Best practice and standards in environmental preservation for cultural heritage institutions: goals, knowledge, gaps

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With common issues and concerns, a growing convergence of institutions – libraries, archives, museums and historic houses – face the same challenges for cultural heritage preservation. These include storage, display, research and exhibition areas that meet the needs of preservation, while also allowing for the increasing demand for access to original historic materials. The needs, demands and requirements for collections and cultural heritage in general have long been recognised, and it is nothing new for the cultural heritage field to have to deal with funding challenges and the prioritisation of resources in a difficult economic environment. This puts an even greater emphasis and a broader and encompassing focus on the identification of best practices and 'appropriate' standards for environmental preservation. This is of critical importance since the range of environmental parameters has now greatly expanded to include economic, political and climatic challenges, while also encompassing the need to address the digital age and the global explosion of demand for access to knowledge.

In this new climate of change, it is imperative that cultural heritage professionals and practitioners collaborate to share and integrate the knowledge required to underpin environmental guidelines, recommendations and standards that are based upon real material science, rather than on accepted practice, since as organisations are called upon to justify costs and allocation of resources, we must ensure that energy, money, personnel and other resources are being utilised most effectively for the long-term preservation of collections.

Goals

The underlying goal of best practices in environmental preservation is to attain the optimum conditions for the protection of items of cultural heritage. This should be closely aligned with the specific material-based needs of the artefact. Environmental controls for preservation of cultural heritage items are long overdue for revision, since conservation recommendations often impose rigid controls that do not relate to local environmental conditions and are liable to misinterpretation as people fail to relate to a range rather than a specific number and set-point. Nor are they necessarily based upon a true understanding of the underlying needs of various materials in collections. Furthermore, standards should enable cultural heritage professionals to optimise the preservation of our collections, not deter them, while at the same time recognising the need to move from a reliance on accepted or historic practice towards standards that are based upon evidence-based material science needs of collections.

The current economic, political and ecological climate challenges us to address these issues and develop standards that are optimal for the specific artefact and location, and that can be met without greatly expanding the carbon footprint. Closely aligned with this are climate change issues and the sustainability of institutions – including libraries, archives, museums and historic houses. Current economic, political

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and climate changes challenge cultural heritage professionals to address the revision of standards in the context of these issues.

There is global move towards reducing energy costs and the carbon footprint of human activities. The preservation of cultural heritage is not exempt from this. Institutions are forced to consider how they can justify costs (e.g. of humidification) as well as to reduce energy costs for controlling the environments that preserve our heritage. The impact of global warming suggests a greater range of variability of external climates – a higher incidence of storms, extreme events and seasonal fluctuations. These factors all point to the importance of control of fluctuations to try to reduce the impact of changes on our cultural heritage, and this has to be achieved within the context of reduced budgets, while also addressing actual material tolerances in terms of upper and lower limits and rates of change.

Cultural heritage institutions of all kinds need to address the common issues of storage, exhibition and access in conjunction with the implementation of standards requirements for environmental control Figure 1. Owing to human comfort factors, the environmental conditions in specific spaces may differ in order to meet the needs of those requiring access to the collection. This often results in variable conditions that can cause damage, as well as tolerance levels that may not be the best for the specific collection.

Figure 1. Converging issues for cultural heritage institutions.

The environment for cultural heritage that needs to be controlled may be defined in terms of a 'macro to micro' perspective, and standards for cultural heritage need to be considered in the context of a spectrum leading from the macro-environment down to the micro-environment Figure 2:

- building (historic architecture or modern)
- room (storage / exhibition / research)
- case (display / storage / long-term visual storage).

Figure 2. Impacts on environmental control: building, room, case.

The building may feature historic architecture or be of more recent construction – modern, or increasingly often, a customised building for the storage needs of cultural heritage materials. Buildings consist of a range of materials with specific properties that may or may not be capable of achieving current environmental standards. There are issues of cost for both the maintenance of the existing structure and the upgrading of the infrastructure and systems. Whether the building can be retrofitted, and the cost of this, often elicits extensive debate when institutions are trying to determine the best option for meeting standards for environmental control. In addition, there are energy costs involved depending on the building type, including those for the installation of humidification and other environmental control systems. These have an impact on the building itself, which is of additional concern when the building is considered to be of cultural significance. The vagaries of mechanical systems in maintaining stable environmental control also need to be considered since mechanical breakdown can create damage to materials. The variation from a tightly controlled temperature and relative humidity (RH) environment to one reflecting the external ambient conditions may be severe, depending on both the seasonal and the geographical location of the collection.

To achieve required set-points and ranges specified in standards, buildings may be customised, zoned or divided into separate components to meet the often conflicting needs of storage, exhibition, research and access, and of collection versus human occupancy requirements. Customised buildings for long-term storage control include the British Library Additional Storage Project (ASP) building at Boston Spa, the Library of Congress (LC) Fort Meade module storage to maintain conditions of reduced temperature and relative humidity (RH), and the Library of Congress National Audio Visual Conservation Centre (NAVCC) building Figure 3.

Figure 3. Building structure: historic architecture, modern customised (Library of Congress Fort Meade and NAVCC buildings below).

As noted above, the top level of macro- to micro-environment spectrum is that the building which houses and influences the collection needs to take into account the effect of external factors. These include not only meeting standards, but also the energy costs of controlling the environment, political mandates for reducing energy costs, and climate changes – geographical and local variations that may vary widely within the limits set by standards, as well as global changes in climatic conditions. All these are influenced by economic considerations for individual cultural heritage institutions as they struggle to meet and justify the costs of energy and resources to achieve required environmental standards.

The next level in the macro- to micro-spectrum is the room or defined space within the building. Traditionally, rooms or spaces within cultural heritage buildings are divided on the basis of the required level of access, as well as the specific content of the collection. While the distribution of collections based upon subject may seem logical and simplify cataloguing, whether this adequately addresses the needs of the collection should be considered. A better allocation of resources may be the separation of materials according to their different environmental needs, while also optimising conditions for the control of environmental parameters commensurate with the collection materials' tolerances to minimise damage. Rooms can be modified by adapting the entry (e.g. double sets of doors to reduce fluctuations in RH and temperature) and access to maintain better conditions. Monitoring can establish the level of control within rooms, both with passive and active control, and these levels of control can be related to the material tolerance of collection items.

At the micro-level of control is the exhibit, display or visual (long-term) storage case that is capable of creating and controlling a microclimate for more fragile artefacts and those requiring separate cases. The use of visual storage (encasement for display and storage) helps minimise the potential impact of handling when an item of significant cultural heritage is moved from storage to display. More importantly, it ensures that the environmental conditions of the local environment remain stable. The challenge in creating efficient visual storage systems is the selection of materials which are capable of achieving the required hermetic seal that can attain a low rate of leakage and tight control of the microclimate. While the initial cost outlay may seem larger than for less controlled spaces, the long-term energy costs of this type of environmental control are greatly reduced since a passive environment is constantly maintained and the stable buffering against external fluctuations minimises the risk of damage for the artefact. In addition, the conditions can be customised to control the specific environmental parameter that is the major cause of deterioration for the material-based needs of the artefact – whether it is RH, temperature, oxygen or pollutants. An example of this is the Waldseemüller 1507 world map, where protection of the map due to the requirement for long-term exhibition necessitated an anoxic and lowered RH encasement. This has been engineered to allow a 150-year seal by using to a truly hermetic seal with lowered energy costs due to passive control of the encasement Figure 4.

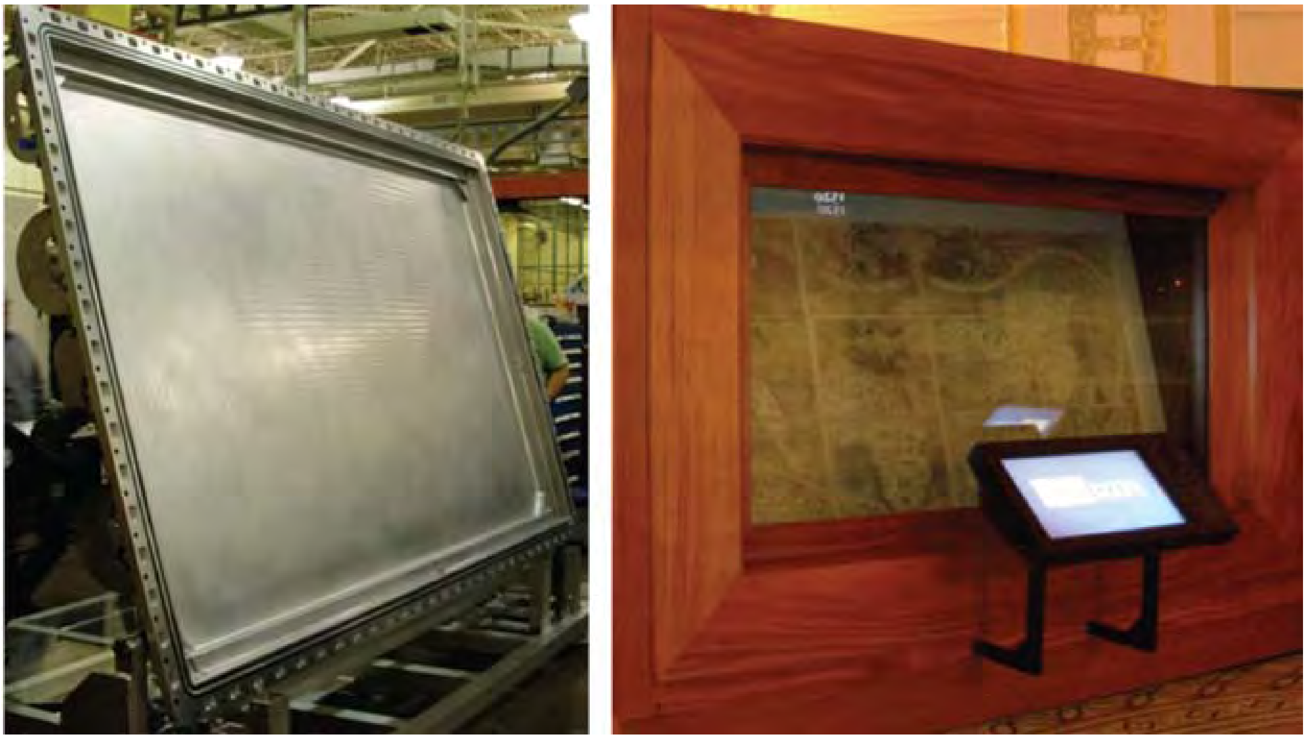

Figure 4. Waldseemüller 1507 world map anoxic encasement.

The concept of cases or microclimates can be extended to storage areas where encasing cultural heritage materials helps to buffer the environment to achieve the required material tolerances in relation to external changes, while addressing the need to optimise preservation requirements.

Knowledge

In the 1970s, Garry Thomson's *The Museum Environment* (Thomson 1986) recommended 50 or 55±5% RH and a temperature of 19 or 24 ±1 °C for winter and summer, respectively. This established an overarching requirement for controlling and limiting fluctuating conditions. Continued research in the field further recognised the need for drier and cooler conditions. Standards such as British Standard 5454 state that the temperature and relative humidity should be at fixed points within the range of 13–16 °C and 45–60% respectively, with time for acclimatisation if materials are moved to different conditions. To promote longevity, the LC special storage modules are maintained at a constant 10 °C and 30% RH. There exist a number of standards and guidelines for recommended display and/or storage conditions for archives and libraries; including British Standards (BS), International Organization for Standardization (ISO), National Information Standards Organization (NISO) and the American National Standards Institute (ANSI). There are also published recommended practices adopted by specific organisations such as the National Archives and Records Administrations (NARA, USA), American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and the European Committee for Standardization (CEN); and many locally adopted guidelines too. Each organisation setting standards, guidelines and recommendations has different underlying needs and motivations.

These consensus standards and advisory bodies comprise a range of professionals with varying expertise, and their backgrounds mean that there are often fundamental differences in specifications. For example, a preservation scientist will develop recommendations from a materials science background that focus on the structural materials tolerances to specific deterioration factors as well as the rate of change. This emphasis is based on different priorities from those of a mechanical engineer who is basing recommendations on known limits and tolerances of machinery rather than materials.

In terms of the knowledge that currently exists, it is well established in the preservation field that there is a recognised overarching need to control and limit fluctuating conditions for a range of materials. The standards outline the main environmental parameters that require control and attention, such as maintaining temperature at fixed points in a range, controlling levels of visible and ultra-violet light, and pollutants. To promote longevity, customised buildings and specialised storage have evolved (e.g. LC special storage modules maintained at a constant 10 °C and 30% RH), and there are many detailed studies in the literature that investigate and advance the knowledge of changes in materials on the basis of scientific studies. In addition, there have been significant developments in relevant technology and engineering.

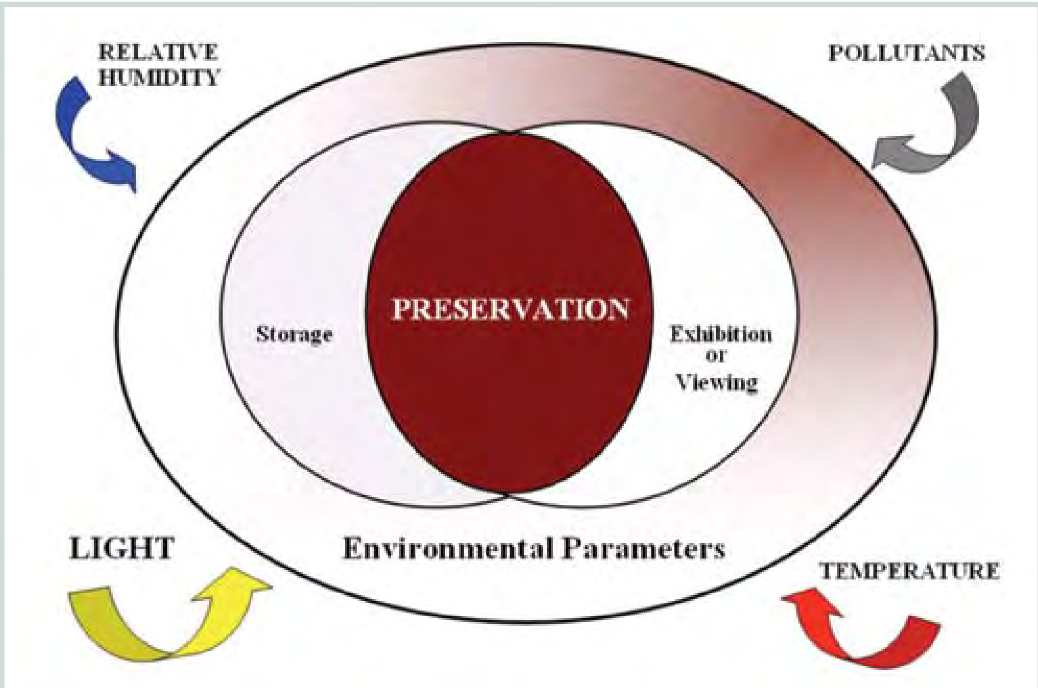

Figure 5. Effect of the environment on preservation.

As illustrated in Figure 5, the deteriorating effects of RH, light, temperature and pollutants – both for storage and exhibition – must be taken into account. There is also recognition that cooler and drier conditions are beneficial, but that the needs of collections and humans often do not coincide, as highlighted in Figure 6. Most institutions raise temperature to address the needs of humans working in or accessing collections and collection areas.

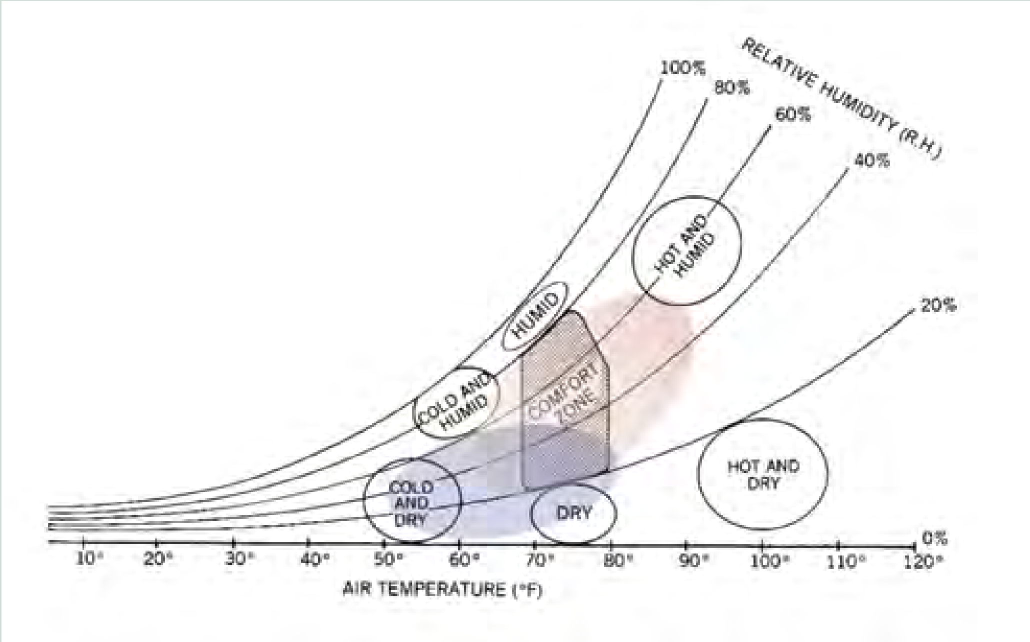

Figure 6. Collection needs and human comfort.

Therefore there is a need both to maintain and to understand better the required environment, while addressing the needs of collections, as opposed to human comfort. The adaptation of current standards and existing knowledge to local environments and circumstances must be managed in order to create stable rather than fluctuating conditions. In order to balance preservation and access, we need to utilise scientific, technology and engineering advances more effectively. There are two areas to be addressed: linking these developments with material properties, and increasing access while preserving the original artefact.

Gaps

The challenge in applying the above standards, guidelines and issues to cultural heritage preservation is that many of the past recommendations and standards adopted for preservation applications were not based upon a true understanding of known changes in cultural heritage artefacts derived from research into cultural materials. Standards should be critically assessed in light of advances in knowledge of changes in cultural materials based on scientific studies. Consideration should be made of specific research into changes in paper and other substrates to define appropriate set-points for specific parameters and safe ranges for specific material requirements. This knowledge needs to be linked with engineering capabilities, building structures (historic or modern), types of collections (including mass treatments) and local climate parameters. Other factors to be considered include the effect and rate of change in the environment, linked with the acclimatisation required for the adaptation of an artefact to changes in environmental parameters while minimising risk of damage.

Gaps in what is known include the effects of fluctuations and cycling for RH responses of specific materials, including the different requirements for materials and material composites for storage, microclimate and display areas. In addition, the buffering necessary in relation to linking these data with building control systems and the levels of control that can be attained and maintained and are required, need to be considered. This should incorporate the impact of local climate adaptations based upon measured material properties and the upper and lower tolerances that can occur without inducing unnecessary damage. The control of levels of light, pollutants and temperature is an area of investigation. Collaborative research efforts between the British Library (BL) and the LC are underway to address some of these issues and their implications for two of the world's largest collections, collectively encompassing over 250 million items. Further research with regard to implementing scenarios for cost-effective solutions and material-specific parameters is also needed.

Further considerations for defining required research include determining the major cause of deterioration for specific materials so that the best utilisation of energy and resources can be made to address the preservation requirements of collection materials. The determination of deterioration from environmental parameters needs to evolve from an understanding of the impact of each damage parameter and how this has an impact on the individual artefact or collection material. Currently we simply control such factors as RH and temperature overall, and a disparity exists in the understanding of what happens at the micro-level in terms of molecular changes that lead to irreversible damage or of acceptable changes that do not adversely affect the mechanical stability of the artefact. By increasing our understanding of the tolerance levels and micro-changes, we can reduce the potential for damage and optimise preservation and long-term accessibility to collections. We must address the extensive materials science needed to define the rate of change, tolerances and range of environmental control for common cultural heritage collection materials Figure 7.

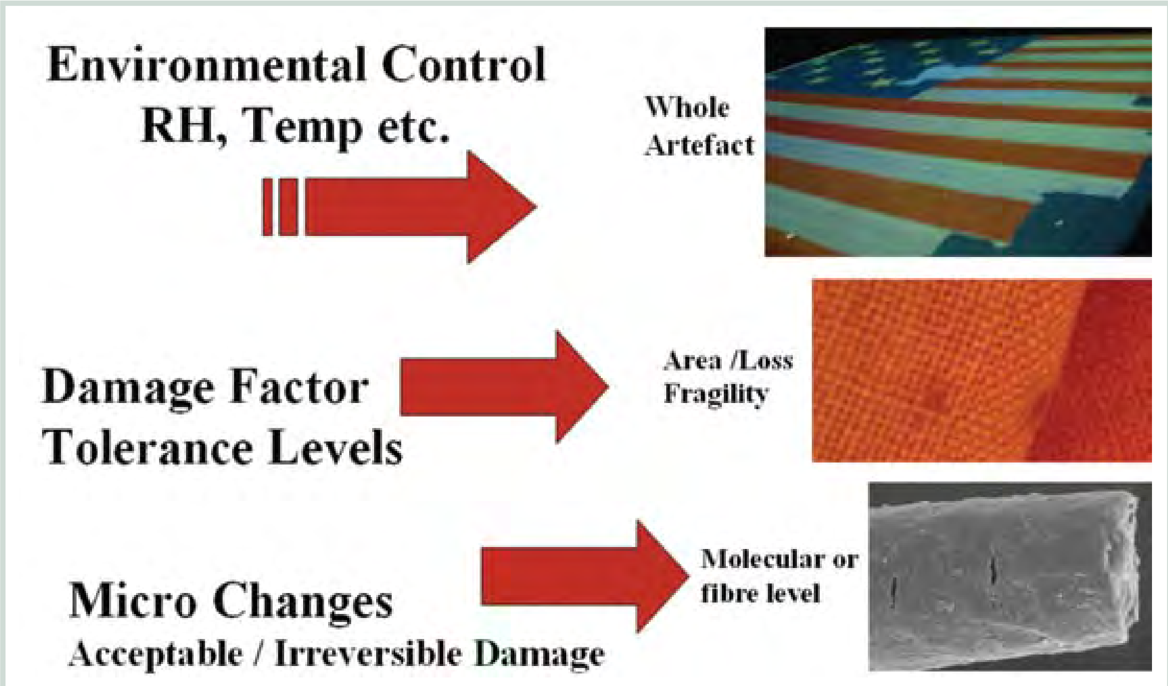

Figure 7. Artefact and material properties: macro to micro.

The global impact of lack of information translates into ongoing discussions about internationally agreed standards for cultural heritage buildings and collections. Until we can incorporate into material science an understanding of the impact of local, regional and global variations, we shall not be able to arrive at balanced and accurate standards and recommendations that we can use in protecting our collections.

One effective way of increasing our global knowledge base for cultural heritage materials and collections is through the development of a preservation reference materials database and repository. The LC is currently undertaking the development of an open-source software architecture/platform through the utilisation of a customised resource description framework (RDF). Open access would allow international access to data with data interoperability. Enhanced access through attention to the use of standardised file formats would ensure that proprietary software and file format structures do not impose barriers for access to the collection. The reference collection would comprise a wide range of reference materials of new, naturally aged and accelerated aged samples, including but not limited to the following:

- Physical samples:
  - characterised reference papers such as the American Society for the Testing of Materials (ASTM) 100-year study
  - naturally aged mass deacidification paper samples

- naturally aged book collections such as the LC Barrow collection (books from 1500 to 1900)
- pigments
- leather samples
- stone samples
- fibre samples

- Digital files associated with both LC collection objects and the above reference samples (hyperspectral images, FTIR, Raman, XRF, SEM, etc.)

- Extant and associated international database collections.

The availability of well-characterised aged samples that are relevant in terms of measured materials properties is important, since they reflect the changes manifested in actual artefacts, as opposed to starting with material analysis of new and accelerated aged samples. This gives a better understanding of the impact of environmental parameters on aged materials that have already undergone various levels of deterioration as well as exposure to treatments and other effects.

More effective utilisation needs to be made of non-destructive techniques that can enhance the preservation of original artefacts with greater access to the digital object – this can often provide the researcher with more information than can normally be accessed visually from the original. The development of hyperspectral imaging – integrated narrow-band spectral imaging – with low heat, low light exposure LED conservation lighting to reveal information from the ultra-violet, visible and infra-red spectral regions, allows for non-destructive characterisation of inks, colorants, substrates and treatments, while also revealing information not apparent in the visible region. Use of digital images and spectral combination of images allows increased access to objects, while enhancing their preservation through reduced handling and exposure to changing environments Figure 8.

Figure 8. L'Enfant Plan of Washington DC (1791): viewing in visible light and infra-red.

This brief overview demonstrates that there are a number of key issues to be addressed in the review of current standards and future developments. Those include enhanced understanding of material-specific properties and the tolerance and rate changes that should be included in environmental standards for cultural heritage. That needs to be achieved while addressing storage, exhibition and research access requirements and balancing the needs of preservation and access. Monitoring and determining the relevant major deterioration factors that lead to damage should integrate risk factors related to the impact of the local environment – both climatic and cultural. Incorporating energy efficiency in the light of reducing costs and meeting government mandates is another critical component of the current economic and political environment. The overarching need to establish a consensus for international agreed standards for cultural heritage loans underpins the assessment of risk versus value, and what is acceptable loss that allows access while optimising preservation.

Conclusion

In order to preserve our cultural heritage adequately for future generations is it imperative to establish and apply advanced knowledge of materials science to protect our collections in relation to:

- tolerances and actual damage
- control of deteriorating factors rather than bulk parameter control.

To achieve this we need to focus on international research collaborations that allow the implementation of consensus standards optimised for protection of cultural heritage buildings and collections. This has to be objectively based in economic and political reality – achieving preservation within the current focus on economic, energy and climatic responsibility. This will allow the best allocation of resources and enable us to balance preservation and access, while providing standards that enable international agreement and the best conditions for cultural heritage.

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