



Science and Heritage
Programme

Science and Heritage Programme

Research Programme
Specification March 2009



Arts & Humanities
Research Council

EPSRC

Science and Heritage Programme

Executive Summary

The AHRC/EPSRC Science and Heritage Programme has been established to fund research activities that will deepen understanding and widen participation in research in the field of heritage science. The Programme aims to strengthen and develop the hybrid discipline of heritage science through interdisciplinary research of its different facets, increase the number of researchers in the field and communicate new knowledge to the policy, practice and public domains.

This document sets out the final specification for what the Programme in its entirety will achieve. It builds on the intellectual framework of the Programme and describes the Calls that are now being published: **Interdisciplinary Research Projects** and **Post-Doctoral Fellowships** as well as the competitions that have already been funded: **Collaborative Research Studentships** and **Research Clusters**. It is through these Calls that the research funding from the Programme will be distributed.

Programme Specification

The AHRC/EPSRC Science and Heritage Programme is a 5-6 year strategic initiative that will investigate new relationships between both portable or moveable heritage (e.g. small 3D and 2D objects or collections of objects), and fixed or immovable heritage (e.g. buildings, ruins, monuments, objects in situ, archaeological sites or cultural landscapes), and their meaning, history, value, significance, composition, condition, conservation and use. The Programme will seek to develop a deeper and critical understanding of the whole object. By not only considering the constituent materials of an object but also its context and the cultural and environmental challenges it faces in the 21st century our understanding and the resilience of material culture will be transformed. The Programme will embrace researchers and stakeholders who fall within the AHRC's and EPSRC's subject domains and areas of interest. These include: anthropology, the applied arts, archaeology, archaeometry, art history, architecture, biological sciences, building science, chemistry, computer science, conservation, conservation science, electronic and electrical engineering, environmental design, environmental science, history, management, materials science, mathematics,

philosophy, physics, sensor and instrumentation design, statistics and technology including nanotechnology.

Research in heritage is well established in some specific fields such as archaeological science, building conservation and technical art history. The Programme will seek to support and encourage areas of ground-breaking interdisciplinary research that has not previously received substantial research investment, such as preventive conservation, building science applied to cultural heritage, conservation science, and research which will add to the meaning and appreciation of cultural objects.

The Programme will build on and complement important research that is already being done in, for example: Universities, the National Museums and Galleries, English Heritage and Historic Scotland, CADW: Welsh Historic Monuments and the Environment and Heritage Service (Northern Ireland). Together new knowledge and data will be developed on the characterisation, analysis and interpretation of materials and their production, and their condition and environmental context. The Programme will support proposals that have well-articulated research questions, issues or problems, set clearly in the context of other relevant research and that utilise appropriate research methods and/or approaches in heritage science across the full range of disciplines. The research questions may therefore range from intellectual questions that require critical, scientific or theoretical investigation, to practical issues or problems that require other approaches such as testing, experimental development and evaluation. The outputs of the research funded by the Programme may include peer-reviewed papers, monographs or articles; electronic data including sound or images; films or broadcasts, information technology, technological products, exhibitions, policy documents and public dialogues. It is expected that data generated through projects funded by the Science and Heritage Programme will be made available in a format suitable for inclusion on the European NET-HERITAGE portal which is being developed by AHRC on behalf of a European consortium of 14 national ministries and agencies responsible for research and cultural heritage.

The Programme will encourage new and different approaches to research and communication. It will bring innovative insights into heritage science by addressing various aspects of cultural heritage - historical, physical and environmental - together within one programme. It is intended that new interdisciplinary groups as well as established and experienced groups will

develop their research interests in science and heritage. The purpose is to scientifically analyse, understand, explore, reinterpret and conserve collections, buildings, sites and landscapes, to reach new audiences and to fascinate the public by the juxtaposition of arts and sciences.

The hybrid nature of the Science and Heritage Programme requires an interdisciplinary approach to heritage science research. Interdisciplinarity requires an appreciation of where other disciplines are coming from and a willingness to understand how other disciplines think and work. It requires some learning of other disciplines such as their language, vocabulary, taxonomies and research methods. Projects funded by this Programme are expected to identify among the project collaborators a champion committed to promoting interdisciplinary research and who can demonstrate with examples an interdisciplinary track record.

This document provides information on the remaining competitions under the **Science and Heritage** Programme: Interdisciplinary Research Grants and Post-Doctoral Fellowships, and explains some of the activities to date.

Research under the Science and Heritage Programme, in particular the 'Resilience and Adaptation' theme, will help us understand environmental change and so will also contribute towards the cross-Research Council Programme, Living with Environmental Change (LWEC). More information on LWEC can be found at <http://www.lwec.org.uk/>.

Programme Aim

The Programme will aim to transform our understanding and the resilience of cultural materials in order to be better placed to avoid drastic change in the face of natural, environmental and human challenges in the 21st Century. It will advance and expand knowledge by supporting innovative research, seeking answers to pressing cultural and scientific questions.

Programme Framework

By the end of the five-year period, the **Science and Heritage** Programme will have:

- *Overcome a fragmented research base by developing the hybrid heritage science research discipline:* the Programme will have stimulated high-quality research in the six **Science and Heritage** thematic areas (described below and in the Annex) by drawing on a wide range of discipline based knowledge, resources and skills and undertaking interdisciplinary collaboration among and beyond universities.
- *Developed significant understanding of the relationship between cultural and scientific research questions:* the Programme will have made distinctive contributions to the theoretical, conceptual, applied and empirical study of heritage science. It will have created an arena for shared debate among the arts and humanities and science, technology, engineering and mathematics (STEM) communities on the creation and use of data, evidence, approaches and methods in order to address issues of meaning, interpretation and conservation of those working with museum, gallery, archive and library collections, historic buildings and their contents, archaeological sites and cultural landscapes.
- *Increased the capacity of heritage science:* the Programme will have developed a vibrant research community whose activities will continue beyond the life of the **Science and Heritage** Programme. It will have supported interdisciplinary research projects and built capacity in this field in part by supporting early career researchers and postgraduate students.
- *Addressed national research priorities within an international context:* the Programme will have provided opportunities for critical and creative collaboration among universities, heritage organisations, museums, galleries, archives and libraries, industry and professional bodies in order to generate research findings and outcomes of international significance. Synergies will have been created with research taking place overseas and results will have been disseminated to international audiences both within and beyond academia to influence policy makers and future research priorities both in the UK and overseas.

- *Facilitated connections, communication and exchange:* the Programme will have brought together – at both project and programme levels – academic researchers and a wide range of individuals and organisations outside academia with an interest in the research and its outcomes, including but not limited to those in cultural heritage, museums, galleries, archives and libraries but also public policy and legal sectors, media, industry and commerce.
- *Increased public engagement with science and heritage:* the Programme will have contributed to public awareness of this research through programme and project-based outputs and events.

The Programme as a whole will meet these objectives with contributions from individual projects and leadership from the Programme Director. Projects are expected to demonstrate their contribution in achieving the above, but are not expected to deliver all of the Programme's objectives.

How do we define 'Science and Heritage'?

Society is underpinned by its understanding of history and the quality of society is enhanced by its appreciation of the endeavors of human creativity such as objects held within museum, gallery, library and archive collections, historic buildings, archaeological sites and cultural landscapes. This appreciation, often expressed as values, is in turn profoundly influenced by the survival of the physical artifacts that embody much of cultural heritage. In order for heritage to survive, it needs to be protected, but it will only be protected if it is understood and valued. 'Science and Heritage' brings together the values, meaning, materials and conservation of cultural heritage.

The **Science and Heritage** Programme is arranged around six themes which together capture the cross-domain aspects of 'Science and Heritage':

- Nature of transformation
- Authenticity, authentication and security
- Interpretation and representation
- Cultural encounters and explorations
- Human and machine interfaces

- Resilience and adaptation

To explore the full richness of the Programme, projects under each theme will require arts and humanities, as well as STEM disciplines, to be involved. Though the balance of the full range of disciplines will vary depending on the research question, interdisciplinary research is a requirement of this Programme.

Contributing Disciplines and Collaboration

Heritage science is a complex field, requiring input across the full range of disciplines and practices covered by the AHRC and EPSRC. Drawing together diverse traditions, knowledge, resources and skill, will bring a unique perspective to this challenging area of research. The Programme aims to fund projects that can demonstrate an intention to create a purposeful discourse between disciplines and to recognise possible synergies that flow from the integration of different knowledge and methods. The Programme themes mentioned above and described in the Annex are therefore intended to attract researchers from academic to heritage organisations, to develop interdisciplinary proposals in the broadest sense, that explore or address questions that involve the subject areas of both AHRC and EPSRC. We expect to fund a range of basic, applied, theoretical and empirical research, and research where practical applications are integral. Research is intended by the Programme to be international in scope at a project level.

The Programme wishes to attract researchers and practitioners from a number of different types of research organisations (higher education, research institutions, heritage institutions, museums, galleries, libraries and archives), in order to achieve the kind of intellectual expertise, interaction and exchange envisaged under the Programme. The inclusion of researchers from beyond the academic community, for example through the involvement of industry where appropriate, is encouraged.

Programme Timetable and Competitions

The £8.1 million **Science and Heritage** Programme will run for 5-6 years under the direction and management of the Programme Director and an advisory group. All proposals to all the competitions will be peer-reviewed and specially convened panels will make the final funding decisions. In addition to the funding already

provided for collaborative research studentships and research clusters, there will be funding provided through two further competitions:

- Interdisciplinary Research Grants
- Post-doctoral Fellowships

The Programme will also support its own networking events including a cluster symposium, open workshops for discussion and postgraduate student seminars. An interactive website has been developed to publicise information about these events, to feature projects, to make connections, and to disseminate research.

Interdisciplinary Research Grants (for up to £800,000 fEC) will support 5-8 collaborative projects (depending on value) with a duration of up to 3 years. The competition will be conducted in 2 stages: first, an outline phase, followed by a request for full applications from short-listed candidates. The closing date for outline applications is Thursday 14th May 2009 with the subsequent closing date for full applications on Thursday 17th September 2009.

Post-doctoral Fellowships will enable outstanding early stage researchers to carry out research and so establish an independent research career in heritage science. Successful candidates will be within 5 years of completing their PhD or equivalent and will develop ways of combining techniques, approaches and expertise from STEM and the arts and humanities disciplines. The Programme will invest in talented individuals who have the potential of becoming future leaders in this new hybrid field. Fellows will also be expected to work closely with the Programme Director in activities and at events to demonstrate research supported through the Science and Heritage Programme. The Fellowships will provide funding to cover the Fellow's salary, a small amount of travel and subsistence, equipment and consumables, and will last for up to the equivalent of three years full-time¹. It is expected that between 4 and 6 Fellowships will be offered. The closing date for this call is Thursday 10th September 2009.

¹ If the proposed Fellow has held, or currently holds, an academic post, they will be required to relinquish this appointment if taking up a Science and Heritage post-doctoral Fellowship, whether or not the fellowship is to be held full time or part time.

Programme Planning, Management and Evaluation

The Director of the Programme is Professor May Cassar from the Centre for Sustainable Heritage, University College London. She is supported by an advisory group comprising academics from a range of arts, humanities, engineering and physical science disciplines, along with other stakeholders. With their help, and that of a Programme administrator, Professor Cassar will oversee the running of the Programme, develop its coherence, ensure that it meets its objectives, contribute to its dissemination, maximise its wider impact, and report annually on its work to the AHRC and EPSRC.

As part of its responsibilities, the advisory group will oversee the Programme. Its members will receive annual reports and the final Programme report and will ensure that the objectives of the Programme as stated in this specification are met. They will advise the Director, the AHRC and EPSRC on the development and management of the Programme.

The Programme's focus on developing capacity and new knowledge in the hybrid discipline of heritage science provides opportunities for links among researchers and projects funded by the Programme. The Programme Director will therefore bring together grant holders to reflect on issues or findings, and to benefit from the added value that comes from researchers and research teams meeting to extend their thinking and ambition beyond individual project boundaries. To these ends, grant-holders will be expected to attend regular workshops at which they will share and discuss their research and to provide material and links promptly as requested for the website as well as participating in a final series of events at the end of the Programme. Submission of annual reports is mandatory and will contribute to the annual Programme report. To ensure co-ordination within the Programme, the Director will support exchanges between researchers on different projects and will seek to involve other researchers in Programme activities. The outputs and outcomes generated by the Programme's projects will be connected via the Programme's activities where appropriate in order to make the Programme visible to a wider audience.

Researchers and practitioners from outside the academic sector will be involved in the Programme through participation in the funded projects, Programme events, and representation on the Programme advisory group. The involvement of colleagues from outside higher education will be vital in terms of fully

understanding and providing access to the communities and individuals involved in the research supported and disseminated by the Programme.

It is through activities such as those outlined above that the coherence of the Programme and its impact will be assured. In addition, monitoring and evaluating the volume, level and quality of activity (e.g. of conferences, workshops, lectures, media and electronic output, peer-reviewed papers and articles and other opportunities) will demonstrate the value added by the Programme and its contributing projects to public knowledge and understanding. Moreover, it is anticipated that capacity building in the study of the issues raised by the Science and Heritage Programme will contribute to the sustainability of Programme activities. The legacy of the Programme – the extent to which researchers continue to collaborate, issues continue to be discussed and researched, the quantity and quality of researchers that continue to be developed and the people and prospects that will grow beyond the Programme's lifetime-will also be a mark of its success.

Programme Activities to date

Thirteen **research clusters** were awarded in winter 2008. Research clusters are intended to act as a catalyst for building a community around a number of key research themes for the advancement of scholarly knowledge and practice in heritage science. The awards that have been made provide a framework for interdisciplinary groups to examine potential research topics in preparation for future Calls for collaborative research projects and/or to build heritage science capacity that will last for the duration of the Programme and beyond.

Ten **collaborative research studentships** were awarded in the summer of 2008. The three-year studentships leading to the award of a PhD are intended to help overcome the shortage of young researchers in heritage science. Supervised jointly by academic and non-academic supervisors, the students are investigating a range of topics that are essential for developing new knowledge in the heritage science field.

Throughout the 5-6 year life of the Programme, a series of events are being organised by the Programme Director around the United Kingdom to encourage new collaboration among researchers interested in heritage science. Full

information on current events can be found on the Science and Heritage website at www.heritagescience.ac.uk

Enquiries about the scholarly content of the Science and Heritage Programme should be directed to the Programme Director, Professor May Cassar, at the contact address below:

Professor May Cassar
Director, Science and Heritage Programme
UCL Centre for Sustainable Heritage
The Bartlett School of Graduate Studies
(Torrington Place site)
University College London
Gower Street
London WC1E 6BT
Tel: 020 7679 1780
E-mail: m.cassar@heritagescience.ac.uk

Other enquiries about the Science and Heritage Programme, this call and the Councils' remits should be directed to one of the people below:

AHRC Programme Manager

Dr Gail Lambourne, g.lambourne@ahrc.ac.uk 0117 987 6670

AHRC Senior Awards Officer

Helen McConnell, h.mcconnell@ahrc.ac.uk, 0117 987 6655

EPSRC remit queries should be directed to:

Dr Louise Tillman, louise.tillman@epsrc.ac.uk, 01793 444 510

General enquiries about science and heritage competitions and the application process can also be directed to one of the people below:

Karen Giles, k.giles@ahrc.ac.uk, 0117 987 6664

Wendy May, w.may@ahrc.ac.uk, 0117 987 6663

Natalia Rowlands, n.rowlands@ahrc.ac.uk, 0117 987 6660

Julie Warrington, j.warrington@ahrc.ac.uk, 0117 987 6661

ANNEX

The **Science and Heritage** Programme is structured around six themes which raise a range of research questions that require an interdisciplinary response from arts, humanities, science, engineering and technology researchers. Underpinning these themes is a set of broad research questions which are intended to guide inquiry rather than to prescribe individual research topics. These broad research questions are:

- How might we better understand and explain the causes of damage or material change to cultural heritage, and when is material change acceptable and damage unacceptable?
- How do we overcome gaps in recorded data on the environmental history of collections and what can be learnt from other heritage fields such as archaeology and related sectors?
- How do we create research frameworks or methodologies that draw on a range of evidence on cultural heritage – oral, aural, visual and written – leading to a hybrid heritage science discipline?
- What can novel materials and technologies offer cultural heritage and its representation, interpretation and conservation?
- What conditions are required to sustain cultural heritage in the future – political, cultural, intellectual, institutional and regulatory – and how might richer and more critically reflective interdisciplinary scholarship be developed?
- How might we better understand and evaluate the ways in which heritage science data and information can be captured, compared and disseminated for future study?
- How can different research communities come together to work effectively and innovatively? Can the predominant distinctions between different disciplines be harnessed in the interests of cultural heritage?

- What are the new challenges and opportunities presented by an increasingly globalised and environmental and security-conscious society and what are the possible responses? How can we harness advances in interactivity, visualisation, simulation and new forms of participatory media to the widest possible benefit?

Successful projects will be expected to bear these broader research questions in mind when undertaking their research as these broad questions will be discussed by the Programme Director in meetings with grant holders throughout the Programme.

Research Themes in Detail

1. Nature of transformation
2. Authenticity, authentication and security
3. Interpretation and representation
4. Cultural encounters and explorations
5. Human and machine interfaces
6. Resilience and adaptation

These themes focus on understanding, valuing, protecting and enjoying cultural heritage. The wide ranging statements and indicative questions that follow are intended to set the themes as problems and to stimulate proposals, but not to prescribe or specify projects to be funded. Even if not stated, issues surrounding the lifetime of heritage, portable and fixed, in complex individual assemblages or as large groups, are understood to inform these themes. While the UK is the pivot of the Programme, and these themes have been identified by the Programme Director through extensive discussion and research including cognizance of the work underway to develop a National Heritage Science Strategy, it is understood that the themes are trans-national, and that some of the projects may also involve international collaboration. To make a significant impact, all themes require a high level of interdisciplinary research collaboration.

1. Nature of transformation

From the moment the materials for an object are selected, through to its production and use, an object may undergo many cycles of cultural and material change and renewal, decay and intervention. The changes in cultural materials captured in the word 'transformation' have cultural, aesthetic and physical

dimensions, and combine the values and practices of different disciplines. This theme will focus on important cultural-scientific research questions that will enable us to develop greater understanding of change, particularly rates of change in materials, the effectiveness of past conservation treatments including the use of synthetic materials in conservation interventions and assessing current and new conservation materials particularly the assessment of 'green' alternatives. These problems are informed by a range of values, including aesthetic, commercial, spiritual, scientific, social, historical, ethical, political, environmental, cultural, technological, legal and economic values. The resulting research is expected to enable researchers and practitioners to answer: how, in assessing composition and condition of materials, we reconcile qualitative and quantitative criteria; what criteria and protocols do we use to arrive at acceptable limits of damage; what do we presently know about damage for a range of materials; are we able to suggest consistent protocols for modelling material change; and is our understanding of risk, monitoring and simulation sufficient to inform life-cycle and cost/benefits studies and new or improved conservation interventions?

- What are the essential historical and cultural contexts that have to be understood to permit the judging of perceived value against aesthetic change?
- How might environmental conditions, now and in the future, affect the public perception of cultural heritage?
- How should we consider questions of environmental influence in relation to decisions about the presentation of historical material objects?
- What innovative technologies are needed to measure physical change in objects and structures?
- How can we measure the impacts of intervention and how does intervention affect the aesthetic quality of an object?
- How might we relate the unknown impact of intervention to society's need to appreciate the aesthetic?
- How can existing economic or social models be applied to understanding the lives of cultural artefacts?

2. Authenticity, authentication and security

Fakes and forgeries have long sought to confound understanding, value and appreciation of culture and society. At the same time faithful copies and

surrogates of cultural artifacts make a positive contribution to increasing access to cultural heritage. For example, what makes the reproduction of a cultural object a fake? The debate on what is considered to be original and authentic in cultural heritage and why brings together disciplines as diverse as physical science and philosophy. More recently, theft and trafficking of art works have created new risks and broadened our discussions on authenticity to include the role of 'place' or context in authentication. This theme will focus on historical, ethnographical, bio-medical, scientific and technological processes of dating and characterisation of materials and contexts. The evidential value of materials, combined with advanced technologies, and the stories and memories associated with cultural heritage will be used to further understanding of the meaning of authenticity and the practice of authentication, and to develop recognition techniques and tools to improve the traceability of heritage materials.

- How can we understand and so propose solutions to the threat of displacement and loss of cultural heritage through, for example, conflict and globally-organised crime?
- How can material traceability be improved through the application of advanced technologies?
- How can the composition and condition of objects be assessed quickly and accurately, in situ and on the move?
- What can be done to develop common protocols for storing and accessing data relating to works of art /cultural heritage?
- How does physical change or material loss in an object or structure affect its authenticity?

3. Interpretation and representation

The approach to exploring this theme is richly layered. Science can help our understanding of how the natural world and human society are represented in art, artifacts, architecture, archaeology and landscapes; it can also deepen cultural interpretations of heritage. The scientific analysis of moveable and immovable objects can also help us understand and interpret the physical relationships between those objects and their changing historical and geographical contexts. At the same time research on the cultural, social and political forces that influenced their creation will shed new light on those contexts as well as illuminating heritage for diverse audiences. Research under this theme will be expected to contribute to the interpretation and representation of change

in appearance and substance, as heritage materials age or are altered. For example, along with historical and art historical inquiry, how can predicting and modeling material behaviour, surface textures and sub-surface construction and the consequences of alterations to objects help improve understanding of heritage objects?

- How do local communities and tourists shape the questions asked about cultural heritage?
- How can the heritage science research process affect the interpretation and representation of cultural heritage to visitors and local communities?
- What can heritage science contribute to the interpretation and representation of cultural heritage when at some socio-cultural level it is considered acceptable to destroy and renew cultural artifacts?
- How might the tensions and synergies between tangible and intangible heritage be balanced?
- How can emerging hard, soft and virtual technologies and approaches improve awareness of artistic values?
- How might conservation processes be harnessed within a sustainability framework to help develop a new display ethos?
- How might the perceived need for intervention jeopardise ideals of interpretation and understanding?
- How will concepts of recycling and reuse, and responsible use of natural resources affect the design and management of future heritage?
- Do the necessary conceptual and analytical tools currently available allow us to forecast what the Olympic Stadium in London might look like in 2000 years' time?

4. Cultural encounters and explorations

All cultures are rich and diverse, with histories and communities that may have withstood centuries of social and cultural change. These societies have different languages, values, religions and traditions, and a variety of complex social, political, institutional and technological structures. Trade and travel leave their mark on a wide range of objects that are exchanged, dispersed or acquired, used and valued in different ways. This theme will explore cultural encounters with physical objects, both moveable and immovable. It encourages the exploration of different strategies of access and conservation for a wide spectrum of heritage from historic buildings and their collections, to monumental landscapes, parks

and gardens. The opportunities and barriers to cross-cultural and cross-sectoral engagement with heritage science will be explored, underpinned by an exploration of the cultural and scientific basis of different approaches to conservation. It sets the human experience of cultural heritage at the heart of this encounter – sometimes denied, often conditional. Many claims, yet to be proven, have been made about the wellbeing, both cultural and therapeutic of physical encounters with an object, yet objects in turn need protection from excessive ‘wear and tear’. While a combination of language-based, philosophical, historical, cultural, scientific and technical knowledge and skills will help us to understand better cultural heritage and its protection, a range of other disciplines from mass communication and media studies, to argumentation and rhetoric may help interpret and influence the public understanding of heritage science.

- What are the wider cultural and social impacts and benefits of encounters with physical cultural heritage?
- To what extent can we measure the cultural and therapeutic wellbeing that is derived from cultural encounters with objects?
- How can the limits of use of an object be defined and measured?
- How might decision-making for the protection of cultural heritage be informed by integrating research from both the arts and sciences?
- Where is the balance between historic integrity and modern use, including tourism and lifestyles?
- How does tourism influence cultural heritage?
- What can heritage science contribute to improving our understanding of the artist’s or maker’s intent and to determining the effectiveness of modern application of traditional craft skills to cultural heritage?
- How can we understand and develop public perception of deterioration and conservation of heritage structures and objects?

5. Human and machine interfaces

Cultural heritage consists of complex assemblies of materials often with unknown variables. With a relatively small number of highly skilled researchers and practitioners worldwide, with cultural heritage available in quantity and sometimes in inaccessible or remote places, new technologies are needed to support knowledge and skills to deliver exacting interventions. Remote technologies such as robotics and cutting edge communication technology (including high speed data connections and management information systems)

could lead to the development of tele-conservation. Such developments promise to permit the expertise of specialised researchers and practitioners to be available to heritage managers worldwide without the need for cultural objects to be transported beyond their local museum or site. On the other hand, specific product requirements could include cheap effective instruments for monitoring environment/ component/system failure. Evidence-based management of cultural heritage could be transformed by new or re-engineered tools, predictive models and expert systems. The usefulness of remote sensing such as aerial and satellite technology, advances in gas phase bio-sensing, non-destructive techniques coupled with simulation tools and the adaptation of wireless protocols to building sensors, advanced fire/security systems, infestation surveying equipment and flood recovery technologies need to be tested on real collections, historic buildings and sites. The near-future developments of technologies should enable advances in heritage science to be made.

- What development in non-contact and non-destructive 2-D and 3-D imaging tools might be possible for chemical and physical identification and damage evaluation?
- How can these developments help art historical analysis of objects and materials?
- How can computation-intensive spectroscopic, laser and acoustic technologies be applied to develop hand-held tools for conservators?
- What do smart materials for packaging based on integrated sensors and functional materials such as textiles have to offer exhibition designers, fine art transporters and preventive conservators?
- How can conservation scientists and building technologists work together to develop integrated systems for environmental control based on real-time damage sensing?
- What types of bespoke materials can be designed with the pre-requisite mechanic properties for conservation/restoration, nano-structured corrosion inhibitors and molecular repair?
- How can intellectual, sensory and physical access to heritage be improved through advanced intelligence, haptic, full or hybrid robotic systems?
- How can the experience of vulnerable or remote cultural heritage be enhanced and informed through an interdisciplinary approach?

6. Resilience and adaptation

Environmental and anthropogenic effects such as climate change, will take their toll on cultural heritage in the 21st Century. Changes in cultural materials and the necessary conservation response as a consequence of environmental change will be a key focus of research under this theme. There are important research gaps that need to be resolved such as how to quantify the exposure to different risks of different parts of cultural heritage in order to map vulnerability to environmental change. The sensitivities and significance of cultural heritage sites could lead to research and development of specific indicators of climate change impact in terms of scale, time and design guidance. This will require major interdisciplinary effort involving curators, conservators, heritage scientists and climate scientists if the data relevant to cultural heritage is to be produced. It will also involve scientists, building scientists and building services engineers, along with art historians, architectural historians, artists and philosophers so that the gain or loss in value and significance from adaptation is given full consideration in this research.

An overarching question for this theme is how can heritage science assist in establishing the extent to which historic buildings are sustainable – physically, culturally, socially and environmentally? Research is required on how we protect the historical and physical integrity of important cultural buildings, particularly museums, libraries, archives and historic buildings when a substantial adaptive response to climate change is required. Research is urgently needed that links damage risks, environmental control and energy use as part of a re-assessment of conservation standards, materials tolerance and environmental thresholds in order to avoid cultural heritage buildings from becoming obsolete. Another issue for this theme is research on the impact of environmental change on collections. Most important are predictions of the effects of extreme and local climate, and the combined effects of different parameters such as wind-driven rain and the effect that these will have on the indoor environment and on changes in the time between cycles of conservation intervention.

- What combination and range of philosophical, scientific and cultural issues need to be utilised to permit the setting of the standards and tolerances that society would accept for the conservation of objects?
- How might conservation techniques be adapted to enhance resilience of objects and materials to future changes?

- What level of deterioration to all forms of cultural heritage is acceptable to the public in terms of access?
- What is the effect of extreme weather such as rain penetration, high summer temperatures and salt-loading on outdoor and buried cultural heritage?
- What effect will upgrading the historic building stock to reduce energy use and carbon emissions have on their survival under extreme weather conditions?
- Given the heterogeneity of historic buildings and their surroundings, how do we achieve successful refurbishment?
- What evidence can heritage science contribute to future-proof historic buildings?

This theme, in particular, will contribute towards objectives under the cross-Council Living with Environmental Change Programme (<http://www.lwec.org.uk/>).