboratory |
| Science Museum Group |
| Southampton University |
| The James Hutton Institute, Aberdeen |
| University of Bradford |
| University of Brighton |
| University of Cambridge (Department of Archaeology, Department of Earth Sciences, McDonald Institute for Archaeological Research) |
| University of Durham (Department of Archaeology) |
| University of Edinburgh (Digital Cultural Heritage) |
| University of Glasgow (Centre for Textile Conservation) |
| University of Liverpool |
| University of Manchester (Biomolecular Archaeology Research Group) |
| University of Northumbria |
| University of Sheffield – Archaeomaterials Laboratory |
| University of Stirling |
| University of Strathclyde |
| University of York – Centre of Excellence in Mass Spectrometry |
| Wellcome Collections |
| Wellcome Sanger Institute |

Appendix 4 Individual heritage science research capabilities/facilities

The individual facilities that responded to the survey are listed below in alphabetical order by host institution.

| Host Institution | Facility and description |
|--|--|
| Amgueddfa Cymru – National Museum Wales | ACNMW PANalytical X’Pert PRO X-RAY Diffraction unit (FIXLAB) X-ray diffraction facility for identification of crystalline materials with applications for geology, archaeology and conservation (identification of materials, including fabrication and decay). |
| Cardiff University | Cardiff University Conservation Laboratories (FIXLAB) Suite of 11 teaching and analysis laboratories equipped to image, identify and characterise material properties, performance, decay routes and rates. World-leading for investigation into corrosion rates of archaeological and historical iron. |
| English Heritage | Conservation Research Lab (MOLAB, FIXLAB) Portable suite of equipment, tailored to investigating environmental interaction in 130 museums and stores cared for by English Heritage. Fixed ion chromatography. |
| Historic England | <p>Conservation (FIXLAB) Laboratory for analytical and conservation work on marine, listed and at-risk historic sites, buildings and wrecks.</p> <p>Environmental Studies (ARCHLAB) Collections of national importance for archaeological research. Of particular significance is the zooarchaeology reference collection (c.3000 accessions representing 390 different taxa), archaeobotanical collection (c.5000 specimens), archaeological human skeletal remains.</p> <p>Environmental Studies (FIXLAB) National facility for the study of human-environmental interactions over time. Co-located with other research disciplines and facilities which provides conjoined insights into the understanding of the historic environment.</p> <p>Geophysics (MOLAB, FIXLAB) Facility for high resolution survey at landscape scale. Imaging and site characterisation. Some facility for laboratory analysis (archaeomagnetic and magnetic minerals).</p> <p>Geospatial Imaging (MOLAB, FIXLAB) Geospatial imaging team for survey of historic objects, buildings and landscapes.</p> <p>Historic England Archive (ARCHLAB, DIGILAB) Major collections of national importance, covering archaeology, architecture, social and local history. Includes photographs, drawings, plans and documents. Over a million records can be searched online. The Aerial photographic collection contains over 4 million images covering the whole of England.</p> <p>Material Science (FIXLAB, MLOAB) Laboratory focusing on scientific research into archaeological objects, mainly metal and glass and waste (slag) from production. Particular expertise in application of XRF and XRD (especially portable XRF). Holds several thousand samples taken from archaeological artefacts, tools and production waste from metal and glass manufacture. This research collection is available for study by prior arrangement.</p> |
| Historic Environment Scotland | The Engine Shed (FIXLAB, DIGILAB, MOLAB, ARCHLAB) The Engine Shed is Historic Environment Scotland’s centre for technical conservation research and education. It has public access to permanent and topical exhibitions, is a venue for training, education and traditional skills, and has research facilities in Heritage Science and Digital Technology. There is international expertise in Digital Documentation (including 3D laser scanning), Heritage Science (in particular stone conservation) and Climate Change. |
| Historic Royal Palaces | Conservation and Collections Care Scientific Laboratory (MOLAB, FIXLAB, ARCHLAB) |

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| | <p>Laboratory supporting research to conserve the institution's historic buildings, collections and archaeological evidence.</p> <p>Track record in national and international multi-disciplinary research projects.</p> |
| Imperial War Museums | <p>Conservation Hangar, Hangar 5 (ARCHLAB, DIGILAB)</p> <p>Facility for Conservation Engineering team work on large objects: assessment, analysis, conservation.</p> <p>Conservation Studio, Building 6 (ARCHLAB, DIGILAB)</p> <p>Conservation studio facility for assessment, analysis and conservation of IWM collections.</p> |
| National Gallery, London | <p>National Gallery Scientific Department (ARCHLAB)</p> <p>Large archive of documentation from technical examination and conservation of the institution's world-class collection of Western European paintings.</p> <p>National Gallery Scientific Department (FIXLAB, MOLAB)</p> <p>Specialist laboratories for research on painting materials, including equipment for detailed analysis of paint samples, non-invasive analysis on paintings and advanced imaging techniques of various kinds.</p> |
| National Museums Scotland | <p>National Museums Scotland Collections Centre (FIXLAB, ARCHLAB, DIGILAB)</p> <p>NMS-CC is the RII for National Museums Scotland (NMS), Edinburgh, UK with collections of national and international importance. The Collection Centre has facilities for undertaking research on collections, as well as conservation and scientific research laboratories. Analytical equipment ranges from PDA-UPLC, XRF, SEM-EDX to XRD and FTIR. In addition, National Museums Scotland maintains an online repository of its collections and, separately, its research outputs.</p> |
| National Trust for England, Wales and Northern Ireland | <p>Preventive Conservation (MOLAB)</p> <p>Facility to support institutional environmental research and management.</p> <p>Excellence and expertise in devising meaningful experimental investigations to understand and solve building and collections conservation problems. Expertise in deploying sensing equipment and gathering data in historic buildings. Expertise in interpreting data and drawing meaningful, useful conclusions.</p> |
| Natural History Museum | <p>Digital Collections Programme (DIGILAB)</p> <p>The Digital Collections Programme (DCP) was initiated in 2014 to organise the digitisation the Museum's collections of over 80 million specimens and make the data and images publicly available.</p> <p>Over the last four years, DCP has positioned itself among the global leaders in natural collections digitisation with regards to workflow development and optimisation, digital innovation, tool development and digitisation strategy.</p> <p>Imaging and Analysis Centre (FIXLAB)</p> <p>International centre of excellence for Imaging and Analysis specialising in non-destructive or minimally destructive examination of natural samples. The Centre is particularly strong in geochemical and inorganic analyses and in electron microscopy, XRD, micro-CT and electron microprobe micro-analysis.</p> <p>The Conservation Centre (FIXLAB)</p> <p>International centre of excellence for all aspects of natural history conservation and fossil preparation. The team is responsible for the care and preservation of 80 million collection items. The fully equipped facility consists of 4 conservation studios, acids laboratory and 2 quarantine facilities.</p> |
| Nottingham Trent University | <p>Imaging & Sensing for Archaeology, Art History and Conservation (ISAAC) (MOLAB)</p> <p>Facility established in 2006 to develop advanced imaging and sensing instrumentation (hardware, software, data processing and analysis) for application in archaeology, art history and conservation.</p> <p>Access to unique in-house developed instruments and a range of complementary non-invasive techniques for in situ analysis. Particular expertise in OCT systems.</p> <p>Imaging & Sensing for Archaeology, Art History and Conservation (ISAAC) (FIXLAB)</p> <p>ISAAC services (above) can also be provided as FIXLAB.</p> |
| ISIS Neutron and Muon Source (STFC) | <p>ISIS Neutron and Muon Source (FIXLAB)</p> <p>World-leading centre for research in the physical and life sciences.</p> |

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| | <p>ISIS Neutron and Muon Source produces beams of neutrons and muons that allow scientists to study materials at the atomic level using a suite of over 30 instruments operating at two target stations.</p> <p>The facility supports a national and international community of more than 2000 scientists who use neutrons and muons for research in a wide range of disciplines including cultural heritage.</p> |
| Tate | <p>Conservation Science Labs (FIXLAB) Conservation science department that leads and participates in research projects and offers analytical and scientific support to the institution's conservation department. Particular expertise in 20th C and 21st C paints, plastic preservation and other contemporary art materials. Substantial reputation for historic British painting technical art history.</p> <p>Conservation Archive (ARCHLAB) A small archive built up over many decades that includes artists conservation files, artists interviews, paint and materials, paint samples, cross-sections, frames, stretchers, paint tubes, paint swatches and synthetic organic pigments.</p> |
| The British Library | <p>The British Library Collections (ARCHLAB) The British Library's collection includes books, journals, manuscripts, maps, stamps, music, patents, photographs, newspapers, websites, archives and sound. It is estimated that the total collection contains around 200 million items, of which there are over 25 million books, 310,000 manuscript volumes from Magna Carta to the Beatles, 2 billion pages of UK web content, 6.5m audio items, 60 million patents and over 260,000 journal titles. This is the largest national library collection in the world. The Library builds, curates and preserves the UK's national collection of published, written and digital content. The collection contains a large number of unique items across all disciplines – from heritage manuscripts to sounds and web content. The collection is integrated within an extensive infrastructure enabling physical and digital collecting, storage, access, conservation, digitisation and research.</p> <p>The British Library Collection Care (ARCHLAB, DIGILAB) Research into formats, structures, sewing and binding styles, as well as the use and deterioration patterns of substrates and media. Conservation Science and Research – testing materials and researching the underlying properties of materials, using imaging techniques to enhance the interpretation of the Library's collections, environmental assessments and interpretation. Preventative Conservation – risk management, collection disaster and salvage procedures, pest management, handling and use research, including issues linked to digitisation. Digital Preservation - software preservation, representation information registries, digital forensics, emulation, virus checking, information packaging, preservation of mobile eBook apps, format analyses, requirements for the preservation of new and emerging formats of digital content.</p> <p>The British Library Digitisation Studio (ARCHLAB, DIGILAB) Specialist digitisation studios in London's St Pancras or Yorkshire's Boston Spa, each fully equipped with state-of-the-art imaging systems, monitored for light and temperature levels. Covers a range of processes converting physical (or analogue) materials into digital versions which can be understood and stored by computers. Analogue materials can be any item which conveys text, image, sound or video – drawings, manuscripts or recordings.</p> <p>The British Library Datasets (DIGILAB) As part of its work to open its data to wider use, the British Library is making copies of some of its datasets available for research and creative purposes. We aim to describe collections in terms of their data format (images, full text, metadata, etc), licences, temporal and geographic scope, originating purpose (e.g. specific digitisation projects or exhibitions) and collection, and related subjects or themes. They are made available via site www.data.bl.uk – the site is a 'beta', and is in the early stages of development, but is widely used by researchers.</p> <p>DataCite (DIGILAB)</p> |

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| | <p>DataCite provides a way for researchers to obtain credit and recognition for sharing their research data. This is built on the use of digital object identifiers (DOIs) to identify and link to datasets with a unique and persistent identifier.</p> <p>Shared Open Repository for Heritage (DIGILAB) Open repository for UK cultural heritage, including discovery, improvement of reuse by: enhancing/linking metadata (e.g. persistent identifiers); developing a cross-organisational search linked into Google etc and advancing persistent access.</p> |
| The British Museum | <p>Department of Scientific Research (ARCHLAB, FIXLAB) Scientific Research department with staff with strengths in interdisciplinary research and an internationally-renowned reference collection for comparative analysis supported by specialist laboratories and equipment for analysis and imaging.</p> |
| The National Archives | <p>Collection Care Department Analytical Lab (FIXLAB, MOLAB, ARCHLAB, DIGILAB) A growing centre for research excellence in conservation science. Research focuses on material composition and degradation of collection items, together with development of novel treatment strategies, environmental management and preventative conservation research.</p> |
| University College London | <p>UCL Collections ARCHLAB Enquiries are welcomed from researchers who wish to gain access to the collections for study and research. The collections have partially been made digitally available, and the catalogue of UCL collections has been made available online. The collections are available for research, and access may involve the application of scientific research tools.</p> <p>E&MC² Integrated Environmental Chambers with Mechanical Testing Frames (FIXLAB) An integrated system of facilities to provide access to full scale environmental and mechanical testing for the heritage built environment, in one single laboratory. This is a unique facility anywhere in the EU, and globally, fully supported by an highly experienced team of researchers and technicians.</p> <p>Heritage Imaging Facility (FIXLAB, MOLAB) The Facility brings together a number of research labs with complementary technical expertise to provide access to a broader range of imaging and analysis techniques than are available in any single laboratory. There is no similar suite of this complexity anywhere in the EU, possibly globally, with the available computational and imaging expertise. Some elements are easily mobile, some are transportable.</p> <p>Mobile Heritage Lab (MOLAB) A laboratory vehicle to support heritage science field research. It can be equipped for a variety of research projects, drawing from a catalogue of more than 50 portable pieces of equipment. There is no similar mobile facility in the UK or globally. The UCL Mobile Heritage Lab combines scientific expertise and measurement quality with a great degree of mobility. It is equipped with a unique collection of hand-held and portable equipment, including portable versions of commonly “fixed” equipment.</p> <p>Preventive Conservation Lab (MOLAB, FIXLAB, DIGILAB) The Facility consists of fixed and mobile laboratory facilities, as well as online tools and expertise that assist users in the development of preventive conservation strategies for heritage buildings and collections. Strengths include tools for modelling of indoor pollution, particulate matter deposition, collection degradation and damage development and for modelling of building behaviour, energy consumption and associated costs. In addition, the associated expertise involves building physics and engineering, sustainable management of collections, value assessment.</p> |
| Universities of Glasgow | <p>Luminescence Laboratory (FIXLAB) The Luminescence Research Laboratory has an extensive range of equipment for luminescence dating and research, backed by a full suite of sample preparation laboratories, and an unmatched capability for measurement of the environmental radioactivity associated with dating samples.</p> <p>Radiocarbon and Stable Isotope Laboratory (FIXLAB)</p> |

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| | <p>The SUERC Radiocarbon Laboratory consists of the main Radiocarbon group that undertake pretreatment and graphitisation of all samples for dating, the Stable Isotope Laboratory for measuring specifically carbon, nitrogen, and sulphur isotopes in bone collagen for QA of dating and for mobility and diet studies, and finally the AMS group who are responsible for measuring the radiocarbon content of the graphite targets.</p> <p>Radiogenic Isotope Laboratory (FIXLAB) The SUERC radiogenic isotope laboratory is equipped with both thermal ionization mass spectrometers (TIMS) and inductively-coupled plasma mass spectrometers (ICP-MS) allowing access to a wide range of radiogenic isotope applications.</p> |
| University of Bristol | <p>Organic Geochemistry Unit (FIXLAB, (ARCLAB)) The Organic Geochemistry Unit (OGU) is a cross-disciplinary, international research group (~40 members), of over 50 years standing, that uses state-of-the-art analytical techniques to investigate the environment and its inhabitants at the molecular level. OGU research enhances our understanding of the biogeochemistry of contemporary and ancient environments and the way that natural processes and the actions of mankind affect them. This work interfaces with a wide range of fields, in particular: archaeology, palaeoclimatology, environmental science, soil science, forensic science, ecology and geomicrobiology. In particular, the Group pioneered the technique of Organic Residue Analysis, widely used in archaeological research, both academically and commercially.</p> <p>Bristol Radiocarbon Accelerator Mass Spectrometry Facility (BRAMS) (FIXLAB) BRAMS has been established to provide state-of-the-art radiocarbon determinations for biogeochemical and palaeoenvironmental and archaeological research. The facility is built around one of the latest generation of ultracompact MICADAS accelerator mass spectrometers developed by the Laboratory of Ion Physics, ETH Zurich.</p> |
| University of Cambridge | <p>Fitzwilliam Museum (MOLAB, ARCLAB) Comprehensive suite of mobile (largely portable) non-invasive analytical equipment. Expertise in conservation and heritage science of a wide range of museum objects, particularly Egyptian coffins and illuminated manuscripts.</p> <p>Hamilton Kerr Institute (ARCLAB) Holder of technical and conservation archives including archives of: several paint manufacturers (Winsor and Newton archive, Roberson archive, Sheldon/Hassel analytical archive), paint cross-section database, pigment dispersions, retired conservators.</p> |
| University of Oxford | <p>Ashmolean Museum (FIXLAB) Conservation lab and heritage science department which is part of the museum.</p> <p>Bodleian Libraries (FIXLAB) Heritage Science at the Bodleian Libraries covers any research which yields an improvement in the preservation, understanding or treatment of cultural heritage, including reviewing conservation literature, scientific analysis, artificial ageing experiments and real-time condition monitoring.</p> <p>RLAHA (Research Laboratory for Archaeology and the History of Art) (FIXLAB) Archaeological, imaging and photographic equipment and expertise, including: Scanning Electron Microscope and Energy Dispersive Spectrometry, Multispectral and other imaging, Radiocarbon Accelerator Unit, Stable Isotope Analysis, and Tephrochronology and Electron Microprobe. The Radiocarbon unit has over 30 years of experience in the application of radiocarbon dating and associated research.</p> <p>SoGE (School of Geography and the Environment) (FIXLAB, MOLAB) Fixed laboratory and portable instruments suitable for both lab- and fieldwork, along with the relevant expertise are available for the following purposes: Physical and Textural Analysis, Environmental Chemical Analysis, Microscopy and Imaging, Environmental Cabinets, Moisture Analysis, Samples - Environmental Monitoring, Sample Preparation Instruments.</p> |
| University of York | <p>Archaeology Data Services (ADS) (DIGILAB) Open Access digital repository for research data generated by the heritage sector (HEIs, public bodies, commercial) encompassing below and above-ground archaeology and related disciplines.</p> |

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| | <p>BIOARCH (FIXLAB, ARCHLAB) A facility that contains cutting edge laboratories, instrumentation and expertise for the analysis of ancient biomolecules from archaeological remains including bone, artefacts, molluscs, soils and plants tissues. The facility contains instrumentation for light stable isotope analysis (EA-IRMS, 3x GC-C-IRMS) and is the largest of its kind in the UK dedicated to heritage science. There is a facility for proteomics analysis (prep lab and access to protein mass spectrometry facilities) and ancient DNA analysis, plus an extensive vertebrate skeletal reference collection (1925 specimens representing 567 species).</p> <p>NEaar (North East Amino Acid Racemisation) (FIXLAB) The only UK facility for chiral amino acid analysis. The chiral amino acid analysis possible at this facility allows age estimation in fossil samples through amino acid racemization (AAR) alongside other measures of protein breakdown, giving a measure of intra-crystalline protein degradation (IcPD). It also provides essential data on the endogeneity of fossil proteins, providing critical authentication data for proteomic studies. NEaar provides world-leading expertise in sample preparation and analysis of protein within the complex matrices encountered in archaeology and earth science. It is the NERC-recognised facility for amino acid analysis.</p> |
| <p>Victoria and Albert Museum</p> | <p>Science Laboratory (ARCHLAB, FIXLAB) Conservation science laboratory with particular expertise in FTIR and Raman (founding member of the infrared and Raman Users Group). Specific expertise pertaining to the Museum's broad collection and its buildings with emphasis on climate monitoring, evaluation, risk assessment, sustainability and energy efficiency, lighting strategies and solid state lighting developments, object analysis and authentication and preventive conservation.</p> |
| <p>York Archaeological Trust</p> | <p>Conservation Laboratory (ARCHLAB) Two facilities: 1 - a general conservation lab for work on artefacts from archaeological excavations and museums. 2 - a lab with treatment tanks and large freeze-driers to deal with waterlogged structures and artefacts from marine, terrestrial and waterlogged environments. The establishment is one of the main providers of conservation facilities and expertise for marine artefacts.</p> |