International Preservation News

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CSI : Conservation Scientific Investigation

Laboratories, Projects & Technologies

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International Preservation News
is a publication of the International Federation of Library Associations and Institutions (IFLA) Core Activity on Preservation and Conservation (PAC) that reports on the preservation activities and events that support efforts to preserve materials in the world's libraries and archives.

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Front cover:
PIXE microanalysis of the pigments of a 15th century Sienese School anonymous painting, using AGLAE facility (Accélérateur Grand Louvre Elémentaire). Copyright C2RMF

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CSI: Conservation Scientific Investigation Laboratories, Projects & Technologies

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Considering the conferences or forums announced, Preservation will certainly be on the agenda in the months to come and, more particularly, research in that field. New tools, new techniques of treatment, new laboratories and also new issues have led all the cultural heritage curators to wonder about the different aspects of their profession. Due to the mass digitization of collections, a loss of interest in the preservation of originals has been feared for a long time; on the contrary, studies, research and projects on the topic seem to be revived.

As Dianne van Der Reyden already announced it in an interview for *AIC News* in November 2007 (vol. 32, n°6), fruitful collaborations have been established with other professions making us benefit from the techniques they are developing (in the medical, aeronautical, nuclear, optical fields).

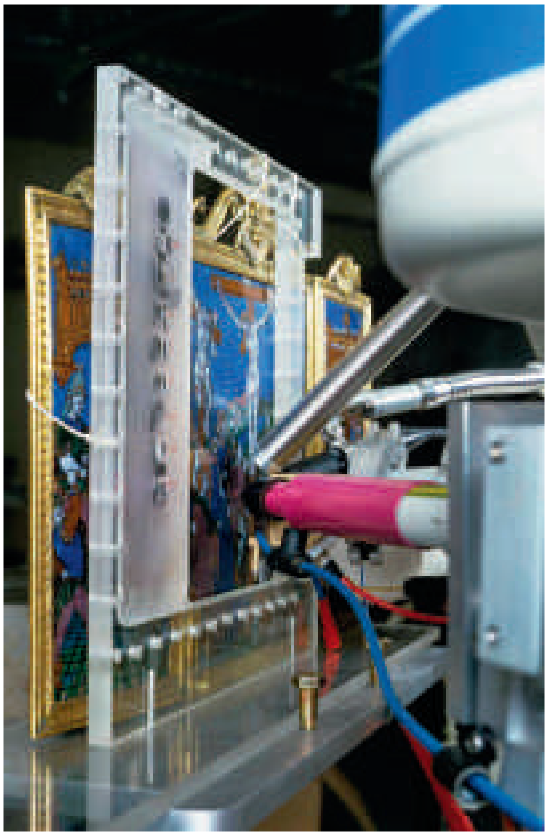
It is the reason why we would like to propose in this issue a focus on some innovations and projects in some state-of-the-art laboratories, making no claim for exhaustiveness, of course, but with the aim to show that the very large universe of the cultural heritage preservation, instead of simply undergoing the economic crisis aftermaths, is evolving, and innovates to resist and adapt itself.

Three laboratories of the Getty Conservation Institute, the Library of Congress and the Centre de Recherche et de Restauration des Musées de France (C2RMF) are presented with their newly developed tools or collaborative projects.

Proposing this topic is also a call to circulate more information through the PAC international centre about all these innovations. Indeed, at the end of this year, we are planning to publish a cyberletter which would not only announce events but also present innovative projects in the field of preservation.

Awaiting the release of this cyberletter, we wish you once again to enjoy reading *IPN* and we hope to see more and more of you subscribing to the PAC publications. Our next issue will be dedicated to the training in our field, and more particularly to E-learning.

Christiane Baryla
IFLA-PAC Director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A lire l'annonce des colloques ou forums à venir, il semble que lors des prochains mois le thème de la Conservation sera vraiment à l'ordre du jour et, plus particulièrement la recherche dans ce domaine.

De nouveaux outils, de nouvelles techniques de traitement, de nouveaux laboratoires et aussi de nouvelles problématiques poussent les conservateurs du patrimoine culturel à s'interroger sur les facettes de leur profession. Paradoxalement la numérisation de masse des collections, qui a longtemps fait craindre une perte d'intérêt à la bonne conservation des originaux, relance la réflexion, les études et des chantiers sur le sujet.

Ainsi que l'annonçait déjà Dianne van Der Reyden dans une interview pour *AIC News* en novembre 2007 (vol. 32, n°6), des collaborations fructueuses s'établissent avec d'autres métiers et nous pouvons bénéficier de techniques développées ailleurs (médical, aéronautique, physique nucléaire, optique).

C'est la raison pour laquelle nous avons souhaité proposer dans ce numéro un éclairage sur des innovations, des projets dans quelques laboratoires de pointe. Nous n'avons évidemment aucune prétention à l'exhaustivité. Ce que nous souhaitons montrer c'est que le domaine très vaste de la conservation du patrimoine, bien loin de ne faire que subir le contrecoup de la crise économique, demeure un secteur en évolution et innove pour mieux résister et s'adapter.

Trois grands laboratoires, celui du Getty Conservation Institute, de la Bibliothèque du Congrès et du Centre de Recherche et de Restauration des Musées de France (C2RMF) nous sont présentés à travers des outils ou des projets collaboratifs.

Avec ce thème, nous lançons aussi un appel pour faire davantage connaître ces réalisations à travers les activités du centre PAC : pour la fin de cette année nous réfléchissons à une cyber lettre d'information où seraient relayés, non seulement l'annonce d'événements mais aussi la présentation de nouveautés ou encore le lancement de projets innovants dans le domaine de la conservation.

En attendant la mise en ligne de cette nouvelle parution, nous vous souhaitons cette fois encore une très bonne lecture en espérant vous voir toujours plus nombreux adhérer aux publications du PAC. Le prochain numéro d'*IPN* sera dédié à la formation dans notre domaine et plus particulièrement au E-learning.

Christiane Baryla
IFLA-PAC Director

The Science-Based Fight Against "Inherent Vice"

by Dianne van der Reyden
Director, Preservation Directorate, Library of Congress, Washington, DC

Are you in any way responsible for the human record that is part of our collective cultural patrimony? If you are associated with a library, archives, or museum, you know these institutions hold responsibility for large legacy collections of traditional documents such books, maps, manuscripts, photographs, paintings, and prints. Their substrates include paper, parchment, papyrus, and, more and more often, plastic. With the advent of time-based and electronic media found on film, magnetic tape, compact discs, and DVDs, preservation challenges for libraries, archives, and museums are growing, not slowing. The greatest threat to long-term access to most cultural documents is mechanical and chemical failure resulting from internal instability, sometimes called "inherent vice".

Individuals entrusted with preservation of and access to the human record face an essential question: **How can we sustain the usability of ever-increasing arrays of formats?** Digitization is not the final answer, since all machine-dependent media are as vulnerable as past physical formats. Despite what we may wish, Web-based documents aren't stored in the ether; they ultimately depend on tapes, discs, servers, hard drives, or other physical media or devices to be sustained and accessible.

Fortunately, there is a solution: we can sustain usability of all formats, should we want to, if we follow four science-based strategic steps, described below:

1. *We must thoroughly understand how various physical formats deteriorate*. We must identify deterioration mechanisms (such as acid hydrolysis, or photo- or thermal-oxidation) of traditional and modern collections, noting optical, chemical, and physical markers of degradation (such as volatile organic compounds emitted by failing books, or polymer chain-scission or cross-linking of polycarbonate compact discs, or magnetic tape and binders).

2. *We must devise solutions to slow or counter deterioration through research programs*. We must develop reliable migration techniques and prototypes for digital access, but we also need to determine more cost-efficient collection-wide ways for environmental control to reduce hydrolysis and oxidation reactions in aging materials. We must continue batch treatments for production-level stabilization through mass deacidification of paper and books, and develop needed individualized treatments, such as phytate stabilization of some acidic media, or new stain removal and cleaning techniques, lest we lose an irreplaceable body of cultural evidence.

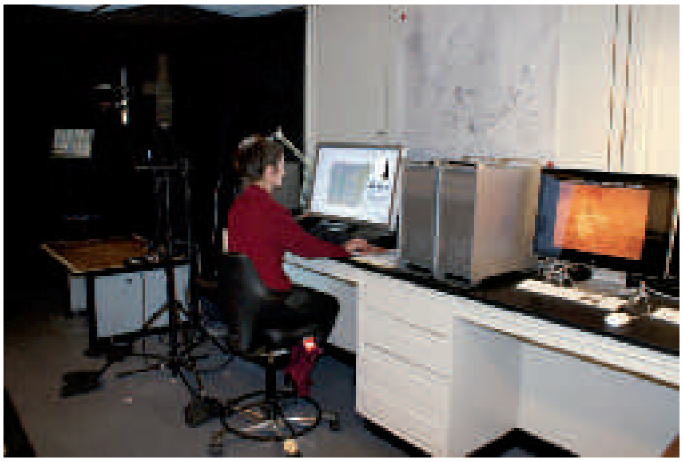
3. *We must ensure preservation and access to the complete record of information inherent in documents, through analytical service programs* that characterize and forensic studies that validate collections (such as analysis of the components of substrates, inks, and other media through hyperspectral imaging, and electrostatic and thermal imaging. These techniques also reveal obscured, hidden, and telling text or details such as fingerprints and other uniquely identifying features).

4. *We must undertake quality assurance programs* to comply with standards based on documented performance or natural and accelerated aging results. We must identify predictive deterioration markers to determine predictive life, and apply responsible preservation strategies based on facts.

So, how do we enact these four steps? At the Library of Congress, we have expanded our science staff and increased partnerships with visiting scholars and allied science laboratories in cultural and forensic institutions. We've updated our research agenda and redesigned decades-old labs to accommodate new needs. Our new staff and redesigned science labs enable us to better enact all the strategies above, enhancing our capability to characterize materials and detect degradation mechanisms, and to identify qualitative and quantitative markers of change in chemical, physical and optical properties. New analytical instruments in the Library's labs are state-of-the-art. They require less sampling and preparation, use a smaller range and quantity of solvents, and foster faster and more efficient processing, effectively meeting the tenets of what is informally called "green chemistry" in "green labs". The Library's new labs incorporate numerous other instruments that eliminate solvents and greatly reduce the necessary sample size. A new laser ablator requires no solvents to prepare samples for inductively coupled plasma (ICP) spectrometry (compared to 100 ml of solvent per experiment). Other instruments that contribute to reduced solvent use and increased efficiency include a thermal gravimetric analyzer, differential scanning calorimeter, image analyzer, and environmental scanning electron microscope.

The following description provides a **virtual tour** of the redesigned spaces of the Preservation Research and Testing Division (PRTD) of the Library's Preservation Directorate. PRTD focuses on identifying the optical, physical, and chemical characteristics of the Library's traditional, AV, and digital collections in order to assure long-term access to the full content of the Library's collections and to understand what triggers their deterioration. This enables Preservation Directorate conservators and scientists to reduce or eliminate risks posed by environmental factors, use, handling, and exhibition. Staff work together to formulate and test new treatments, and to determine optimum environments and best practices.

The **Optical Properties Laboratory** (**Fig. 1**) includes instruments used for various types of analytical spectroscopy. Here scientists reveal morphology and composition of items through a combination of optical imaging and elemental and molecular analysis.

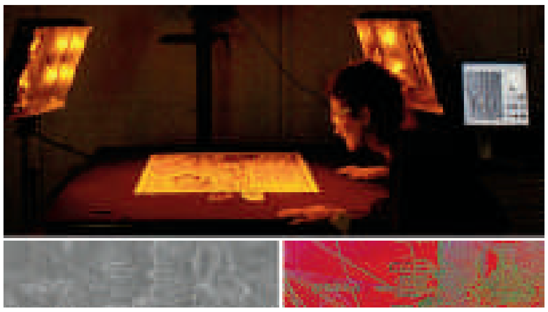


Hyperspectral Imaging Research Instrumentation.

Digital Research Instrumentation; E-SEM.

1. LC's Optical Properties Laboratory Spaces. © LOC

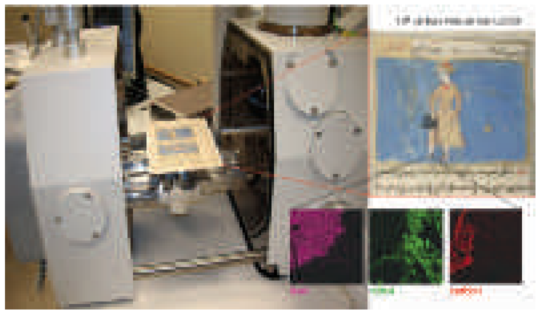
These techniques provide information about how light from different portions of the electromagnetic spectrum interacts with materials, and the chemistry that underlies these interactions. The instruments in the OP Lab are used to examine traditional materials as well as modern media. The Library's hyperspectral imaging (HSI) system (**Fig. 2**) is currently documenting the Library's Top Treasures for security and scholarly purposes, revealing information invisible to the unaided eye, and in some cases significantly enhancing knowledge of our heritage.



2. LC's scientists use Hyperspectral Imaging to the composition of documents, such as the 1507 Waldseemueller Map, called "America's Birth Certificate". © LOC

Principle component analysis through HSI assigns colors to spectrally distinct components. This produces a false color map of components based on optical response. The specific spectral response of components can be matched to reference sample databases. Types and locations of components and changes, from aging or treatments, can be mapped and characterized, allowing scripto-spatial analysis of collections. HSI, like many techniques at our disposal, requires no sampling, so items can be examined non-invasively. Complimenting HSI, x-ray fluorescence (XRF) spectrometry can also reveal inorganic composition of materials without subjecting an object to physical sampling produces.

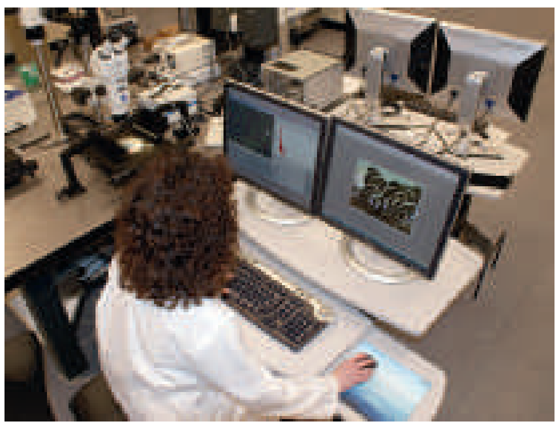
The laboratory's environmental scanning electron microscope (E-SEM) has a chamber that can hold small items or samples to magnify morphology up to 100,000 times. The E-SEM also has a stage that allows the chamber environment to be manipulated, letting scientists see, in real time through a "video" feature, changes to samples impacted by adverse conditions. Scientists can also identify inorganic elements using an energy-dispersive x-ray spectroscopy (EDX) system coupled to the E-SEM, and assign color codes to produce elemental dot maps to increase information about composition (**Fig. 3**).



3. LC's Environmental Scanning Electron microscope can facilitate non-destructive analysis through "elemental dot mapping" of small items place in its environmental chamber. © LOC

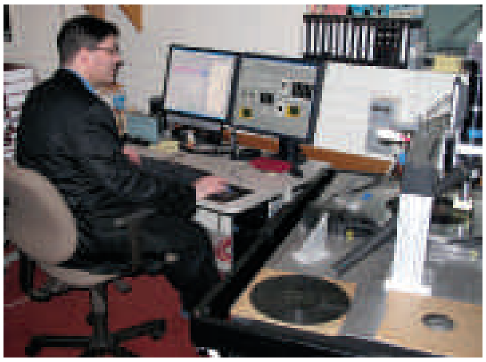
Other instruments in this lab identify molecular groups that absorb, reflect, and emit different wavebands in the ultraviolet-visible-infrared (UV-VIS-IR) spectrum, producing images that map the type and location of compounds, or creating spectrographs, showing presence and relative quantity of elements and compounds. Such instruments include several spectrometers: UV-VIS-IR fluorescence, Fourier transform infrared (FT-IR) for organic analysis, portable XRF, and color spectrophotometers.

These instruments enable the study of both traditional and modern media. Our CD research program (**Fig. 4**) tracks disc longevity through natural and accelerated aging, and matches changes in signal (as detected by a Datarius signal processing analyzer) to blemishes (detected and measured with a specially designed high-power stage microscope and lighting system).



4. LC uses high power microscopes to track physical deterioration of CD-Roms. © LOC

Our AV research program is currently examining magnetic tapes that have "sticky shed," which hinders reformatting. FT-IR spectroscopy can reveal organic chemical markers of deterioration by detecting differences in tapes before and after "baking" treatments. To identify environmental causes triggering change, we eventually expect to correlate FT-IR findings to changes in samples observed by E-SEM, which can not only change chamber temperature and humidity in real time, but create a video of the sample as it changes. The AV program includes earlier sound recordings that can no longer be accessed (such as broken phonograph records or cylinder disks), by developing innovative non-contact reformatting solutions (such as the IRENE machine, **Fig. 5**).



5. LC's IRENE Machine can capture sound using light rather than a stylus. © LOC

The **Chemical Properties Laboratory** (**Fig. 6**) enables analyses of the chemical make-up of collections and associated materials, through mass spectrometry (such as Direct Analysis in Real Time or Gas Chromatograph Mass Spectrometry) and chromatography (High-Temperature Gel Permeation Chromatography, High-Performance Liquid Chromatography, etc.). The work of this lab is especially important to setting and maintaining standards.

6. LC's Chemical Properties Laboratory Space. © LOC

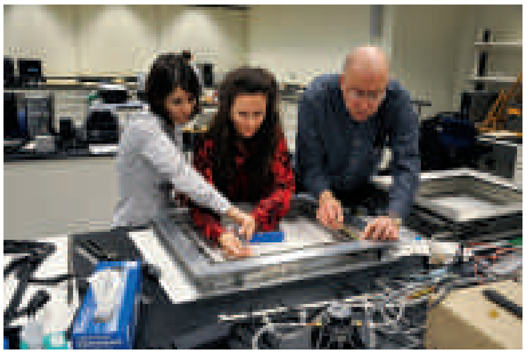
The **Physical Properties Laboratory** (**Fig. 7**) conforms to environmental condition standards set by the Technical Association of the Pulp and Paper Industry (TAPPI) to ensure that all mechanical testing measurements are replicable. The TAPPI room contains instruments that measure physical properties of strength: tear and burst resistance, fold endurance, and abrasion, rub, and tensile testers. An additional room-size inner chamber enables larger scale studies into the effects of varying temperature and humidity.

7. LC's Physical Properties Laboratory Space: the TAPPI Room. © LOC

Finally, the **Center for the Library's Analytical Science Samples** (CLASS) facilitates research by national and international scholars through the Library's rare and unique reference sample collections (**Fig. 8**). The core of the Center are the TAPPI Fiber Collection (70 well-documented paper fiber samples), Forbes Pigment Collection (1000 rare pigments), and the Barrow Books Collection (1000 volumes used for seminal mass deacidification studies). In addition to housing physical samples, CLASS will have a resource description framework (RDF) software system containing digital data (spectra, images, metadata) to exchange with other researchers. Reference samples supplement knowledge gained by the work of our labs by fostering staff connoisseurship and care of heritage collections. The samples enable coalitions of curators, conservators, and material scientists to advance stylistic, historical, and scientific analysis. Stylistic analysis (often based on curatorial expertise) can determine consistency of place, period, and purpose of origin. Historical analysis (the realm of a conservator) can validate consistency of materials and techniques used for the production of substrates and media. Scientific analysis (the primary role of a materials scientist) can determine consistency of material composition and optical, physical, and chemical properties of an item, using magnification along with spectral imaging and spectroscopic and spectrometric analysis, to identify and measure these properties.

8. LC's Center for the Library's Analytical Science Samples (CLASS). © LOC

There is a second question we at the Library often face: **What is the national research agenda to address the pressing need to sustain usability of all formats?** For almost five decades, the Library's scientists and conservators, who have practical experience derived from working with millions of items representing every format used to record the world's heritage, have contributed to preservation decisions by collections stewards around the world. To help answer this question, we have recently convened leading scientists from cultural and forensic institutions within and outside the US to discuss areas of investment in research. These efforts were supported by funding from the Samuel H. Kress Foundation, the American Institute for Conservation, the National Center for Preservation Technology and Training, and by contributions to collaborative research supported by the Institute of Library and Museum Services and the National Endowment for the Humanities. From these convened symposia, we produced a matrix clustering research initiatives by allied institutions. The matrix tallies areas of greatest activity in science labs in nineteen cultural institutions, in effect producing a snapshot of the **National Preservation Research Agenda** for the preservation of the human record. The following six focus areas were identified as the most pressing for national and international preservation research.



9. LC has developed oxygen-free visual storage systems to preserve the Top Treasures, such as Lincoln's Gettysburg Address. © LOC

Technology Transfer

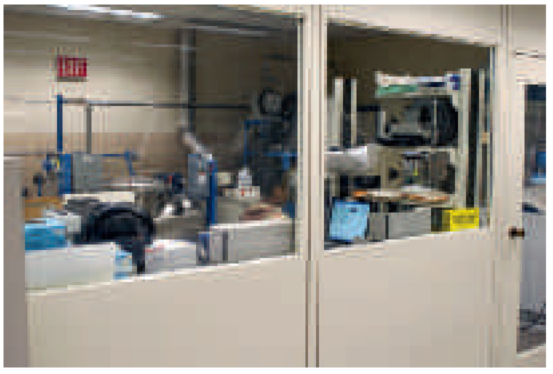
Based on our "focus group" of science labs in nineteen cultural institutions, by far the area of greatest research investment appears to be technology and information transfer, with at least three dozen initiatives underway in these institutions. The Library is engaged in a half dozen. The interest in technology transfer may owe, in part, to advances in imaging science and non-destructive analysis in other disciplines, particularly in forensics, which can be adapted to the needs of heritage preservation. In turn, modifications of these technologies for non-invasive analysis of priceless collections, and to detect deleterious changes at the earliest possible moment, can improve the sensitivity of processes used in forensic disciplines. Examples of related Library initiatives include the use of hyperspectral imaging (HSI) to study original text changes in a draft of the *Declaration of Independence*, and the use of particle physics applications to develop the IRENE prototype. Other Library and allied agency initiatives include the practical application of haptic virtual reality models to train conservators in examination and treatment; laser and other cleaning techniques; confocal scanning; and development and adaptation of a wide range of instrumentation, ranging from DART mass spectroscopy to microfading technology.

Environmental Studies

The cost-efficient impact of environmental control may explain why this topic is the focus of at least a dozen initiatives. The Library is pursuing five. We know from many years of research that temperature, light, moisture, and contaminants can start or speed chemical reactions that cause both visible and microscopic damages. But we don't understand the detailed processes of deterioration in every material commonly found in libraries or archives. The Library focuses on understanding environmental causes of damage; finding ways to predict deterioration related to environmental conditions modeled on natural and accelerated aging studies; and finding efficient, cost-effective, and responsible methods of controlling library environments. Collaborative research has led to new ways to refine and monitor remote storage conditions to slow deterioration, as well as to improve anoxic visual storage systems (**Fig. 9**). The Library and other institutions are studying the efficacy of low-oxygen and robotic storage, effects of exhibition conditions on sensitive items, effects of volatile organic compounds in collections, and risk assessment.

Preservation of Traditional Materials

Science labs in cultural agencies identified over two dozen major initiatives underway relevant to the preservation of paper, parchment, photographs, and other "traditional" materials in their collections. The Library has a half-dozen long-term initiatives underway. The Library's research into mass deacidification (**Fig. 10**), successfully implemented for the last decade to counter acid-related paper damage, continues - as does similar research at four other institutions. Answers to questions about deterioration of legacy collections remain critical because in the transition to more fully digital service, libraries will be challenged to prioritize, treat, and integrate legacy collection workflows with continuing digital developments. Through the period of their copyright protection, information sources in both traditional and digital formats will need to be preserved if they are to fully inform scholarly education and research. Areas of study by the Library and others range from understanding factors of internal or inherent instability to characterizing the components of materials using chemical and other forms of analysis, to developing innovative treatments.



10. LC's Glass-Enclosed On-site Mass Deacidification Space. © LOC

Preservation of Audio-Visual Materials

Fewer institutions appear to have taken on research into the preservation of AV materials, with less than a half-dozen initiatives described by our focus group (half at the Library). This may be a consequence of the challenges involved in understanding this diverse, complex array of rapidly deteriorating materials, many of which are just as rapidly becoming obsolete. The recognition that moving images and recorded sound in their various formats, as well as video and computer tapes and discs, are highly vulnerable to damage and loss has come to our collective awareness relatively late. Preserving audio-visual materials has often taken the form of copying them to newer formats as those become available. Most copying options require two factors: originals in playable condition, and access to machines that can read originals for reformatting. Unfortunately both factors are hard to guarantee in the long term. In the short term, the risk of losing major AV collections has become as urgent as the earlier acid paper threat. The Library's research has helped develop machinery to read and digitally reproduce many damaged sound recordings without additional damage. Other initiatives at the Library and elsewhere have focused on the "sticky shed" phenomenon (which makes many magnetic tapes unreadable), fidelity of reformatted versions, and the challenges of interactive or time-based media.

Preservation of Digital Materials

A half-dozen research initiatives into continued access to digital media are underway by our focus group institutions (again, half at the Library). Digital technology has changed our very paradigms of creating, storing, and transmitting images, sounds, and ideas in ways most people could not imagine even fifty years ago, and we have only begun to tap its potential. Unfortunately collections based on this technology –the devices that store it and the ones that allow us to use it– are the most vulnerable to the most rapid loss. Physical formats change fast and manufacturers use different materials and processes (case in point: the competitive emergence of punch cards vs. paper or magnetic tapes, vs. 8-, 5¼-, 3½ -inch floppy discs, vs. CDs and DVDs). Data storage formats change fast (think of Betamax to VHS to Blu-ray). The machines that play them change fast and the conventions by which we organize access to them ("meta-data") have yet to develop full consensus. Libraries are still experimenting with strategies to preserve long-term access to digital information, which for libraries means 100 years and more. Current Library research focuses on understanding the physical nature of storage media and their deterioration, essential to copying and reformatting collections whose original reading machinery no longer exists. Our primary focus has been on deterioration and longevity of digital discs, complementing work at other institutions, some of which are studying other storage media and the effects of cold storage.

Experimental Sample Reference Collections

The fundamental importance of reference collections is evidenced by the fact that eight institutions in our focus group are investing in setting up such collections. One of the great challenges in understanding library materials and their deterioration is the repeatability of results across experiments, laboratories, and collections in different institutions. Many older storage, handling, and repair histories were undocumented, and it is often impossible to know how or where even modern paper, compact discs, photographic chemicals, or other materials were originally manufactured. Small variations can result in significant differences in the behavior of materials and their combinations over time, and all analytical instruments produce results that can differ with their calibration. These realities make it essential to have reference standards to improve scientists' confidence in relating their findings to those of others. It is heartening to know that in addition to the Center for the Library's Analytical Science Samples, eight other cultural institutions are actively developing collections of photographic materials, model books, dyes and databases.

About the author: Dianne van der Reyden is the Director for Preservation, overseeing approximately 150 conservators, scientists and other preservation professionals and technicians in the Preservation Directorate of the Library Services unit of the Library of Congress. She is the author of over 100 articles and presentations on conservation, preservation and research. Her training includes degrees and certificates from New York University and Harvard University; internships at New York's Museum of Modern Art, Harvard's Fogg Art Museum and the Library of Congress. She was a Senior Conservator at the Smithsonian Institution for twenty years before returning to the Library in 2002.

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LIST of websites as they appear in this article

For more information on the topics mentioned in this article, see the following websites:

LC's research projects updates: http://www.loc.gov/preserv/rt/projects/index.html
LC's visiting scholars program: http://www.loc.gov/preserv/visiting.html
LC's cultural partners: http://www.loc.gov/preserv/symposia/researchsum.html
LC's forensic partners: http://www.loc.gov/preserv/symposia/researchtech.html
National Preservation Research Agenda: http://www.loc.gov/preserv/rt/projects/agenda.html
LC's science labs: http://blogs.loc.gov/loc/2010/02/new-optical-lab-brings-loc-into-21st-century/
Explanation of chemical, physical and optical properties:
http://si-pddr.si.edu/dspace/bitstream/10088/8141/1/mci_JAIC1992-DvR.pdf
LC's instruments: http://www.loc.gov/preserv/rt/PRTDinstruments.pdf
Tenets of green labs: http://www.loc.gov/preserv/rt/projects/lab_renovation.html
LC's Preservation Directorate: http://www.loc.gov/preserv/symposia/schedule.html
CD research: http://www.loc.gov/preserv/rt/projects/cd_longevity.html
LC's sticky shed research: http://www.loc.gov/preserv/rt/projects/sticky_shed.html
LC's non-contact reformatting solutions (the IRENE machine):
http://www.loc.gov/preserv/rt/projects/imaging_audio.html
LC's Center for the Library's Analytical Science Samples:
http://www.loc.gov/preserv/rt/projects/class.html
Explanation of connoisseurship:
http://www.si.edu/MCI/downloads/RELACT/identifying_the_real_thing.pdf
LC's cultural partners with science labs: http://www.loc.gov/preserv/symposia/researchsum.html
LC's forensic partners: http://www.loc.gov/preserv/symposia/researchtech.html
Matrix of research initiatives at LC and similar institutions: http://www.loc.gov/preserv/symposia/SORS Matrix.xls
National Preservation Research Agenda: http://www.loc.gov/preserv/rt/projects/agenda.html
Six focus areas of research into preservation of documents at the Library of Congress:
http://www.loc.gov/preserv/rt/projects/index.html
Technology Transfer: http://www.loc.gov/preserv/rt/projects/index.html#transfer
Confocal scanning initiative of sound recordings:
http://www.loc.gov/preserv/rt/projects/imaging_audio.html
LC's haptic virtual reality study: http://www.loc.gov/preserv/rt/projects/haptic_technol.html
Direct Analysis in Real Time Mass Spectrometry (DART-MS)
Environmental Studies: http://www.loc.gov/preserv/rt/projects/index.html#envir
Visual storage systems: http://www.loc.gov/preserv/rt/projects/anoxic_cases.html
Preservation of Traditional Materials: http://www.loc.gov/preserv/rt/projects/index.html#trad
LC's mass deacidification program: http://www.loc.gov/preserv/deacid/massdeac.html
Preservation of Audio-Visual Materials: http://www.loc.gov/preserv/rt/projects/index.html#av
IRENE machinery to capture sound recordings:
http://www.loc.gov/preserv/rt/projects/imaging_audio.html
Preservation of Digital Materials: http://www.loc.gov/preserv/rt/projects/index.html#digital
Experimental Sample Reference Collections: http://www.loc.gov/preserv/rt/projects/index.html#sample

Science at the Getty Conservation Institute

by Giacomo Chiari, Chief Scientist, and **Gary Mattison**, Department Coordinator,
The Getty Conservation Institute

The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, model field projects, and the dissemination of the results of both its own work and the work of others in the field. The GCI focuses on the creation and delivery of knowledge that will benefit the professionals and organizations responsible for the conservation of the world's cultural heritage.

The work of the GCI is divided into four major areas: science, field projects, education and dissemination. This article highlights the activities of the GCI Science department.

Conservation science focuses on studying deterioration mechanisms of objects of art and — working with conservators — designing and evaluating conservation treatments to provide long-term stability to objects. The ultimate objective of this research is to develop conservation approaches that slow the deterioration of materials and, if possible, prevent further damage, with a primary emphasis on applicability and sustainability. Using a wide variety of instrumentation and analytical techniques, GCI scientists provide essential information to conservators and curators about the principal factors influencing damage mechanisms, as well as offer guidance with respect to compatible treatment options.

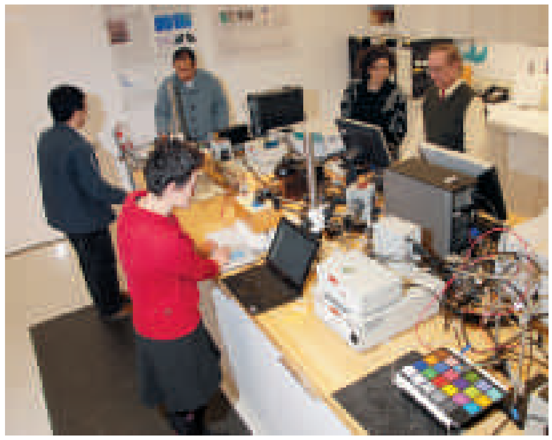
GCI's scientists are often called upon to test works of art and architecture with scientific equipment in order to answer a number of key questions:

- What material(s) did the artist use to make the object (characterization)?
- How did the artist make the object (technical art history)?
- When was the object made (dating)?
- Where was the object made (provenance)?

To address these questions, GCI scientists work in state-of-the-art laboratories, each designed to conduct specific types of analysis. Primary research areas include Collections Research, Preventive Conservation, Modern and Contemporary Art, Photographs, Museum Lighting, and Microfadeometry. In this article we provide a brief introduction to these research areas. We also provide an overview of new analytical instrumentation we have developed in recent years to help scientists more effectively examine works of art.

The Collections Research Laboratory

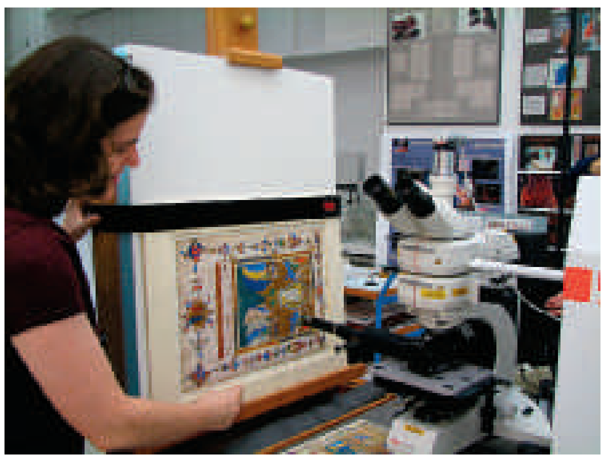
The Collections Research Laboratory's (CRL) primarily conducts scientific research on objects in the collection of the J. Paul Getty Museum and other related institutions. The staff of the CRL investigates questions of authenticity, attribution, and artists' techniques; assists in the development and evaluation of conservation treatment programs; and contributes to the understanding of properties and behavior of art materials.



1. Scientists in the GCI Science Microfadeometry Laboratory. Photo: Dusan Stulik.

The Getty Museum has an extensive collection of manuscripts dating from the ninth to the sixteenth centuries, featuring outstanding examples of Ottoman, Byzantine, Romanesque, Gothic, and Renaissance illumination. Working with the Manuscripts Conservation and Curatorial Departments, the staff of the CRL engages in studies regarding the nature of the inks, pigments, colorants, and support materials found in manuscripts to understand possible deterioration mechanisms, and to better conserve these works. Furthermore, since most illuminators historically did not sign their work, a thorough understanding of the materials and methods used in their creation can help with attribution.

Manuscript illuminations generally cannot be sampled, and therefore scientific analysis must be conducted using the noninvasive technologies of X-ray fluorescence (XRF) spectroscopy and Raman microspectroscopy. Recently, a portable non-invasive X-ray diffraction/fluorescence device was introduced with success.



2. An illustration in Martín de Murúa's *Historia general del Piru*, being examined by GCI scientist Catherine Patterson using Raman spectroscopy. Photo: Dennis Keeley.

The portable XRF was used as part of a scientific investigation carried out on two manuscripts by Martin de Marúa, a Spanish friar who lived in Peru between the sixteenth and seventeenth centuries. Both manuscripts contain numerous watercolor illustrations depicting Inca royalty, history, and traditions.

XRF analysis on the manuscripts was carried out using a Keymaster (now Bruker) Tracer III-V Handheld (portable) XRF spectrometer. This analysis allows for the detection of elements heavier than sodium. The pigments present may be inferred from the elements detected — e.g., mercury infers the presence of the red pigment vermilion or cinnabar. However, many pigments contain the same elements and therefore elemental analysis alone cannot make a conclusive identification: e.g., the presence of lead may indicate lead white, the red pigment minium, the alteration plattnerite, or a combination of all of them.

Preventive Conservation Research Laboratory

Preventive conservation is the process of determining the environmental factors causing deterioration to works of art, and then developing technologies that can mitigate that deterioration and — in some cases — prevent future damage.

External environmental factors that can damage buildings, monuments, and archaeological sites include rain, wind, salt content in soil, sunlight, humidity, and temperature, among others. Indoor environmental factors causing damage to objects in collections or storage (or to the buildings themselves) include lighting, off-gassing (from either the object itself or perhaps the drawer housing the object), airborne pollutants, temperature, humidity, and more.

The first step in preventive conservation is to accurately monitor those changes in environmental conditions that can have a significant impact on a work of art. This type of monitoring allows scientists to observe how changes in temperature, humidity, and other environmental conditions directly and indirectly affect an object or collection of objects, and then, based on these results, make recommendations to conservators and others on ways to protect the objects from further damage.

Since 2004, the Preventive Conservation Laboratory has had a long-term relationship with the Casa di Rui Barbosa Foundation (FCRB) in Rio de Janeiro, Brazil. Rui Barbosa, a prominent Brazilian humanist, lawyer, writer, and statesman, was active in the latter nineteenth century and early twentieth century. His home was the first house museum in Brazil.

The library of Casa de Rui Barbosa consists of five rooms, which contain Barbosa's original book collection in custom-built book cabinets, furniture, and artwork. The GCI's objective was to improve indoor climate conditions, providing a safe environment for the conservation of the art and book collections while maintaining the house's physical integrity.

GCI scientists' recommendations included having the original climate control features of the building reinstated as much as possible. Climate improvements in the cellar and attic were also very important. Books were cleaned and then returned to the bookcases; they are now protected in the micro-environment of the bookcases from both fluctuations of relative humidity and the impact of air pollution and dust.

3. GCI scientist Shin Maekawa takes temperature and humidity measurements in the library of Casa de Rui Barbosa. Photo: Claudia Carvalho.

The Modern and Contemporary Art Conservation Laboratory (ModCon)

The Modern and Contemporary Art team takes a broad approach, including analyzing new art materials and assessing their stability; investigating methods that can improve conservation treatments; and seeking technical solutions for decreasing rates of deterioration. Strategies for the dissemination of information and exploring the most appropriate methods for furthering the debate over ethical issues are also developed.

Conservation issues posed by modern and contemporary art are among the most pressing in the field. Despite their relatively young age (*modern* is loosely defined here as post-1900, and *contemporary* as anything created in the last thirty years), these artworks present substantial conservation challenges. In addition to the obvious scenarios of conservation being required after accidental damage or vandalism—either of which could occur from the very moment a work of art is created—there are several other factors particular to these works that create a need for conservation research.

4. GCI scientists Alan Phenix (left) and Tom Learner assessing the potential of a small, handheld Raman instrument for rapidly differentiating classes of plastic. Photo: Rachel Rivenc.

5. Part of the collection of reference plastics ("SamCo") being used in the POPART project to compare different methods of analysis for plastics. Photo: Tom Learner.

GCI "ModCon" scientists selected one specific class of materials to investigate: plastics. Plastics form a significant part of modern and contemporary cultural heritage. Unfortunately, many plastics deteriorate rapidly due to irreversible chemical reactions, leading to a number of dramatic physical changes: discoloration, opacification, loss of gloss, crazing, cracking, warping, sagging, becoming sticky, crumbling, and powdering.

Knowledge about the composition and aging of synthetic polymers –of paramount importance to curators and conservators entrusted with the care of plastic objects– is often not readily accessible. There is an urgent need for obtaining and disseminating information on the material composition, physical and chemical properties, and aging behavior of a range of plastics –information crucial for devising strategies to slow deterioration rates and for assessing treatment options and their potential long-term impact on plastics objects.

To address these needs, the GCI has joined a consortium of European institutions and laboratories, all of whom are involved in the care or study of modern and synthetic materials to develop and execute a three-year European Commission-funded project entitled Preservation Of Plastic Artifacts in Museum Collections (POPART). The main objectives of POPART are to identify the principal risks associated with the cleaning, exhibition, and storage of plastic artifacts, and subsequently to develop a strategy to improve the preservation and maintenance of three-dimensional plastic objects in museum collections.

The Photograph Conservation Research Laboratory

The GCI's Photograph Conservation Research Laboratory seeks to advance the identification of photographs and photographic processes beyond optical microscopy, the current standard methodology for identifying photographs.
A visual and microscopic method of identification of photographs and photographic processes allows for very confident identification of many photographic processes which account for about 75 percent of all photographs found in museums and photographic archives. These standard methods of identification usually fail, however, when: a) dealing with less common photographic techniques; b) trying to identify important variants of photographic processes; and c) dealing with many photographic processes that are visually very similar to one another.

The GCI has developed a new, scientifically based methodology for the identification of photographs and photographic processes. Several portable instruments allow for fast, non-contact and completely noninvasive identification of photographs that are lacking provenance and process descriptions.

Another important aspect of GCI photographs research is the development and application of quantitative methods of XRF analysis for the provenance and authentication studies of photographs. Silver gelatin black-and-white photographic paper was by far the most frequently used photographic printing material of the twentieth century. Silver gelatin photographic paper was also the only printing medium used by Henri Cartier-Bresson, and later by his printers, when creating his photographs that are today found in art museums and private collections around the world.

6. Quantitative XRF analysis of the Cartier-Bresson photograph, *Paris. Place de l'Europe. Gare Saint Lazare. 1932* at the HCB Foundation in Paris. Photo: Dusan Stulik.

Cartier-Bresson preferred certain types of photographic papers when he printed his own photographs, and he requested specific photographic papers be used when working with commercial printers. Each type of photographic paper used by Cartier-Bresson and his printers has a unique chemical composition due to the presence of a baryta layer in the paper substrate. The noninvasive chemical analysis of the baryta layer provides an opportunity to identify the type of photographic paper used and in some cases can aid in the dating of photographs.

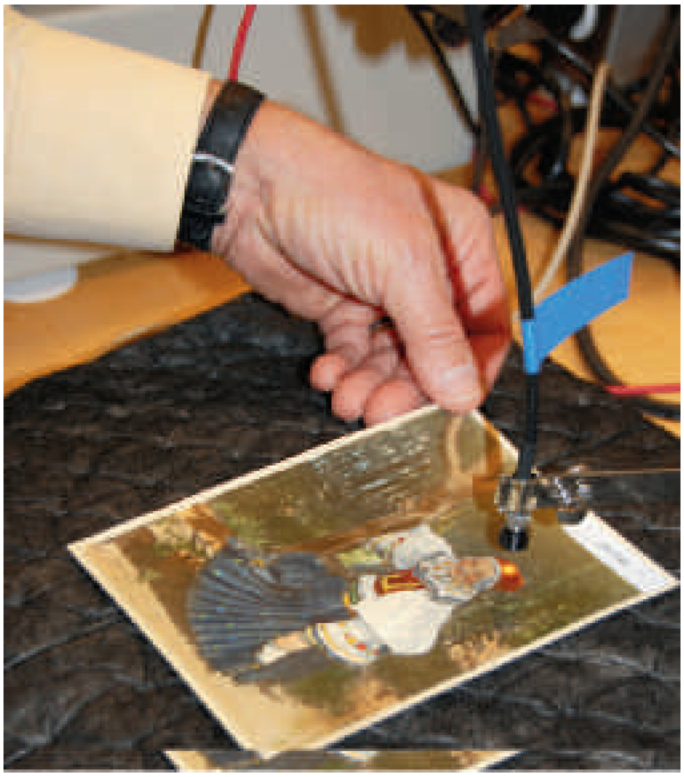
The GCI's scientifically based methodology was recently implemented in a collaborative project of the GCI, the Atelier de Restauration et de Conservation des Photographies de la Ville de Paris (ARCP), the Henri Cartier-Bresson Foundation (HCBF), and several photographic collections in Paris to carry out a systematic analytical survey of Cartier-Bresson's photographs.

The Microfadeometry Laboratory

Three fully functional sets of microfading instrumentation were developed in the GCI's Microfadeometry Laboratory. Two instruments are research-level and the third is a portable unit that has been reduced to the most basic design for ease of transport. Together they support two important aspects of the GCI's work.

GCI scientists are often asked by conservators at the Getty Museum or the Getty Research Institute to assess the light-sensitivity of works going up on exhibition or works requested for loan to another institution.

Multiple factors make assigning a specific level of light sensitivity questionable, even if the chemistry of the colorants is known. For example, the factors influencing fading behavior include the amount of previous light exposure, the concentration of pigment particles, and the presence and type of binder. Direct, virtual noninvasive testing is the only way to circumnavigate these difficulties.



7. A scientist positions the measurement probe of a new portable microfader on a test area of a Gretag Macbeth Color Checker. Photo: Dusan Stulik.

Areas of pigment or dye considered potentially sensitive are selected and an intense beam of xenon light is focused on a spot generally smaller than one-half millimeter. Simultaneously the color is measured and spot-faded. The color change is calculated and shown on a computer in real-time and the test is terminated at a predetermined level—three to four units of E, which is not visible at this small size.

Blue Wool standards have been used in conservation for more than forty years, and their fading rates under museum levels of illumination are fairly well known. If a pigment or dye changes color at a similar rate under microfading conditions as one of the blue wools—there are eight dyed samples of progressively higher and higher lightfastness—then the pigmented or dyed area is given that level of sensitivity. An unknown red colorant that fades at the same rate as blue wool #2 can be said to fade to a just noticeable extent in 900,000 lux hours of light exposure under exhibition conditions. The future light exposure of that particular artifact can then be scheduled to achieve a visible change over a predetermined period of time into the future—say fifty or one hundred years.

The Museum Lighting Laboratory

The Museum Lighting Laboratory is committed to re-evaluate the safety of current illumination guidelines for art museums, and to offer institutions such as the Georgia O'Keeffe Museum, the Getty Museum, and ultimately the entire conservation field, improved lighting specifications applied to works of art on paper. Improvements in safety and exhibition durations, as well as assessments in visitor satisfaction, are being implemented in a program of design and manufacturing of filters.

8. GCI scientist Jim Druzik holding one of several filters being evaluated for use in museum lighting as part of the Institute's Museum Lighting project. Photo: Jessica Robinson.

The data, products, and techniques developed by the Museum Lighting Laboratory are largely independent of the technical sophistication of the environs in which they find themselves being used. This means methods can be employed in developing countries, as well as industrial ones; historical and local organizations, as well as large urban institutions; and collections with internal conservation expertise and those without it. Likewise, these methods are disseminated to natural and other cultural history collections with art objects at risk of lighting damage.

Incandescent lighting is the most common form of artificial display lighting found in museums and libraries. Such lighting has low levels of natural ultraviolet light but is high in the infrared. An established principle is to remove irradiation that does not contribute to the overall aesthetic experience of the viewer or scholar. Generally this has been achieved with simple UV and IR filters that cut off wavelengths beyond the visible range with varying degrees of success. But as four-color printing processes have demonstrated, most colors can be fairly well represented with cyan, magenta, yellow, and black printing inks.

This suggests that a continuous spectrum may not be required in most cases to render artworks accurately. In fact, tri-phosphor fluorescent lamps have produced an acceptable white light for some time. Given these facts, the GCI's work has focused on applying computational methods to design filters optimized for high color rendering and high luminous efficiency.

Portable Instrumentation

Finally, an important component of GCI Science is developing new analytical instruments to better address scientific questions in cultural heritage. When no scientific instrument exists for performing the type of analysis that is required –occasionally to address profound, unanswered questions in conservation or art history– conservation scientists help to design and build instruments that can provide more advanced, cutting edge scientific analyses.

9. The portable XRD/XRF is ready to analyze the pigments of underpainting in the *An Old Man in Military Costume* by Rembrandt van Rijn, property of the J. Paul Getty Museum. Photo: Giacomo Chiari.

These so-called noninvasive instruments are advantageous because no samples need to be taken. The instruments are also designed to be portable so that the analysis is taken to the object and not the object to the lab.

A **portable XRD/XRF** prototype developed by inXitu in collaboration with the GCI was used in analyzing the Red Shroud Mummy that is part of the Getty Museum collection. For the painting *An Old Man in Military Costume* by Rembrandt van Rijn, also part of the Getty Museum collection, a noninvasive stratigraphic study was conducted, identifying the pigments in an underlying painting, not visible from the front. It was also used in situ in the Tomb of Tutankhamen to analyze the mural painting and the sarcophagus.

This is one of the first instruments that allows for the identification of the chemical compounds (XRD) on the same spot where the elemental analysis is carried out (XRF). It is particularly useful to identify the inorganic components of illuminated manuscripts.

10. GCI chief scientist Giacomo Chiari uses the portable XRD/XRF to analyze pigments found in an Ethopian gospel manuscript owned by the Getty.

These applications, together with analyses of tests specifically prepared for the instrument, have shown the portable XRD/XRF to be highly accurate. This instrument is likely to radically change how analytical imaging is carried out, including reducing the number of samples that need to be taken.

Laser speckle interferometry is an imaging technique capable of registering minute surface details of an object known as *microrelief*. When an object is illuminated by a defocused, divergent laser, the microrelief generates a speckle pattern, which looks like a random distribution of small dots moving haphazardly in front of the observer's eye. Mathematical calculations analyze changes in the speckle pattern in order to map movements of the object's microrelief. Laser speckle interferometry can be used by wall painting conservators to determine which areas of a painting have lifted off of the wall. Gentle tapping, or the sound of a loudspeaker, causes the painting to vibrate. More so the detached parts, which can be easily visualized through real-time computer analysis of the speckle pattern.

CT-scan or computerized tomography is a noninvasive technique which gives information on the "inside" of objects. Tomography stands for virtual cutting slices of the object that are then put together by computer calculations in order to reconstruct a complete three-dimensional image, including the internal parts. To do this, one needs to use a penetrating radiation (X-ray or, even better, neutron beams).

Polynomial texture mapping (PTM) was developed by Hewlett Packard Laboratories and subsequently adapted at the GCI for portable use in documenting the fine texture of art objects. It is based on taking a large number of photographs with varying incident light. The computer puts them together and with a click of the mouse one can change the illumination on the object. Portable PTM is especially well-suited for use on paintings, murals, and rock carvings because it can document surface changes caused by aging or by conservation treatment.

GCI Science remains at the forefront of conservation science, working with institutions around the world to develop new analytical methodologies and techniques to preserve the world's cultural heritage. The array of techniques at the disposal of GCI conservation scientists include those developed specifically for conservation augmented by analytical and diagnostic techniques developed for other fields. New and ongoing partnerships art centers, academia and industry broaden the range of available equipment and, thus, expand our range of knowledge and analytical capabilities. Given the rapid pace of technological advances, questions that have remained unanswered with today's technology will almost certainly have real solutions in the near future.

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Focus on POPART

To learn more about this three-year European Commission-funded project on Preservation of Plastic Artefacts in Museum Collections, read the paper entitled "POPART: An International Research Project on the Conservation of Plastics" *in Conservation Perspectives, the GCI Newsletter*, Fall 2009: http://www.getty.edu/conservation/publications/newsletters/24_2/popart.html

Ciencia en el Getty Conservation Institute

The Getty Conservation Institute (GCI) trabaja internacionalmente para desarrollar la práctica de la conservación en las artes visuales, que abarcan objetos, colecciones, arquitectura y sitios. El Instituto está dirigido a la comunidad de la conservación a través de la investigación científica, la educación y la capacitación, los trabajos de campo y la difusión de los resultados. El objetivo del Departamento de Ciencias del GCI es el desarrollo de enfoques de la conservación que frenen el deterioro de los materiales y, de ser posible, eviten mayores daños. Los científicos del GCI trabajan en laboratorios con tecnología de punta, diseñados para llevar a cabo tipos de análisis específicos. Las principales áreas de investigación incluyen:

- *Laboratorio de Investigación de Colecciones*
Este laboratorio realiza, principalmente, investigaciones científicas de los objetos de la colección del Museo J. Paul Getty y otras instituciones relacionadas a fin de determinar aspectos como la autenticidad, atribución y técnicas de los artistas; brinda asistencia en el desarrollo y evaluación de los programas de tratamientos de conservación y contribuye a comprender las propiedades y el comportamiento de los materiales de las obras de arte.

-*Laboratorio de Investigación de Conservación Preventiva*
La conservación preventiva consiste en el proceso de determinar los factores ambientales que causan el deterioro de las obras de arte, y luego desarrollar tecnologías que puedan mitigar dicho deterioro y, en algunos casos, evitar daños futuros.

- *Laboratorio de Conservación de Arte Moderno y Contemporáneo (ModCon)*
El equipo de Arte Moderno y Contemporáneo tiene un enfoque amplio, que incluye el análisis de los nuevos materiales y la evaluación de su estabilidad; investiga los métodos que pueden mejorar los tratamientos de conservación y busca soluciones técnicas para reducir las tasas de deterioro. El GCI se unió al proyecto POPART: Preservation of Plastic Artifacts in Museum Collections (Preservación de Artefactos Plásticos en Colecciones Museísticas).

- *Laboratorio de Investigación de Conservación de Fotografías*
Este laboratorio del GCI busca desarrollar la identificación de fotografías y de los procesos fotográficos más allá de la microscopía, mediante el desarrollo de una nueva metodología de identificación con base científica.

-*Laboratorio de Microfadeometría*
En el Laboratorio de Microfadeometría del GCI se desarrollaron tres conjuntos completamente funcionales de instrumentación para el envejecimiento acelerado.

-*Laboratorio de Iluminación del Museo*
Este laboratorio es responsable de reevaluar la seguridad de las normas de iluminación vigentes para los museos de arte, y de ofrecer a las instituciones especificaciones de iluminación mejoradas aplicadas a las obras de arte sobre papel.
Se están implantando mejoras en la seguridad y duración de las exhibiciones, así como evaluaciones de la satisfacción de los visitantes, dentro del marco de un programa de diseño y manufactura de filtros.

-*Instrumental portátil*
Finalmente, un componente importante del Departamento de Ciencias del GCI es el desarrollo de nuevos instrumentos para análisis que permitan abordar mejor los problemas del patrimonio documental, tales como:
-Prototipo XRD/XRF portátil
-Láser de Interferometría
-Tomografía computarizada
-Polinomio de Texturización (PTM)

Antibodies and Art: Characterization of Albumen and Gelatin on Paper

by Joy Mazurek
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The enzyme-linked immunosorbent assay (ELISA) is an antibody-based technique commonly used in biological research to quickly and precisely identify very small samples of protein or other biological macromolecules using a reliable colorimetric assay. It requires small sample sizes, is extremely sensitive, and most importantly, is able to identify complex mixtures of proteins.

The identification of gelatin and albumen in photographs and historical paper is often desirable to improve the understanding of the materials and techniques, to make informed conservation treatment decisions, and to identify causes of deterioration in the object. Prior methods for the identification of gelatin and albumen have used quantitative amino acid analysis by gas chromatography-mass spectrometry (GC-MS) and liquid chromatography mass spectrometry (LC-MS). The pattern of relative amounts of the standard twenty amino acids provides a fingerprint for a specific protein. These methods face challenges when mixtures of proteins are present, and the problems can be compounded by the effects of aging and pigment interaction.
Fourier Transmission Infrared Analysis (FTIR) is a highly accurate and non-destructive technique used routinely in the identification of gelatin and albumen in photographs. A pattern of peaks in the amide region is used to differentiate between albumen and gelatin; however, matt albumen may not have this diagnostic pattern because it was mixed with starch, so the concentration of albumen is lower. FTIR does not usually require sampling, however micro-sampling (<10 µg or less) is necessary for ELISA and GC-MS. Mixtures of albumen and gelatin are extremely problematic for GC-MS and FTIR, while ELISA's main advantage is its ability to unambiguously characterize mixtures of proteins.

Albumen and Gelatin

Albumen and gelatin are notably important binders in the technical examination of works of art on paper. In the early 1850's, when photography was in its infancy, egg white was the first binder used to help increase the total amount of silver in the image, thus "albumen prints" were created. Gelatin silver images soon followed in the 1880's, and the use of albumen declined. Silver images on paper or photogenic drawing are made by soaking paper in sodium chloride and silver nitrate solutions, exposing them to sunlight, then allowing the silver halide compounds to darken. In 1850, Louis Désiré Blanquart-Evrard discovered the first albumen silver print. When the paper was coated with albumen it produced higher quality images with fine details and good tone.

Printing paper that was pre-coated with albumen was manufactured at this time and used until the end of the 19th century. Positive albumen photographs have an albumen binder layer that contain a silver image, are supported on a sheet of paper, can be toned with gold, range in color from purple to black, and may be coated with a wax or varnish. Albumen prints can yellow, fade or crack over time, and these are a means of identification. A typical preparation for albumen prints: salt was added to raw egg white and it was beaten into froth and strained. The paper was floated on this solution, dried, and then placed in a silver nitrate bath. Photographs may also contain a denatured layer of albumen followed by a final non-denatured layer.
The silver gelatin process was the most important process of the 20th century. By the early 1900's paper was being manufactured that was coated with a silver and gelatin emulsion. In order to make these early pre-coated papers, two solutions of gelatin were mixed together: one that contained silver nitrate, and the other a chloride or bromide solution. Although albumen and gelatin were very common, collodion, casein, starch, and plant gum were also available to bind the silver and create photographic images.

Gelatin and animal glue were used by artists to make tempera paints or as a glue to bind materials together, such as crafting furniture. It was very important to European craftsmen in the 15th to 18th centuries, and it was applied to handmade papers to minimize ink bleeding and improve certain mechanical characteristics such as abrasion and soiling resistance. Gesso, a paint composed of gypsum and animal glue, was used to prepare canvases for paint. The purified form of animal glue is gelatin and is used in the preparation layers of photographs. Collagen is the most abundant of all body proteins and can be found in bones, tendons, cartilage and animal skin. It is extracted from tissues into water and form a gel-like material that can be used as glue.

Papermaking in Europe from the 15th to 18th centuries was a complex process that took countless hours and many trained specialists to execute. The fine details of this highly prized art are expertly and completely reviewed in *Early European Papermaking Methods 1400-1800* by Timothy Barrett. In order for craftspeople to create a completely finished sheet, it was usually treated with a gelatin external sizing to obtain desired qualities such as increased durability.

Generally, starch sizing was used exclusively before around 1275, but after 1300, gelatin became standard. The concentration of gelatin appears to be related to the present day condition of the paper in that larger amounts of gelatin are often associated with less degraded paper. Gelatin was made onsite, and the grade produced was determined based on the final desired quality of the paper. Animal skins and bones were boiled in water, the collagen dissolved into gelatin in solution, and the fat and other undesired products were strained out or skimmed off. Gelatin was extracted from hooves, horns, hide bits, etc., from cows, calves, sheep, or goats, and more rarely from rabbits or sturgeon. Occasionally materials from different species were mixed, and the quality ranged from poor to excellent.

Immunology: Antibodies and Art

Immunological techniques were first thought of as a means to identify proteins in works of art in 1962, and the direct application of fluorescent antibodies to art was accomplished by Johnson and Packard in 1971. Since then, antibodies have been used to detect egg, animal glue, blood, and casein in a variety of cultural heritage objects. In 2004, Arlen Heginbotham, a conservator at the J. Paul Getty Museum, detected egg in an extremely thin layer of a cross-section that was sandwiched between multiple layers of polychrome from a 17th century French cabinet. By using fluorescent antibodies, he was able to tag and isolate this very thin layer of organic material.

The GCI adapted an ELISA procedure for the identification of plant gums, glues, binding media and other protein-based or polysaccharide-containing materials present in works of art. With this procedure it is possible to detect and differentiate four common binding media types: glue (gelatin), casein (milk), egg (albumen), and plant gums at concentrations in the nanogram range. It is an antibody-based technique that does not require expensive instrumentation, is reliable, and is extremely sensitive with samples containing complex protein and polysaccharide mixtures. This technique was successfully applied to samples from museum objects ranging from 3,000 to 200 years ago (**table 1**).

Immunology grew out of the observation that individuals who recover from certain infectious diseases are protected from that disease in the future (Immunis, Latin for exempt). In 430 BC, a plague struck Athens, Greece, and it was observed that only those who recovered were able to nurse the sick, and they did not become sick again. In 1500 AD, the Chinese purposefully exposed themselves to smallpox crusts in order to impart immunity. In 1881, Louis Pasteur created the first rabies vaccine by injecting a subject with deactivated non-virulent form of the rabies virus.

Antibodies are very important proteins found in the blood of all mammals and are vital to our survival (Crowther, 2001). Exposure to a virus or bacteria such as the flu or common cold initiates an immune system response within seven days by producing antibodies. A virus or bacteria is surrounded by a coat made of proteins, lipids or polysaccharides (many sugars); the antibody is highly specific to these areas and tags it for destruction by recognizing and attaching to it. There are thousands of different antibodies manufactured in the laboratory for use in medicine, such as home pregnancy tests, food allergy identifications, and AIDS virus screenings.

There are two general classes of antibodies: 1) monoclonal, derived from single antibody-producing cells; and 2) polyclonal, a serum product containing many different antibodies. Polyclonal antibodies are used to obtain general identification of the protein, and due to their greater variety, often give a better chance of success at the expense of specificity. Monoclonal antibodies can be used to get specific information about the protein or polysaccharide such as species origin. Small molecules that do not produce an immune response by themselves are called haptens. Haptens (such as a vitamin, steroids, or other small molecules) can be chemically bound to a protein and injected into a host. The antibodies produced in response to foreign antigens such as proteins, polysaccharides, or haptens are termed primary antibodies. Most of the commercially available antibodies are of the IgG class and are made in various mammals, typically rabbit or goat.

ELISA Method Development

The ELISA method is summarized as follows: a sample is weighed and deposited into a vial. An extraction solution (Urea) is added and is allowed to sit at room temperature for 24 hours

Artwork Description	Origin	ELISA Results Binder OD_{405}
Tempera Portraits on wood Getty Museum #74.AP.20	Egypt, c. 200 A.D.	Black (Glue 0.6) Red (Glue 0.4, Egg 0.5)
Jacob Lawrence, *Paper Boats*	American, 1949	Black (Egg 0.6, Casein 0.8)
Potala Palace Wall Paintings	Tibet 17th to present	Green(copper) (Glue 0.9) Yellow (Glue 0.6) Lead Red (No Result)
Model of the plaza (maquetas) with inlayed and painted wood	Tomb of Huaca de la Luna, Peru c. 14th C.	Red (Plant gum 0.6) Gold (Plant gum 0.4) White (Plant gum 2.0)
Maria, das Kind anbetend by Bevilacqua Gemäldegalerie Alte Meister in Dresden	1480 A.D.	Brown (Glue 0.6, Egg 0.6) Gold leaf on blue (Egg 0.4, Plant gum 0.6) Dark green (Egg 0.7)
Wall painting, Church of the Mission of St. Frances by Andrea Pozzo	Italy c.17th C.	Copper green (Egg 0.8)
Nefetari Tomb	Egypt c.1000 B.C.	Red Iron Oxide (Plant gum 0.7)
Cartonnage, #79374 and #79385 Petrie Museum of Egyptian Archaeology	Egypt c. 200 B.C.	Green Earth (Egg 2.0) Green Earth (Glue 2.0)
Painted Wood Head HUCSM A0939 Skirball Center	Egypt c. 200 A.D.	Red (Glue 2.0)

Table 1. Results of various artworks tested by ELISA. The paint samples (color or pigment) and binding media with assay values (binder and OD_{405}) are given in the ELISA Results column.

while the gelatin or albumen is extracted into solution. This solution is diluted and added to wells of an ELISA well-plate where the binder present in the sample attaches to the well. A primary antibody targeted to recognize gelatin and albumen is added to each well, and specifically binds to it, if present. The well is thoroughly rinsed to remove any unbound primary antibody from the well-plate. Then an enzyme-labeled secondary antibody is added that binds to the primary antibody. Secondary antibodies that have an enzyme attached to them are needed to identify and bind to the primary antibody. Secondary antibodies are modified by conjugation with "tags" that aid in detection, i.e., enzymes, fluorophores, gold nanoparticles.
The well is thoroughly rinsed to remove any unbound secondary antibody. P-nitrophenyl phosphate (p-NPP) is added to the wells, and will turn yellow within 30 minutes if albumen or gelatin is present in the original sample. The secondary antibody contains alkaline phosphatase, and it catalyzes the hydrolysis of pNPP, which is colorless to p-nitrophenol, a yellow dye (**figure 1**, p. 19).
The color of yellow OD405 (Optical Density at 405 nanometers) is easily read with a plate reader. In the case of strong responses, the results can be read qualitatively by eye. Blanks (negative controls) and gelatin and albumen (positive controls) are always included on each plate.
Optimization of the ELISA method included testing many possible sources of gelatin and albumen from mammals, birds, and fish. Whole egg, egg yolk, and egg white from hen, duck, pigeon, chicken, goose, pheasant, and codorna (quail) all tested positive regardless of species. Egg yolk, as expected, gave very low results because albumen is not usually found in the yolk; rather, it is a glycoprotein primarily found in egg white.

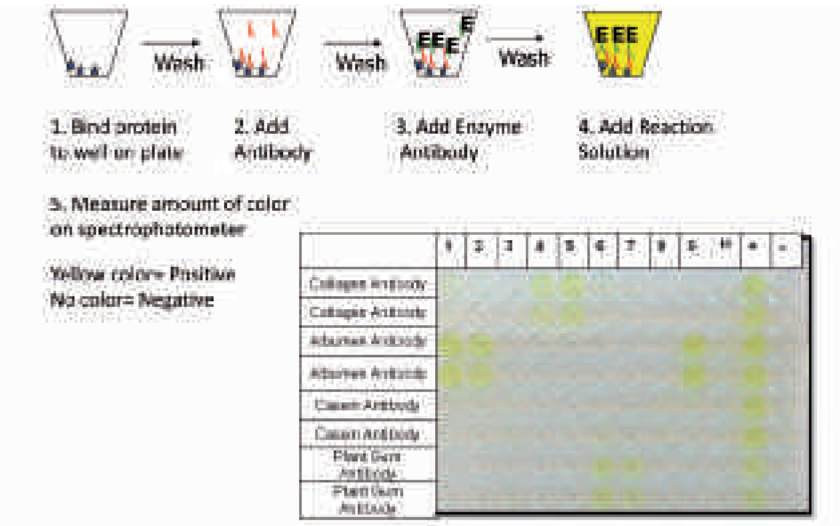


Figure 1. ELISA Procedure and photograph of ELISA well plate result. In columns 1, 2 and 9 ovalbumen was added, in columns 3 and 4 gelatin was added, and in columns 6 and 7 gum Arabic was added. All of the wells in each row were treated with one of the four primary antibodies for collagen, albumen, casein, or plant gum and are listed in the far left column. Each primary antibody was run twice (two rows). Only those wells containing the protein detectable by the corresponding antibody turned yellow. The positive control (+) wells turned yellow and the wells in the blank column (-) had no color.

Gelatin was extracted from grizzly bear, beaver, bobcat, mountain lion, bison, fox, jackal, deer, goat, pig (warthog), rabbit, sheep, and fish (sturgeon) and tested by ELISA. Results show that collagen is highly conserved throughout nature, and that the collagen antibody recognizes all mammal sources except fish (where values were somewhat lower). Species identification of parchment or gelatin necessitates the production of new collagen antibodies. Hodgins and Hedges (1999) manufactured antibodies for species identification of animal based glues and concluded that collagen structure is preserved between similar species, so that it was possible to distinguish between cow and fish, but perhaps not goat and sheep. The production of species-specific antibodies for cultural heritage is interesting in theory, but it can be costly (thousands of dollars to manufacture an antibody). In general, collagen antibodies will not easily differentiate the animal species that were used to make the gelatin, glue or parchment.

Testing of 18th Century European Paper and Early Photographs

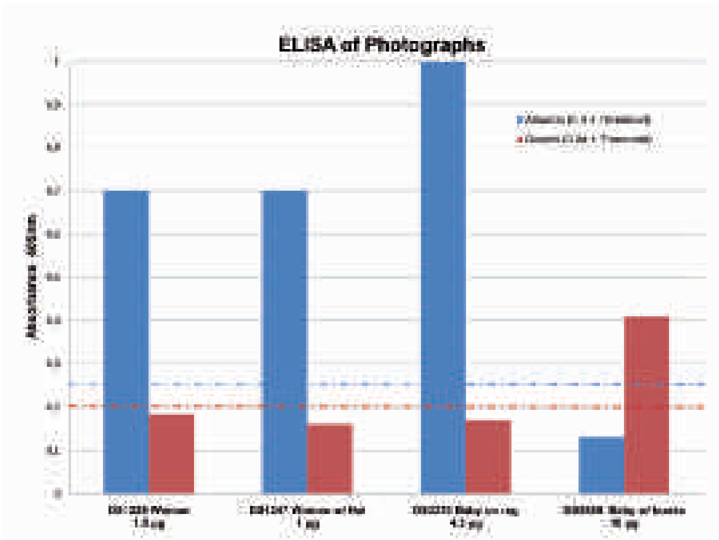
Several photographs, test samples, and 18th century European papers were tested using the ELISA procedure described above (figure 2).
In order to reduce the impact to the photographs, the smallest possible sample was taken. 1 to 10µg were sampled from the sides of the four photographs; it could still be weighed as it is visible to the human eye (1µg is about the size of a period at the end of this sentence). ELISA shows that the photographs of the woman DS1229, the woman in a hat DS1247, and the baby on the rug DS3270 are albumen prints, and the picture of the baby with books DS2689 is a gelatin print (**graph 1).**

Test samples were also prepared by applying gelatin and albumen to paper and dried at room temperature. The samples were: 100% albumen, heat denatured albumen at 70° C and 80° C, denatured albumen with rubbing alcohol, 70% gelatin and 30% albumen, 90% gelatin and 10% albumen. The samples weighed approximately 100µg and the results are given in **graph 2,** p. 20.

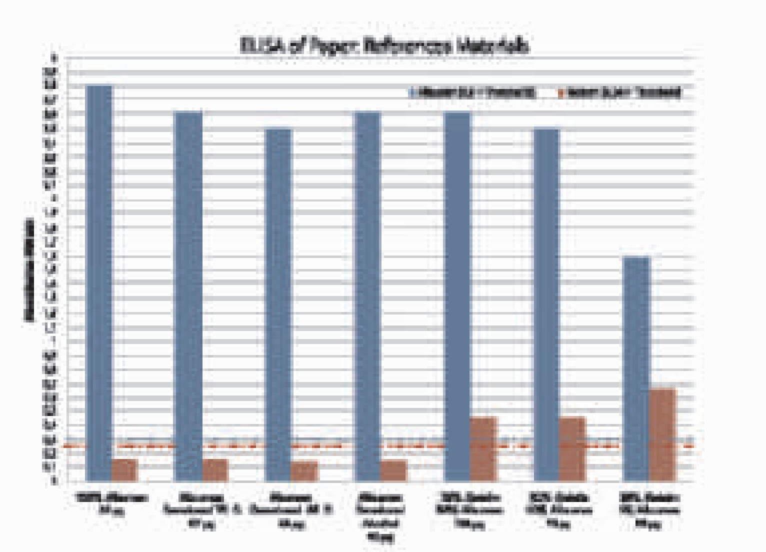
Figure 2. Several of the photographs that were tested by ELISA for albumen and gelatin. DS3270 and DS1229 are albumen prints, while DS3270 tested positive for Gelatin. Examples of 18th century European Paper that tested positive for Gelatin.

The albumen antibody is remarkably sensitive even at very low concentrations in the presence of complex mixtures as evident in the OD values for the mixture 1% albumen (1.6) and 99% gelatin (0.68). The OD value for albumen is relatively high, and does not directly correlate to the known values of the mixture. A calibration curve that contains known concentrations of albumen and gelatin would give more accurate data for mixtures.

The gelatin antibody is much less sensitive than the albumen antibody due to the partial hydrolysis or denaturing of the collagen that occurs when boiling in water and treating it with harsh chemicals. It is composed primarily of partially denatured collagen which decreases the sensitivity of the antibody. The gelatin antibodies that are manufactured target mostly native or non-denatured forms of collagen.



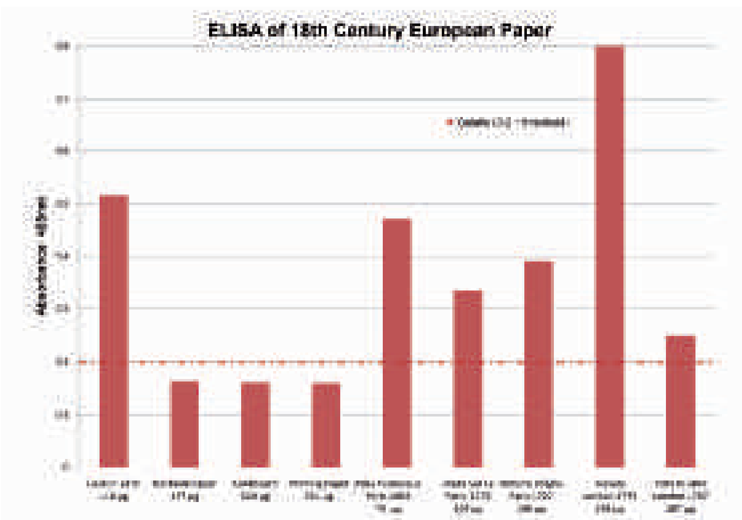
Graph 1. Sample descriptions with weights are given on the x-axis, and absorbance at 405nm (intensity of yellow) is given on the y-axis. The red dashed line (gelatin) and blue dashed line (albumen) give the absorbance value (threshold) above which is positive. Three photographs (DS1229, DS1247 and DS3270) tested positive for albumen, and (DS2689) tested positive for gelatin.



Graph 2. Sample descriptions with weights are given on x-axis, and absorbance at 405nm (intensity of yellow) is given on the y-axis. The red dashed line (gelatin) and blue dashed line (albumen) give the absorbance value (threshold) above which is positive. The reference materials (albumen, denatured albumen, and mixtures of albumen and gelatin) were applied to paper and tested by ELISA.

18th Century papers from England and France were tested by ELISA, and all tested positive for gelatin: *Atlas Historique*, 1803-1853, *Traité Sur La Cavalerie,* Paris, 1776-1779, *History of Polybe*, 1727, *Travels through the North America*, London, 1775, and *Introduction to the Making of Latin*, London, 1757. Gelatin taken from the crease of a 1479 manuscript tested positive, while notebook paper, cardboard and printing paper tested negative, results are shown in graph 3.

As discussed above, ELISA gelatin results are not quantitative. GC-MS is a highly precise method that has been used for this application. In a previous study, the GCI tested historic paper by GC-MS for weight % gelatin. First, the gelatin was extracted from the historic paper samples by heating at 105 in 0.1N HCL for one hour. The solution was then analyzed for amino acids by GC-MS, and the gelatin content was calculated based on the amount of stable amino acids detected.



Graph 3. Sample descriptions with weights are given on the x-axis, and absorbance at 405nm (intensity of yellow) is given on the y-axis. The red dashed line (gelatin) gives the absorbance value (threshold) above which is positive. The reference materials (notebook paper, cardboard and printing paper) and historic papers were tested for gelatin by ELISA.

If GC-MS and ELISA results from both methods are compared for the historical paper samples (% gelatin and OD405), *Atlas Historique* (1.8%, 0.48), *History of Polybe* (1%, 0.38), *Traité Sur La Cavalerie*, Paris (0.8%, 0.32), the results appear to have a positive correlation (as % gelatin increases, so do the OD values). Future testing on historic paper may show that as gelatin degrades, the OD values decrease.

ELISA is a highly accurate and sensitive procedure; it provides qualitative information on protein or polysaccharide media, most importantly on mixtures. However, it is limited to protein or polysaccharide containing media, so that GC-MS or FTIR remain necessary for oils, resins, waxes, and modern materials such as alkyds. Antibody labeling techniques can be a standard analytical technique, and is complementary to existing GC-MS and FTIR techniques. At this time it appears ELISA may not be useful for quantification of gelatin in historical materials due to the technique's sensitivity to the denaturing of gelatin that result from long term natural aging or other causes. However, ELISA is very useful in the characterization of gelatin and albumen, common and important components in photographs. ELISA can offer us a deeper understanding of the materials and techniques used by artists and craftsmen. It gives insight into the crafting of handmade paper, and it may also be used with other techniques to gain information on the extent of gelatin deterioration.

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New Knowledge Is Born
The Technique of Multi-Spectral Imagery Revolutionises Painting Analyses

by Pascal Cotte
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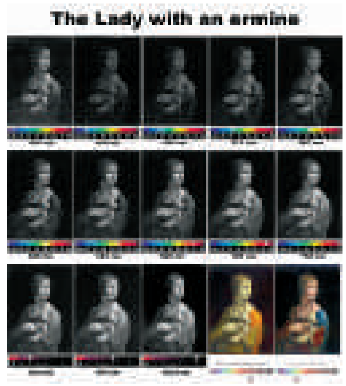
Introduction

In one hour, the time for a photograph taken with the multi-spectral camera, billions of information are collected from the painting or work of art (parchment, drawing, illumination, etc.) placed on an easel in front of the camera.
The principle is simple: obtain the spectrum of the light diffused at each point of the object to extract all the information therein. The information covers ultraviolet (UV), the visible and the near infrared (IR) thereby giving it far more depth than when only infrareds are used. This technique produces photographs with exceptional colour quality in particular.
The three pillars are colorimetry, spectrometry and photometry. The many resulting applications are the main attraction of this new non-invasive investigation technique.
The process[I, II] was patented in 1998 and has already been the subject of several scientific publications[III, IV, V, VI] under a European research programme[VII].
The use of a wide variety of scientific techniques means that this wealth of information is analysed in a painting far more extensively than when examining a precision photograph. The photograph thus becomes a "scientific measurement" and that changes everything.
Henceforth, the physical comparison of works and documents can draw conclusions which can then constitute proof. It revolutionises the appraisal of works of art.
An essential supplement to X-rays and infrareds, multi-layer multi-spectral imagery produces a batch of new information. This is a new source of information for exploration, as were X-rays in their time.
This technology has recently been the key in identifying a Leonardo da Vinci portrait *The Bella Principessa*, published[VIII] in 2010 in London by the renowned Prof. Martin Kemp from Trinity College Oxford, following a positive opinion from Professors Pedretti, Director of the Leonardo Center at UCLA, Dr. Strinati, former Director of Museums of Rome, Prof. Vezzozi, Director of the Muséo Ideale da Vinci, and Dr. C. Geddo, Prof. Gregori, Dr. N. Turner and others, all eminent Leonardo specialists.

I – The principle of the camera

The work is placed on an upright support. An adjustable lamp either side focuses a narrow beam of light on it. It ensures the necessary homogeneity and level of lighting whilst protecting the document from too much accumulated light. This remains lower than light received during one day in an exhibition room. The camera measures the ray diffused in its direction with a CCD array of 12,000 pixels in geometry where the total absence of parasitic specular reflections is guaranteed. A filter system in the camera cuts the luminous spectrum into thirteen strips, staggered from the near UV (380 nm) to the near IR (1050 nm).

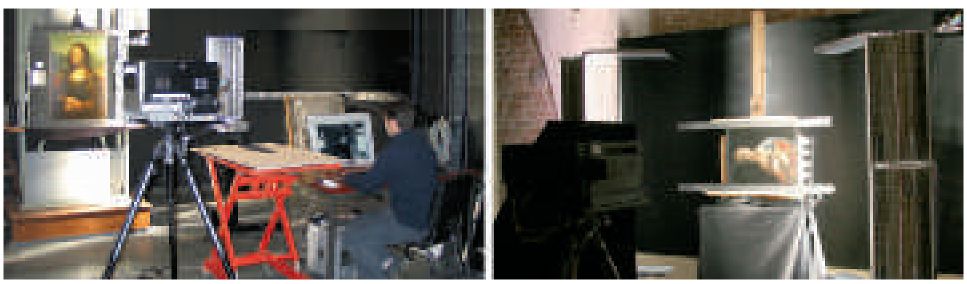


1. The thirteen measurements made on *Lady with an Ermine* – Leonardo da Vinci.

The thirteen measurements are taken at the maximum resolution of 240 Mpixels[1] and are supplemented with an incident light measurement. The total acquisition can be more than six billion bytes (octets).
The size of files for a painting varies from 6 to 13 Gb including the raw measurements and reconstructed images (D65[2], infrared, false colour, etc.). A collection of one thousand paintings takes up about 10 Tb. This can easily be managed these days.

Proven technology
The camera has been mass produced since the digitisation of the *Mona Lisa* in October 2004 in the Louvre and the *Lady with an Ermine* at the Czartoryski Museum in September 2006. It has been used worldwide at the Van Gogh Museum, the Kröller-Müller Museum, the Museum of Fine Arts in Lille, the Art Institute of Chicago, the Cleveland Art Museum, the Museum of Fine Arts in Rouen, the Royal Museum of Fine Arts in Brussels and numerous private collections.

1. I.e. 12,000 high and 20,000 wide, which for a painting of 60 x 100 cm^2 corresponds to pixels of about 50 µm square.
2. Colours calculated for a daylight source at 6500 K, CIE standard D65.



2. Multi-spectral photographic session of the *Mona Lisa* at the Louvre and of *Lady with an Ermine* at the Czartoryski Museum in Krakow.

II – Advantages of the multi-spectral camera

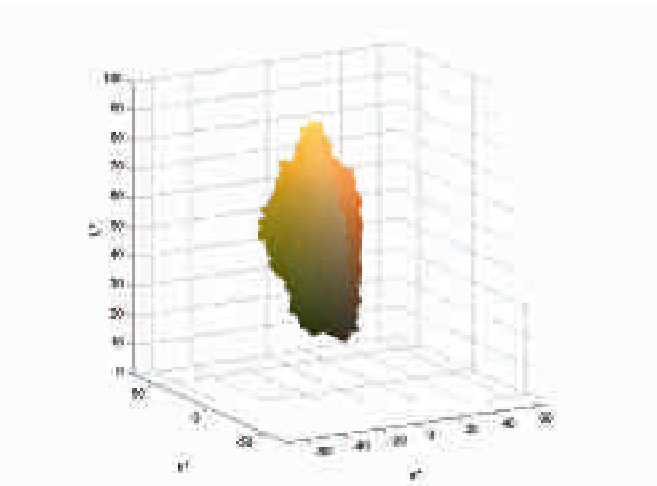
The technique has tremendous advantages, the main sixteen being:

1. High resolution: macro photography

The camera definition is 240,000,000 pixels in the entire spectral cover (UV, Visible and near IR). Enlargements in the order of x30 to x50 are possible (depending on the size of the document). This represents the equivalent of about a hundred macro photographs with the same resolution; they may therefore be superimposed.
Thus, examining the craquelure, brush strokes on a canvas or its surface appearance (smoothed, graininess, lacks, etc.) is made easy using a simple office computer. Images can be diffused and knowledge shared.

2. Colorimetry

Colour is a composite quality relating to the materials, the light shining on them and the spectral sensitivity of the photoreceptor, mainly the eye.
Thus a painting will not show the same colours in daylight as under a tungsten lamp or fluorescent tube. A painting does not have a "single" range of colours but an infinity.
The light reflection spectrum has to be recreated in the blends of pigments to understand this phenomenon. This is precisely what the camera does, by breaking down the light diffused by the painting with thirteen filters.
The spectra thus measured for the different pixels with any light source can be combined to calculate the colour seen by the human eye with tremendous accuracy.
Any light source can therefore be simulated in a painting whilst ensuring colour depiction of unrivalled precision.
This is a photographic revolution, for it resolves a century-old problem – colour fidelity. There is a spectral measurement in each pixel. Traditional photographic (digital or silver-based) is doubly enclosed in a restricted colour space (Red Green Blue space) and in the luminous sources used. A photographer in New York does not have the same lights as his colleague in Madrid or Paris; the photographs cannot be compared scientifically and many colours are lost through problems of metamerism (different colours perceived to be identical under certain lights).
Including a reference test chart in the photograph will change nothing. No colorimetric profile, no calibration, no method can regain what has been lost once and for all.
The colorimetric certification is born with this new investigation method. All the colours used in a painting are ordered in a three-dimensional space (CIE Lab.). They thus delimit a shape with unique characteristics.



3. Colorimetric certification of a work by Renoir. *Femme nue dans un paysage*, Musée de l'Orangerie.

The colours of works are digitised faithfully and can at last be compared on a standardised scientific basis. This opens the doors to many areas in expert appraisal and restoration. Imagine a database with a painter's colour ranges characterised with precision. The way in which Renoir or Ingres paints flesh tints or tree colours are unique signatures with this level of precision.

3. High-fidelity reproduction

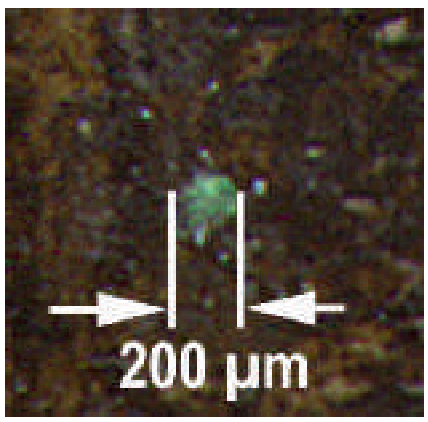
Up until now, it has been tricky, if not to say impossible, to print whilst maintaining the quality of the work. The multi-spectral images encoded in a standardised, linear colorimetric space (CIE Lab) guarantees that the original colours are fully respected. No more problems of metamerism, colour shifts or shade fluctuations. Titian pink and Veronese green can be faithfully reproduced in unrivalled fashion. No more balancing colours "by guesswork" empirically on the computer monitor.
This does of course mean having to review the printing chain and the pigments of inks used. But modern printers can cope with these parameters. Many manufacturers produce printers with eight or twelve inks and some even up to 24, thereby offering a huge choice of printing solutions with wide ranges of papers, fabrics, canvas, etc.

4. An unusual conservation condition report

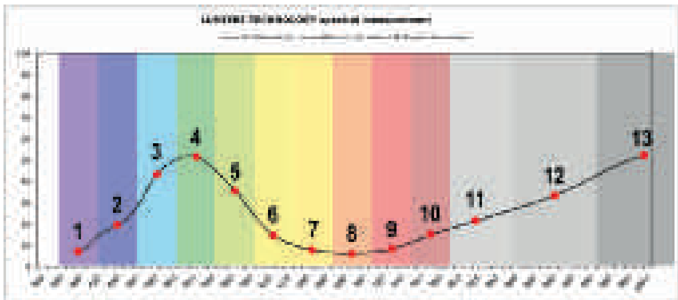
An image is worth a thousand words. An apt summary for this considerable asset in conserving and preserving our Heritage. In a single shot from the UV to the IR, the visible and the invisible are stored for eternity. An unprecedented witness for the conservation condition, which in addition is extremely accurate and can be compared with other conservation conditions thanks to automatic matching software programs.
All museums should have to note the condition of their collections this accurately before any loan to be able to measure the damage in transport and even more so, before any restoration project.
Measuring the density of craquelure and assessing its advancement as well as calculating the colours and measuring any changes over intervals of several years are added advantages of the multi-spectral technique.

5. Spectrometry in micro-samples extended to the IR

The multi-spectral camera can be used to recreate the spectrum of each of 240 million pixels. This ultimately gives 240 million spectra. Its very high resolution can be used to measure the spectra of micro-samples. For 500 dpi resolution, the size of the virtual "sample" reconstitutes the spectrum of a surface area of 50 µm2, with 25 µm2 for 1000 dpi resolution.
In the example below, the green stain measures less than 200 µm. Different algorithms use the thirteen measurements of each pixel (see the red dots on the graph p. 23) to recreate the spectral curve.



4. Example of micro-sample.



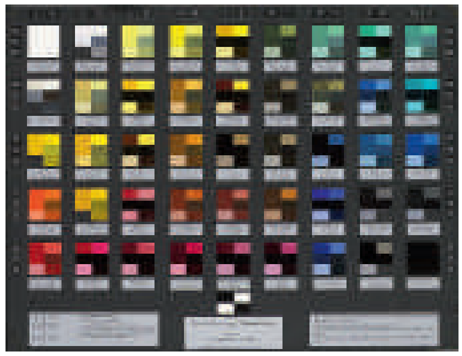
5. Example of spectrum graphic recreation by threefold polynomial interpolation.

Everything else depends on this recreation. The spectrum contains the basic information: the colours, the influence of the varnish, the pigment characteristics – everything is there. The form of the signal simply has to be processed to extract all the information.
Virtual "sampling" is by definition non-invasive. It allows thousands of analyses without danger for the work.

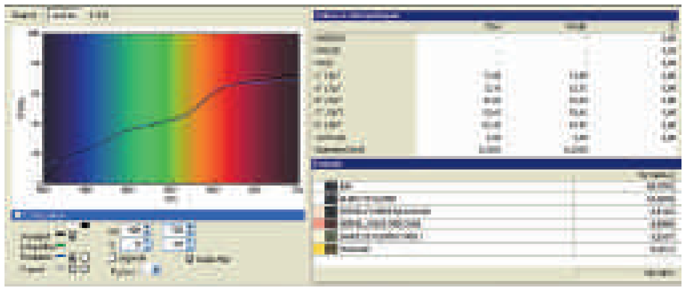
6. Identifying pigments. *Lady with an Ermine*, Leonardo da Vinci.
© Czartoryski Museum/Lumière Technology/Pascal Cotte

6. Identifying pigments

Every pigment has a characteristic spectral curve. For example, azurite (blue) absorbs almost all the IR at 900 nm whilst Egyptian blue reflects them. Certain pigments can therefore be identified by their spectral curve.
With this in mind, a test chart of pigments used up to the 17th century has been manufactured specially. Every pigment is included six times. On white background and black background with different dilution rates and mixed with white lead and ivory black. A database of physical and optical properties for each pigment is created from these measurements. The Colibri™ software program developed by Ciba™ analyses the spectrum and suggests blends of pigments with a neutral binder to recreate the desired spectrum. It is based on the multiflex[IX] version of the Kubelka-Munk[X, XI] formulation. The results are only reliable, however, if the influence of the aged varnish is removed from the analysed spectrum in advance.



7. Pigment identification test chart – 17th century pigments. © Lumière Technology/F. Pérégo/P. Cotte



8. Identifying a blend of pigments in *Lady with an Ermine* (sanguine).

It can therefore be determined that the sanguines are painted with a blend of white lead, mercury vermilion, lead-tin yellow I and shades of umber. Or that the blue mantilla on the shoulder is produced from lapis-lazuli.
Chemical analyses of samples taken in 1955 have confirmed[XII] these identifications.

7. Identifying the pictorial technique

Knowing that a painter used a glaze is one thing, proving it scientifically is another. With the cooperation of the INSP, Université Pierre et Marie Curie, CNRS[XIII], it was possible to demonstrate this in 2008 on the superficial layer of Mona Lisa's face using the multi-spectral technique. This publication proves that multiplying the measurements provides invaluable information on how the pigments are applied. It may therefore be possible ultimately to identify the painter's technique. Proofs and "signatures" which can help with attribution and expert appraisal.

8. Comparing pigments and pigment blends

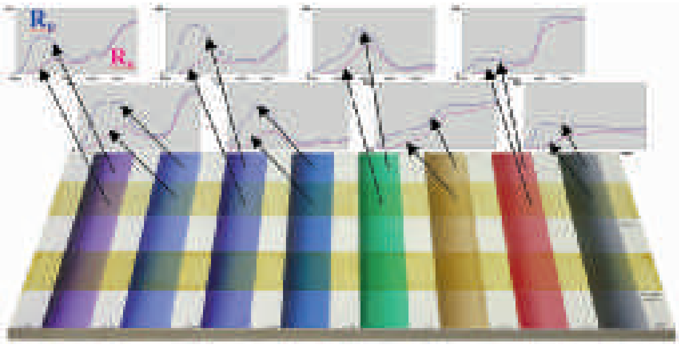
There are sometimes only ten or so strictly identical spectra in a painting among the 240 million measured by the camera. What are the chances then of finding the same spectrum in another painting?
Seeking spectral similarities by comparing paintings is a powerful investigation method. The likelihood of finding two strictly identical spectra in two paintings by different painters is in the order of one in several million. It could be argued that the palette of available pigments is limited, that there are few suppliers of paints. But the way in which each painter creates his blends is his, and his alone.

9. Virtual varnish removal

The influence of the varnish on the pictorial layer is highly complex[XIV]. Looking at it more closely, it is only a simple filter effect which yellows and darkens the colours (Beer-Lambert law)[3]. Although the yellowing is perfectly genuine, it is not uniform in all types of pigment and has added effects of saturation and con-

3. The luminous flux I_o is weakened in I according to the exponential law $I = I_o \exp(-\varepsilon h)$, where ε is a coefficient of absorption (or extinction) and h the thickness of the material crossed.

trast. Removing the influence of the varnish is therefore far from easy and all theoretical models have their limits. In addition, any project to take ageing into account is therefore too risky.
For this reason we have chosen a method based on actual measurements which is already proven.



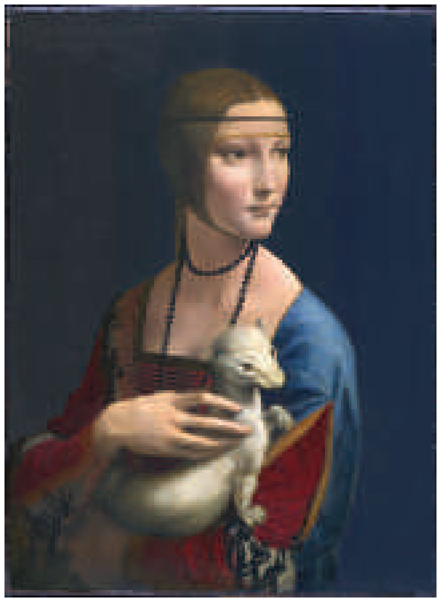
9. Pigment test chart with aged varnishes.

It is based on recording spectra in a shade card made up of current pigments, both non-varnished and covered with two, artificially-aged varnishes. All the spectra thus measured are entered in a "learning" matrix[4]. This is applied to the spectra recorded in the work. The "varnish-removed" spectra thus obtained make it easier to identify pigments and are used to calculate the corresponding trichromatic coordinates and recreate the entire work, without its varnish. The result is presented below. The lapis-lazuli is once more blue, the sanguines have re-found their pink shade, etc.

10. Virtual varnish removal of *Lady with an Ermine*, Leonardo da Vinci. © Czartoryski Museum/Lumière Technology/ Pascal Cotte

10. Virtual restoration

But removing the influence of the varnish does not reveal the original colours. In very old paintings, the pigment layer has also suffered the indignations of time. Some pigments react to each other, others change colour under the influence of UV, the binder yellows, etc.



11. Virtual restoration of *Lady with an Ermine*, Leonardo da Vinci. © Czartoryski Museum/ Lumière Technology/ Pascal Cotte

Virtual restoration is based on identifying pigments by restoring the original colours of the main components identified. Thus, we have found azurite in the painting's background, which has confirmed the hypothesis of a degraded blue background[XV] upheld by The National Gallery of Art in Washington.

11. Multi-spectral infrareds

Infrareds have been used for many years to study paintings. Firstly with silver-based films, then with cameras. What was being sought was an "image" with extra information, to find out what was underneath the layer of paint. The high definition was of no significance and a single infrared shot seemed sufficient.
Multi-spectral infrareds show five major differences:
I/ There is not one but three infrareds at three different wavelengths.
II/ Three images are obtained at different depths underneath the pictorial layer, all capable of being superimposed.
III/ The differences between these three infrareds can be calculated (see IR emissiography).
IV/ The infrareds are standardised over the entire surface, which makes it possible to measure pigment transparency with IR and identify pigments.
V/ The high resolution detects the tiny underlying details such as drawings, overpaints, etc.
Lastly, as the measurement is calibrated and standardised, it can be used for scientific comparison with other paintings and its wealth of advantages to identify the painter and the restoration studies.
The infrareds can be combined with the visible information to give "false colour" images. They give an immediate vision of restorations as the spectral "signature" of restoration pigments is often very different in the IR.

12. The ten basic recreations provided by the multi-spectral camera software.

4. R C^T $(C\,C^T)^{-1}$ where R is the matrix of measurements made without varnish using a laboratory spectrophotometer and C the matrix of measurements made with varnish by the camera. C^T is transposed from C.

12. False colours[5] in multi-spectral technique

Human vision is limited to the colours of violet to red, from 400 nm to 750 nm.
A false colour image "sees" the infrareds (beyond 750 nm) but in a coloured translation. It simulates human vision extended to the infrareds.
False colours have been used for some time and Kodak marketed two types of film (I and II). Sadly their images were very blurred and the colours lacked precision.
Multi-spectral technology has revolutionised this technique, with the following advantages:

- Perfectly clear images
- Standardised colours
- Infrareds up to 1050 nm
- More relevant and more discriminating information
- Raking light

Lastly, digital reconstruction allows multiple combinations.
False colours II are one example; the infrareds are offset towards the blue, which is very useful when studying restorations. An extremely accurate chart of all the restorations can thus be drawn up.

13. Infrared emissiography[6]

The infrareds are re-emitted through the surface layer of the paint which can sometimes prevent a view of the underlying drawing. Infrared emissiography is calculated by subtracting the brightness of the visible in the visible layer from that of infrareds, which are deeper. This produces highly relevant results for the observation.

14. Relief

Using an additional projector very close to the digitisation plane, a fourteenth photograph is taken. All the reliefs are thus enhanced, producing invaluable information on the painter's brushwork as well as on the pictorial layer support. More often than not the relief of the canvas appears, despite the make layer. Sometimes overpaints, invisible to X-rays or infrareds, are spotted thanks to the relief.

5. Technical term used by Kodak for special, infrared-sensitive films which transform the colours.

6. Term used by analogy with X-ray emissiography, which gives details on materials which are barely transparent, or not at all.

Where the process breaks new ground is that for the first time infrareds can be seen in relief. The false colour infrareds give the relief of restorations, making diagnostics and restoration studies easier. The restorations appear in pink/orange and in relief in the right-hand image (r).

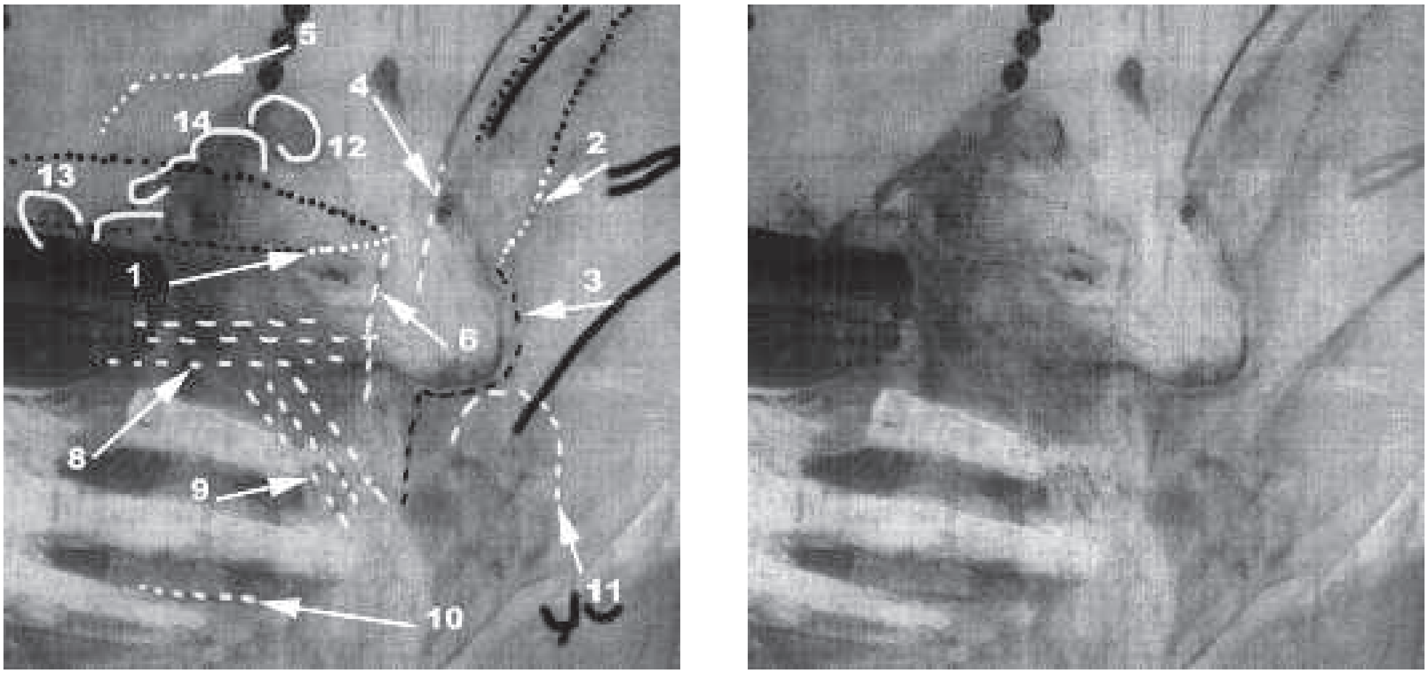
15. Differential multi-layer imagery

This is the most innovative part of this invention, a new source of images. Multi-layer images reveal the overpaints, pentimentos and underlying drawings with far greater accuracy than normal techniques. It produces results where they fail. In many cases, this information hidden in the pictorial layer is totally invisible with the traditional analysis methods. There is many examples and the technique is proving how effective it is in the majority of studies we have performed on paintings by David, Goya, Picasso, Poussin[7] and da Vinci.
The principle of differential multi-layer lies in the underlying information which cannot be perceived directly, which could be called digitised in a state of marks and rare signals. Complex algorithms analyse the information either as spatial frequencies (two-dimensional Fourier transform, frequential filters, etc.) or as a law of probability (maximum entropy, Shannon entropy, etc.) or in optical form (PSF[8] optimisation, deconvolution matrix, etc.). Of course the results are always portrayed visually by grey-scale images as shown in the example below. No need to be an expert to read these images which are available to all. Curators, restorers, scientists, museum directors and art historians can therefore access a new source of images offering decisive, even crucial information on items in their collections. New knowledge is born.
The combination of thirteen photographs produces 12 x 13 possibilities.
There are therefore 156 images for analysis, with only a few providing interesting information which has to be reprocessed and filtered. This huge amount of information produces totally new images, like the remarkable example found in *Lady with an Ermine* by Leonardo da Vinci (See fig. 14, p. 26). On the right, the image produced by combining images at 640 and 900 nm, on the left the plotting of details revealed, barely or not at all visible in any monochromatic images nor in the painting itself.

7. In a study of the *Flight into Egypt* under the direction of Mr Sylvain Laveissière, Curator of the Louvre Paintings Department, for the Lyon Museum of Fine Arts.

8. Point Spread Function, description of optical characteristics of the elementary point.

13. Colour D65 (l)/Raking light (c)/False colour infrared in raking light (r). *The Bedroom of Arles*, V. Van Gogh (detail). © Van Gogh Museum/Lumière technology



14. *Lady with an Ermine*, Leonardo da Vinci. © Czartoryski Museum/Lumière Technology/Pascal Cotte. Processing by multi-layer analysis after filtering 640 and 900 nm measurements using Fourier transform.

Fourteen major discoveries were made in this detail (annotations in white). Some supplemented the observations made in 1992 with the infrareds with a vidicon camera (1100-1400 nm) by the laboratory at the National Gallery of Art in Washington[XVI] (black lines) and others are totally new:

1/ This *spolvero*[9] had never been seen, it was thought to be a line.

2/ In its bottom section, this *spolvero* had never been seen.

3/ This line, which had until now been taken as shadow, proves to be an initial placement as it can be seen continuing in the neck of the ermine.

4/6/8/9/10/ These lines had never been seen.

5/ These *spolveri* had never been seen and have no connection with the drawing of the dress!

11/ This outline, of a first position of the paw, had never been seen.

12/13/14/ These drawings represent other positions of the ermine's ears and head, never until then mentioned in any publication.

Neither the scientific study by the National Museum of Warsaw[XVII], nor the documents made available to us by the Czartoryski Museum (X-rays, infrared and UV fluorescence) reveal these details.

This is explained simply by the physical principles used. The X-rays are capable of penetrating much too far. Only the heavy atoms (like lead) stop them and if the underlying drawing or overpaint does not have any, it remains invisible. The infrareds can be either totally reflected by a pigment or totally absorbed; in both cases, the underlying information remains invisible. The multi-layer technique has the advantage of exploring several narrow domains (40 nm) of the electromagnetic spectrum of the light and therefore offers greater likelihood of obtaining information.

It is up to the art historians to seize on this new knowledge to deduce totally new certainties.

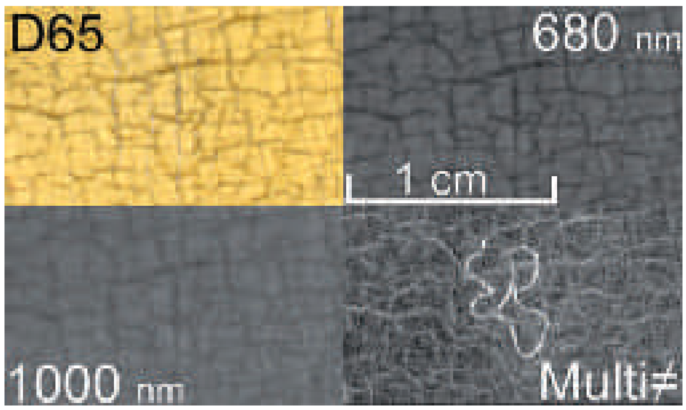
9. *Spolvero* (or *spulvero*) is an Italian term designating a preparatory plotting technique using points marked by a powder through a template pierced with small holes. It is typical of Leonardo's technique.

There are many other investigation techniques. These include principally OCT (Optical Coherence Tomography[xviii]), autoradiography, electronic paramagnetic resonance, Synchrotron Radiation Based X-Ray Fluorescence Elemental Mapping (recently made famous with the discovery of a portrait underneath a Van Gogh painting by the team from the Kroller-Muller Museum), nuclear magnetic resonance, ultrasonography, etc.

But all these techniques are long, sometimes very long and can be above all extremely costly.

16. Seeking physical clues

Another application for differential multi-layer imagery is the search for such things as hair from the head, hairs, fibres, dust and so on included in the pictorial layer. This is of course of particular interest in the search for clues to identify the technique used by the painter, in the expert appraisal or in the authentication.



15. Example of a clue found in an old painting.

In the above example, the D65 image (colour) reveals nothing, nor do to the photographs taken at 680 nm (visible) and 1000 nm (infrared). Only the differential multi-layer image (bottom right) reveals the 80 µm-thick fibre (very light grey) included in the blend of pigments (not in the varnish).

This demonstrates the performance of the multi-spectral technique extremely well.

III – Conserve better, restore better, teach better, analyse better

All sorts of complex calculations become possible with this high-fidelity digital acquisition process, beside the final safeguarding of the painting. The invisible is henceforth likely to appear thanks to the spectra analysis and statistical or mathematical functions. The results presented here are only a promising start to a long series of discoveries. The multi-spectral technique is extremely economic and has the advantage of being self-sufficient. It can be supplemented by other analysis techniques although this is not necessary.
One of the initial objectives of this on-going study is to create a global multi-spectral database of masterpieces. Four reasons justifying putting this into practice spring immediately to mind:
Firstly, the conservation of humanity's world pictorial heritage;
Secondly, the diffusion of pictorial art as it immediately becomes possible to consult these works and therefore to disseminate the knowledge;
Thirdly, as an aid to education;
Fourthly, the possibility of certifying certain works, especially based on the comparison or knowledge of new, decisive elements.
Thus, the IP4AI project by the Van Gogh Museum in Amsterdam recognised that no serious scientific work comparison study could be led based on photographs and traditional laboratory investigations. The digitisation protocol of the multi-spectral camera guarantees a calibrated, standardised measurement capable of matching at an international scale. At the request of the Scientific Division of the IP4AI Committee, we have created an initial multi-spectral database of works by Van Gogh. These data are stored on a secure server and are analysed by about twenty university laboratories specialised in mathematics, physics, colorimetry and related disciplines. The laboratories include Princeton, Campbell, Cambridge, Maastricht, Penn State, etc. The results were not long in coming as the first analysis software programs will be presented soon.
Upon request, these multi-spectral data will be accessible to museums, curators, restorers and art historians.
Such is the advent of the scientific dimension of colour.
New knowledge is opening up to the world of art.

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La technique d'imagerie multispectrale révolutionne l'analyse des tableaux

Brevetée en 1998, la caméra multispectrale développée par Lumière Technology permet d'extraire d'un tableau ou d'une œuvre d'art (parchemin, dessin, enluminure) une multitude d'informations à partir du spectre de la lumière diffusée en chaque point de l'objet. Avec un domaine couvrant l'ultra-violet (UV), le visible et le proche infrarouge (IR), cette information est beaucoup plus riche que celle fournie par les seuls infrarouges. Il en découle de nombreuses applications qui font tout l'attrait de cette nouvelle technique d'investigation non-invasive.
En complément indispensable des rayons X et des infrarouges, l'imagerie multispectrale multicouche, élément le plus novateur de cette caméra, apporte un lot d'informations nouvelles déterminantes pour les conservateurs, restaurateurs, scientifiques, directeurs de musées et historiens d'art.

Depuis les numérisations de *La Joconde* en octobre 2004 au Louvre et de *La Dame à l'hermine* au Musée Czartoryski en septembre 2006, la caméra a été fabriquée en série et a été utilisée de par le monde au Van Gogh Museum, au Kröller-Müller Museum, au Musée des Beaux-arts de Lille, à l'Art Institute of Chicago, au Cleveland Art Museum, au Musée des Beaux-arts de Rouen, au Musée Royal des Beaux-arts de Bruxelles et dans de nombreuses collections privées.
Les atouts de cette technique sont considérables :
- *La haute résolution : la macrophotographie*
- *La colorimétrie*
Grâce à la combinaison des spectres mesurés par la caméra pour les différents pixels en fonction de la source de lumière, les couleurs des œuvres peuvent être fidèlement numérisées.
- *La reproduction haute fidélité*
- *Un rapport d'état de conservation hors du commun*
- *La spectrométrie sur micro-échantillons étendue aux IR*
- *L'identification des pigments*
- *L'identification de la technique picturale*
- *La comparaison des pigments et des mélanges de pigments*
- *Le dévernissage virtuel*
L'influence du vernis sur la couche picturale est un phénomène très complexe. Si le jaunissement est bien réel, il n'est pas uniforme sur tous les types de pigments, et il est aussi accompagné d'effets de saturation et de contraste. Les spectres d'un nuancier composé de pigments courants, non vernis mais aussi recouverts de deux vernis artificiellement vieillis, sont enregistrés et entrés dans une « matrice d'apprentissage » qui est appliquée aux spectres enregistrés sur l'œuvre. Les spectres ainsi « dévernis » facilitent l'identification des pigments et permettent de calculer les coordonnées trichromatiques correspondantes et de reconstituer l'ensemble de l'œuvre, sans son vernis.
- *La restauration virtuelle*
La restauration virtuelle s'appuie sur l'identification des pigments en restaurant les couleurs d'origine des principaux composants identifiés.
- *Les infrarouges en multispectral*
Les infrarouges en multispectral apportent des informations supplémentaires comparés aux seuls infrarouges car ce ne sont pas 1 mais 3 infrarouges à 3 longueurs d'onde différentes à partir desquelles on obtient 3 images à des profondeurs différentes sous la couche picturale, toutes superposables.
- *Les fausses couleurs en technique multispectrale*
La vision humaine se limite aux couleurs du violet au rouge, de 400 nm à 750 nm. Une image en fausses couleurs permet de « voir » les infrarouges (au-delà de 750 nm) mais dans une traduction colorée. On peut alors établir une carte de toutes les restaurations avec une grande précision.
- *L'émissiographie infrarouge*
Les infrarouges sont réémis à travers la couche superficielle de la peinture qui empêche parfois de voir le dessin sous-jacent. L'émissiographie infrarouge est calculée en soustrayant la luminance du visible dans la couche apparente de celle des infrarouges, de provenance plus profonde.
- *Le relief*
Le procédé permet pour la première fois de voir les infrarouges en relief facilitant le diagnostic et l'étude des restaurations.
- *L'imagerie multicouche différentielle*
C'est la partie la plus innovante de cette invention. Les images multicouches révèlent les repeints, les repentirs, les dessins sous-jacents avec une précision bien supérieure à celle des techniques habituelles. Le principe du multicouche différentiel repose sur l'information sous-jacente non directement perceptible. Les rayons X, qui ont un pouvoir de pénétration très important, ne sont arrêtés que par les atomes lourds (comme le plomb) et si le dessin sous-jacent n'en comporte pas, il reste invisible. Quant aux infrarouges, ils peuvent être soit totalement réfléchis par un pigment soit totalement absorbés, et dans les deux cas l'information sous-jacente reste invisible. La technique multicouche offre l'avantage d'explorer plusieurs domaines très étroits (40 nm) du spectre électromagnétique de la lumière et, par conséquent, offre une plus grande probabilité d'obtenir une information. Il existe de nombreuses autres techniques d'investigations (*Optical Coherence Tomography*, autoradiographie, résonance paramagnétique électronique, *Synchrotron Radiation Based X-Ray Fluorescence Elemental Mapping*, etc.), qui sont plus longues, et peut-être surtout très coûteuses.
- *La recherche d'indices matériels*
Une autre application de l'imagerie multicouche différentielle est la recherche d'inclusions dans la couche picturale, telles que cheveux, poils, fibres, etc., utilisées pour identifier la technique utilisée par le peintre, l'expertise ou l'authentification.

La técnica de generación de imágenes multiespectrales revoluciona el análisis de las pinturas

La cámara multiespectral desarrollada por Lumière Technology, patentada en 1998, permite recolectar de una pintura u obra de arte (pergamino, dibujo, iluminación, etc.) gran cantidad de información extrayéndola del espectro de la luz difundida por cada punto del objeto. La información abarca el ultravioleta (UV), la luz visible y el infrarrojo cercano (IR), lo cual permite profundizar más que cuando se utiliza sólo el espectro infrarrojo. Las numerosas aplicaciones que ofrece son la principal atracción de esta nueva técnica de investigación no invasiva.

El aspecto más innovador de este proceso es la creación de imágenes multiespectrales multicapas, complemento esencial de los rayos X y los infrarrojos, que produce información nueva, fundamental para los conservadores, restauradores, científicos, directores de museos e historiadores del arte.

La cámara se está fabricando en forma masiva desde la digitalización de la *Mona Lisa* en octubre de 2004 en el Louvre y *La dama del armiño* en el Mueso Czartoryski en septiembre de 2006. Se ha utilizado en el mundo entero, en el Museo Van Gogh, el Museo Kröller-Müller, el Museo de Bellas Artes de Lille, el Instituto de Arte de Chicago, el Museo de Arte de Cleveland, el Museo de Bellas Artes de Ruán, el Museo Real de Bellas Artes de Bruselas y numerosas colecciones privadas.

La técnica ofrece enormes ventajas, siendo las dieciséis principales las siguientes:

- *Alta resolución: fotografía macro*
- *Colorimetría*
Los espectros medidos para los diferentes píxeles con cualquier fuente de luz pueden combinarse para calcular el color que capta el ojo humano con gran precisión. Los colores de las obras pueden entonces digitalizarse fielmente.
- *Reproducción de alta fidelidad*
- *Informe inusual del estado de conservación*
- *Espectrometría en micro-muestras ampliada a los infrarrojos (IR)*
- *Identificación de los pigmentos*
- *Identificación de la técnica pictórica*
- *Comparación de pigmentos y mezclas de pigmentos*
- *Remoción virtual de barniz*
La influencia del barniz en la capa pictórica es muy compleja. Aunque el amarillamiento sea perfectamente real, no es uniforme en todos los tipos de pigmentos y tiene efectos adicionales de saturación y contraste. El método usado se basa en registrar los espectros en una tarjeta de tonos hecha con pigmentos actuales, tanto no barnizados como cubiertos con dos barnices envejecidos artificialmente. Todos los espectros medidos de esta manera se introducen en una matriz de "aprendizaje". La misma se aplica a los espectros registrados en la obra. Luego, los espectros "con el barniz removido" que se obtienen facilitan la identificación de los pigmentos y se utilizan para calcular las coordenadas tricromáticas y recrear la obra completa, sin el barniz.

- *Restauración virtual*
La restauración virtual se basa en la identificación de los pigmentos mediante la restauración de los colores originales de los principales componentes identificados.

- *Infrarrojos multiespectrales*
Los infrarrojos multiespectrales aportan información suplementaria en comparación con los infrarrojos, ya que no es uno sino tres infrarrojos a tres longitudes de onda diferentes los que se obtienen, los cuales crean tres imágenes a tres profundidades por debajo de la capa pictórica, que se pueden superponer.

- *Colores falsos en la técnica multiespectral*
La visión humana se limita a los colores que van del violeta al rojo, de 400 nm a 750 nm. Una imagen de color falso permite "ver" los infrarrojos (más allá de 750 nm) pero en una traducción coloreada. De este modo se puede elaborar una tabla extremadamente precisa de todas las restauraciones.

- *Emisiografía infrarroja*
Los infrarrojos se reemiten a través de la capa superficial de la pintura que algunas veces impide ver el dibujo subyacente. La emisiografía infrarroja se calcula sustrayendo el brillo de la capa visible de los infrarrojos, que están en un nivel más profundo.

- *Relieve*
Gracias a este proceso, por primera vez se pueden ver los infrarrojos en relieve, facilitándose así los diagnósticos y estudios de restauración.

- *Creación de imágenes multicapas diferenciales*
Éste es el aspecto más innovador del invento. Las imágenes multicapas revelan las pinturas superpuestas, los pentimentos y los dibujos subyacentes con mucha mayor precisión que las técnicas normales.
El principio de las multicapas diferenciales radica en la información subyacente que no puede percibirse de manera directa. La explicación sencilla está en los principios físicos aplicados. Los rayos X son capaces de penetrar más allá. Sólo los átomos pesados (como el plomo) los detienen y si el dibujo subyacente o la pintura superpuesta no los contienen, permanecen invisibles. En cuanto a los infrarrojos, los pigmentos pueden o reflejarlos o absorberlos totalmente; en ambos casos, la información subyacente permanece invisible. La técnica de multicapas tiene la ventaja de explorar varios campos más estrechos (40 nm) del espectro electromagnético de la luz y, por lo tanto, ofrece una mayor probabilidad de obtener información.
Existen muchas otras técnicas de investigación, que incluyen principalmente OCT (Tomografía de Coherencia Óptica), autorradiografía, resonancia paramagnética electrónica, *Synchrotron Radiation Based X-Ray Fluorescence Elemental Mapping*, resonancia magnética nuclear, ultrasonografía, etc. Sin embargo, todas estas técnicas son lentas y pueden resultar extremadamente costosas.

- *Búsqueda de pistas físicas*
Otra aplicación para la creación de imágenes multicapas diferenciales es la búsqueda de pistas tales como pelo, fibras, etc., incluidas en la capa pictórica, a fin de identificar la técnica usada por el pintor, o para el peritaje o la autenticación de expertos.

New Synergies for a Multidisciplinary Approach to Conservation: MOLAB Activities within CHARISMA

by Prof. Bruno Giovanni Brunetti
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A new Research Infrastructure project has been recently co-funded by the European Commission within the 7th FP (Programme Capacities). The project, entitled CHARISMA - *Cultural Heritage Advanced Research Infrastructures: Synergy for a Multidisciplinary Approach to Conservation/Restoration* (http://www.charismaproject.eu), aims to create a solid base for outstanding innovation in the capacity-building policies of science and technology for the safeguard and protection of the European cultural heritage. It consists of a consortium of 21 leading institutions, that provide the best opportunities for developing research and applications in conservation/restoration at the forefront of the field. The consortium combines advanced research institutes with prestigious technology organizations on cultural heritage, in order to couple cutting-edge research with the development of effective new interactions among scientific experts, conservators and curators.

Within CHARISMA, that represents the natural evolution and growth of the project Eu-ARTECH (Access, Research and Technology for the conservation of the European Cultural Heritage - 6th FP, http://www.eu-artech.org), the consortium partners jointly carry out activities of: coordination, scientific research, and transnational access.

Coordination has the aim to promote exchange of knowledge on artwork material studies among scientists, conservators and curators, and to diffuse the use of the most advanced technique for artworks' analyses, studies, and monitoring. Long term objective is to create a permanent interoperability among European infrastructures in the perspective of the creation of a common ground for advanced research and applications.

Within **joint research activities**, innovative instrumentation for in-situ 2D and 3D examination of artworks are designed and set-up, exploiting the most advanced non-invasive techniques based on light-matter interactions. New restoration methods based on "monitored" use of lasers for the cleaning of panel and canvas paintings are also experimented.

Core of the project are three different **transnational access programmes**, which have the aim to provide adequate scientific, technical and logistic support to the European researchers in order to let them carry out at best their studies, exploiting innovative and state-of-the-art technologies. Within CHARISMA, transnational access is open to the instrumentations of the medium and large scale facilities of French and Hungarian laboratories including: (a) the AGLAE ion beam installation at the *Palais du Louvre,* in Paris; (b) the IPANEMA laboratory at the Synchrotron SOLEIL, in Gif-sur-Yvette; (c) the microPIXE facility at ATOMKI-HAS, in Debrecen; (d) the Budapest Neutron Centre, BNC, in Budapest.
Transnational access is also open to the mobile facility MOLAB and to the analytical data archives of prestigious European laboratories, as those of the National Gallery of London, UK, Centre de Recherche et de Restauration des Musées de France, Palais du Louvre, Paris, FR; Opificio delle Pietre Dure, IT; British Museum, London, UK; Museo Nacional del Prado, Madrid, ES, and Instituut Collectie Nederland, Amsterdam, NL.

Within the European programmes of access to scientific resources, **MOLAB** represents the singular case of a *mobile* facility. In fact, MOLAB permits scientists, curators and/or conservators to carry out *in-situ* multi-technique measurements on

Fig. 1 – The MOLAB facility during the measurements on the Tryptich *Christ among Angels*, 1480 by H. Memling, at the Royal Museum of Fine Arts of Antwerp, BE.

artworks that can not be moved from their location because immovable or fragile, avoiding any sampling and even any contact with the surface of the object, guaranteeing its security and integrity. MOLAB available techniques are: multispectral imaging in the visible (16 or 32 bands) and in the infrared (14 bands), mid- and near-FT-IR spectroscopy, X-ray fluorescence, X-ray diffraction, UV-Vis absorption and emission spectroscopy, emission decay-time, Raman spectroscopy, and others. The service is offered by the University of Perugia, the CNR-Istituto Nazionale di Ottica, Firenze, and CNRS-LC2RMF, UMR 171, Paris.

Fig.2 – MOLAB at the Gemeentemuseum of Den Haag, NL, during the study of he last painting by P. Mondrian: *the Victory Boogie-Woogie*, 1944.

MOLAB transnational access, already operative in the previous EU-ARTECH project, has had a significant impact in the practice of conservation in the last years. Its effect has been revolutionary as it was in the early 90s the wide diffusion of portable PCs characterised by performances comparable to those of common bench computers. In fact, the introduction of high-performance portable analytical tools in conservation has led to a progressive modification of the way of thinking about the best approach for the scientific examination of artifacts, even influencing the quality of the interactions among scientists and the other professionals in conservation, as conservator/restorers and art-historians.

First, the movement of the laboratory to the artwork, instead of the contrary, has practically reduced risks (and costs) connected with the transportation of a high-value and fragile object into a lab, opening the way to the scientific examinations of a very large number of artworks, as was never done before; second, the ability to get valuable information without touching the surface of the object has made it possible to analyze an object on a virtually unlimited number of points all over its surface, obtaining in most cases a more thorough description than in case of sampling; third, the results have been obtained practically in real time, creating a new form of relation among scientists, conservators, and scholars, based on immediate group-discussion of the results. This possibility did not simply improve the quality of the examination, but strongly contributed to the creation of a "common language" between these professional figures, overcoming any barrier possibly imposed by their different disciplinary basis.

Participants to CHARISMA are:

1. University of Perugia Centre of Excellence SMAArt, Perugia, IT
2. Centre National de la Recherche Scientifique LC2RMF (Laboratoire du Centre de Recherche et de Restauration des Musées de France, UMR 171) and LOA (Laboratoire d' Optique Atmosphérique, UMR 7639), Paris, FR
3. Foundation for Research and Technology Hellas, Institute of Electronic Structure and Laser Heraklion, GR
4. The National Gallery of London, UK
5. Société Civile Synchrotron SOLEIL, IPANEMA, Gif-sur-Yvette, FR
6. National Research Council of Italy: Institute for Conservation and Promotion of Cultural Heritage, Institute of Applied Physics "Nello Carrara", and National Institute of Optics, Firenze, IT
7. The Nicolaus Copernicus University, Institute of Physics, Toru , PL
8. The Aachen University, Institute of Technical and Macromolecular Chemistry, Aachen, DE
9. Hungarian Academy of Sciences, Laboratory of Ion Beam Applications, Debrecen, HU
10. The Historical Monuments Research Laboratory, Cercle des Partenaires du Patrimoine, Champs-sur-Marne, FR
11. The British Museum, London, UK
12. The Doerner Institut, Bavarian State Painting Collections, Munich, DE
13. Idryma Ormylia - Art Diagnosis Centre, Ormylia, GR
14. Opificio delle Pietre Dure, Italian Ministry of Cultural Heritage, Firenze, IT
15. The Museo Nacional del Prado, Madrid, ES
16. The Netherlands Institute for Cultural Heritage, Amsterdam, NL
17. The Royal Institute for Cultural Heritage, Brussels, BE
18. The Agency for the Promotion of European Research, Roma, IT
19. The National Laboratory for Civil Engineering, Lisbon, PT
20. The Budapest Neutron Centre, through the Research Institute of Solid State Physics and Optics, Budapest, HU
21. The University of Bologna, Microchemistry and Microscopy Art Diagnostic Laboratory, Ravenna, IT

AGLAE
An Accelerator for Art and Archaeology

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Abstract

For nearly twenty years, the Centre for Research and Restoration of the Museums of France has used a particle accelerator for the non-destructive analysis of works of cultural heritage. An external beam line has been specially developed for the implementation of the whole set of ion beam analysis techniques under fully harmless conditions for museum objects. Its use extends from the simple materials identification through the analysis of major chemical elements, to the determination of their provenance by means of the composition in trace elements and to the understanding of the fabrication techniques and the ageing mechanisms of art works.

1. Introduction

A large set of modern analytical techniques is currently applied to get a better insight on art objects as well as to contribute to their conservation and restoration. However these techniques have to meet drastic constraints due to the precious and sometime unique character of works of art. Consequently, non-destructive techniques and even those requiring no (or only minute) sampling, are preferred. Other features should be taken into account, such as the complex shapes and structures, the great variety of constituent materials quite often mixed, their history rarely known, their state of conservation extremely diverse, as well as their degree of alteration susceptible to modify the chemical composition of the outer parts, those directly accessible to analysis. These characteristics generally hinder the simple application of a single analytical technique and require the development of a special experimental approach, combining several techniques of examination and chemical analysis. In this context, ion beam analysis (IBA) constitutes one of the best choices, since it combines quite good analytical performance and non-destructiveness. For 20 years, an IBA facility has been installed in the Centre for Research and Restoration of the Museums of France (**Fig. 1**). Until now it is the only facility of this kind entirely devoted to the study of cultural heritage [1].

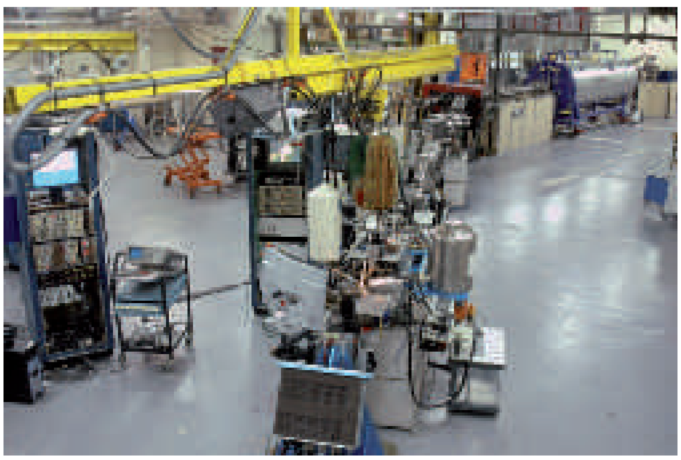

Fig. 1. View of the AGLAE accelerator. © C2RMF-E. Lambert

This facility, labelled AGLAE (Accélérateur Grand Louvre d'Analyse Elementaire) is based on a 2 MV electrostatic accelerator of tandem type, equipped with two ion sources, one for the production of protons and deuterons and the other for helium ions. Two experimental lines are presently in use, a classical one leading to a vacuum chamber and the other called the external beam line, specially designed for the direct analysis of art works without any sampling. [2]. This line has been fitted with a focusing system which enables to reduce the beam size to about 15 μm and thus to make a nuclear microprobe at atmospheric pressure.

The analysis is based on the interaction of atomic or nuclear character between the incident ions and the constituent atoms of materials and the detection of interaction products (photons or secondary ions) the energy of which is characteristic of the target-atom. Three main analytical techniques are applied, either individually or in association: Particle-Induced X-ray Emission (PIXE), Rutherford Backscattering Spectrometry (RBS) and Nuclear Reaction Analysis (NRA) with a sub-category called PIGE (Particle-Induced Gamma-ray Emission), frequently associated with PIXE.

2. Ion Beam Analysis and Cultural Heritage

We should first recall the impact of elemental analysis to the field of cultural heritage.

Concerning art history, the main objective of applying methods originating from the physical sciences is to complement conventional typological approach and contribute to a better understanding of the technique of the artist through the identification of the raw materials used, the way they have been mixed, the treatments applied. The data obtained constitute solid grounds for the authentication of a work or its attribution to an artist, a workshop, etc.

In the field of conservation-restoration, the knowledge of the chemical composition and particularly the elemental depth distribution, is essential for checking the state of conservation of the work and in some cases inferring the ageing mechanism by comparison with materials of similar composition submitted to accelerated ageing tests. Furthermore this kind of investigation can yield useful guidelines for choosing the proper restoration procedure.

In archaeology, the main purpose of analysis of artefacts is to contribute to a better understanding of the technical development in the remote past and to identify the sources of raw materials and the trade routes. It can also serve as an indirect dating by compositional similitude with well-dated objects.

IBA techniques have most of qualities required for the study of materials of cultural heritage, which can be summarised below. These techniques are:
(i) non-destructive for most materials with the possible exception of some inorganic materials (paper, parchment) which could be sensitive to heating or radiation damage;
(ii) quantitative with an accuracy generally better than 5%;
(iii) multi-elemental including light elements;
(iv) very sensitive for at least one of them, PIXE which is well adapted to trace element determination; this high sensitivity permits to limit the irradiation dose necessary for getting a significant signal and thus to reduce the risk of damaging the objects by irradiation;
(v) complementary and able to be implemented simultaneously;
(vi) able to yield information on the spatial distribution of elements (depth profile and mapping with a resolution down to the micrometre range).

One should however keep in mind the following limitations:
(i) the analysis concerns the outer layers of the material (up to several tens of micrometres) and thus can be irrelevant to the bulk composition in case of surface alteration (corroded metals, hydrated glasses, for example);
(ii) no information is provided on the chemical state of elements;
(iii) the analysis of insulators can be problematic due to accumulation of electric charges.

The features mentioned above show that IBA techniques and particularly PIXE, because of its high sensitivity, constitute an extremely useful tool for the knowledge and the preservation of cultural heritage [3]. Indeed they have the essential quality for such a research field, the non-destructiveness. A decisive improvement has been done in developing an experimental set-up permitting the direct analysis of objects without sampling. This is carried out by means of a beam extracted to air through an ultra-thin exit window. This set-up is briefly described in the following section.

3. The External Beam

3.1 A Particle beam in air

This type of set-up is at present increasingly used by scientists involved in applications of ion beam analysis to cultural heritage issues, due to the easy implementation of IBA techniques in air. Its principle consists in extracting the ion beam through a window sufficiently resistant to stand atmospheric pressure and beam induced damage, but thin enough to minimise the energy loss and energy straggling of the incident beam. The art work is then freely placed in front of this window at a distance of a few mm, in air or helium atmosphere.

The exit window must meet the following conditions:
(i) minimum of energy loss and energy straggling;
(ii) minimum of interfering signal;
(iii) good resistance to pressure and irradiation. Three types of window have been used: for macro-beam, 0.75 µm of aluminium (PIXE) and 2 µm of zirconium (NRA deuterons) and for micro-beam, 0.1 µm of silicon nitride Si_3N_4 (all techniques).

In addition to the obviously easy operation in air, the main advantages provided by an external beam are:
(i) the possibility of handling items of any size and shape;
(ii) the possible analysis of fragile objects which could suffer from being put under vacuum;
(iii) a marked reduction of beam induced heating;
(iv) the suppression of accumulated electric charges in insulators with no longer the need of conductive coating necessary when operating under vacuum.

3.2 A micro-beam to explore details

By adding to the external beam line a focusing system constituted of three quadrupole lenses, the performances of the set-up have been significantly improved. Indeed a real external micro-beam has been produced, permitting the direct analysis of museum objects at atmospheric pressure with a markedly increased spatial resolution. When using an exit window made of 0.1 µm Si_3N_4, a beam diameter of about 15 µm is attainable in placing the object at 2 mm from the window in a helium atmosphere. Such a beam size enables the analysis of small details like inclusions in gemstones or illuminated manuscripts. Moreover, the capability of a real nuclear microprobe is reached using a multiparametric acquisition system and moving the sample under the fixed micro-beam with accurate stepping motors. It is then possible to draw elemental micro-maps with a lateral resolution of a few tens of µm.

3.3 Panel of IBA techniques implemented

PIXE is by far the most frequently applied IBA technique to issues relevant to art. This fact stems from its higher sensitivity, its easy implementation and its low demand in beam quality (low sensitivity to energy straggling or to variation of incidence angle). This is even more marked when operating with an external beam. However recent improvements of the set-up permit to apply other IBA techniques: RBS with helium ions, NRA with deuterons.

RBS, currently used in materials science, is generally performed under vacuum with a beam of helium ions of a few MeV. Consequently, it has been relatively little applied to museum objects, as the extraction of a helium beam to air faces a serious difficulty, namely the high energy straggling. The few previous attempts to apply this technique in external beam mode relied on proton beams, poorly efficient in terms of mass and depth resolution. The availability of ultra-thin exit windows enables now to perform RBS runs at atmospheric pressure with a beam of helium ions of energy in the range 2-4 MeV, with a good energy resolution (a few tens of keV with a conventional surface barrier detector, as compared to about 15 keV under vacuum). The first applications concern the characterisation of patinas formed on copper alloys, the alteration of lead seals kept in the National Archives of France and the control of conservation conditions in this institution, using lead monitors [4].

Light element analysis can be performed with deuteron induced nuclear reactions. In the framework of a study of the black patinas formed on archaeological bronzes, we have developed an analytical protocol combining proton elastic scattering and (d,p) nuclear reactions with proton detection, for the determination of the concentration profile of both constituent metals and light elements C, N et O.

4. Examples of applications

Applications of IBA techniques to cultural heritage date nearly from the very beginning of the development of PIXE, with the study of ceramic potsherds and obsidian tools. They have been then quickly extended to all other kinds of materials of cultural significance. However, they are more suitable for some types of materials than for others, as for example those con-

stituted of thin layers of high Z elements over a substrate of low Z elements, a situation found in drawings or illuminated manuscripts. Some materials, such as for example metallic alloys, face another difficulty which hinders their direct analysis, namely the high detection limit for elements lighter than major constituents.
We will only describe below a few examples according to the current issues of cultural heritage.

4.1 Materials identification

The identification of constituent materials of art works is the basic objective of any scientific study. It yields important indices for the knowledge of the artistic technique and the authentication of works. This task can be easily carried out by external beam PIXE. Such an approach is illustrated by numerous studies on papyri, manuscripts, miniatures and drawings, the aim of which is to determine the nature of inks, pigments or metal points.

This technique was applied to a set of drawings by Pisanello, a famous Italian Renaissance artist. It was shown that the artist used several types of metal points: lead or silver-mercury alloy on parchment or paper without preparation and pure silver on a preparation based on bone white or calcium carbonate [5]. Another study has been devoted to the identification of pigments used in medieval illuminated manuscripts, kept in the National Library of France.

Concerning Egyptian papyri, the palette of a Book of the Dead from the Middle Empire has been investigated. Macroscopic distribution maps of elements have permitted to identify the different pigments: red (hematite, ochre), black (carbon), yellow (orpiment) and white (huntite). A light blue pigment containing strontium (celestite) has been revealed for the first time [6].

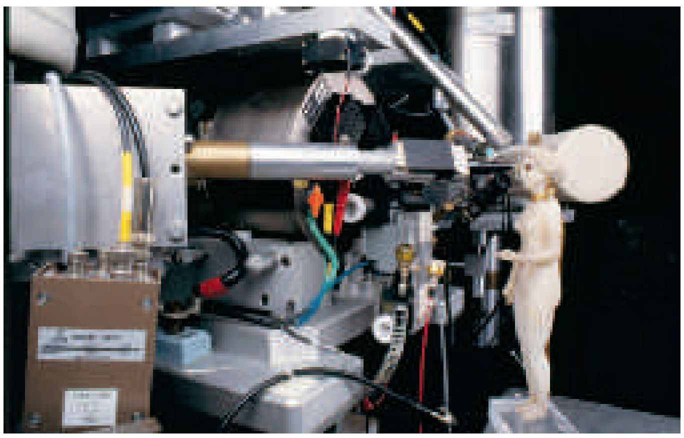

Fig. 2. Parthian statuette facing the external beam. © D. Bagault, C2RMF

Another example of mineral identification stems from the study of a Parthian statuette kept in the Louvre and representing the goddess Ishtar (**Fig. 2**). The red inlays representing the eyes and navel turned out to be rubies and not coloured glass as previously thought. In effect, the PIXE spectrum of major elements (**Fig. 3**) indicates the presence of aluminium and chromium, characteristic of ruby [2].

4.2 Materials provenance

This issue is of great interest in archaeology and to a lesser extent in art history, since it provides clues for inferring trade routes and relationship between past populations. For many years it was almost the monopoly of neutron activation analysis

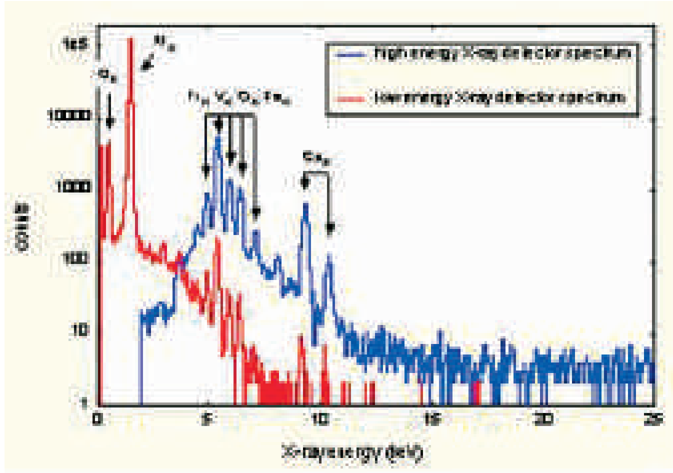

Fig. 3. PIXE spectra of the statuette rubies.

(NAA) due to its high sensitivity for trace elements which act as the fingerprint of materials source. At present PIXE and X-ray fluorescence (XRF) have replaced NAA in most studies where sampling is forbidden. The current protocol consists, first in measuring trace elements in the object and in geological samples of well known provenance.

Then using multivariate statistical methods (principal component analysis, clustering), one identifies discriminating elements and determines the object provenance. Such an approach has been applied to a large number of materials, including gemstones (rubies, emeralds) and ceramics.

A typical example stems from the determination of the origin of the rubies inlaid in the Parthian statuette found in Mesopotamia, which has been mentioned above. For this study a data base of the composition of about 500 rubies from different mines has been obtained by PIXE. The trace element fingerprint of the rubies of this statuette indicates that they come from Burma and that they are a precious witness of a gemstone trade route between Mesopotamia and Far East. More recently this method has been applied to determine the origin of emeralds set on Visigothic votive crowns originating from the royal treasure of Guarrazar Spain (8^{th} century), part of which is kept in the Middle-Age National Museum in Paris. From trace element measurement by PIXE and PIGE, it is concluded that these emeralds have been most likely extracted from the Habachtal mines in Austria. This result is quite interesting, as the exploitation of these mines is only certified after the 15^{th} century [7].

In the case of ceramics, in-situ analysis is seldom performed because of risk of error induced by their heterogeneous structure. Consequently, most studies rely on small samples of matter crushed and then compacted into flat pellets. Sometimes elemental composition is not sufficient to discriminate between several potential sources and additional parameters have to be used.

4.3 Fabrication techniques

Important clues about the fabrication technique of works of cultural heritage can be already derived from the simple identification of materials used for making the object, but most of time the spatial distribution of elements, either lateral or in depth, constitutes a decisive criterion. In the first case, micro-PIXE appears extremely useful and has been used for example

for determining the soldering technique of antique and medieval goldsmith's work [8]. Elastic scattering of protons and more recently of helium ions has been applied to the study of gilded objects in order to determine the composition and the thickness of the guilt.
For example, the study of the gold employed in the different parts of the crowns and crosses of the Guarrazar treasure quoted earlier has provided information on the goldsmith's technology. On one hand, the original parts have been clearly distinguished from modern ones added during the restoration of the treasure shortly after it was found (19th century) and on the other hand, it is demonstrated that in today presentation the crosses and crowns are not correctly associated. Moreover the gold used in these jewels has a content higher than the Visigothic coinage of that period, which excludes the assumption that the latter has been reused in royal jewellery [9].

4.4 Alteration phenomena

The possibility to carry out RBS experiments with external beams of helium ions opens a new field of research focused on the alteration of art works in the museum environment. One of the first applications concerns the already mentioned study of lead seals attached to papal bullae kept in the National Archives. Some of these seals are highly altered, most likely as a result of attack by organic acids emanating either from cardboard boxes in which the documents were formerly kept, or from the nearby storage environment, in particular the wooden structures (various furniture, shelves, etc.). The extent of alteration has been investigated by RBS together with the kinetics of alteration of lead monitors placed in diverse locations of the Archives in order to assess the level of harmfulness of the environment.

5. Conclusion

After twenty years of continuous use, the AGLAE facility constitutes the best tool for the non destructive analysis of works of cultural heritage on which rely almost systematically the studies performed at the Centre for Research and Restoration of the Museums of France. Although PIXE is by far the most used technique, the successive improvements made on the external beam line permit the use of all IBA techniques, under totally harmless conditions for museum objects.

Further progress can be made to render this facility even more efficient. Let us mention three examples: the development of a line dedicated to PIXE-induced X-ray fluorescence which will improve the detection limit (several tens of parts per million at present) in view to measure trace elements in metals (gold or lead alloys). The detection of very light elements, down to hydrogen, is also developed with the ERDA technique, and would eventually allow to date archaeological artifacts by measuring the hydration profiles at their surface. Finally the chemical imaging of materials of the cultural heritage materials, which are often complex and heterogeneous is particularly promising.

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Conservation of Birch-Bark Manuscripts – Some Innovations

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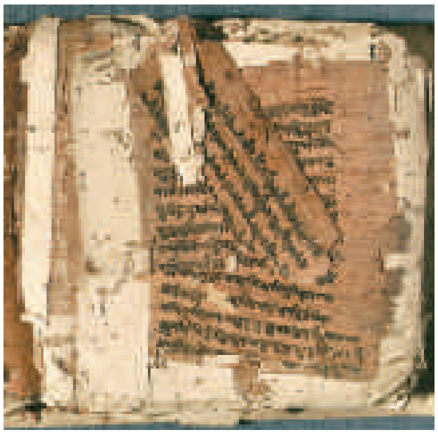
Introduction

Birch-bark (*bhoj patra*) and palm-leaves (*tad patra*) were the main materials used for writing purpose in India before the advent of paper sometime in the 10th century A.D. Even after the paper was introduced, these materials continued to be used, since in the initial stages paper was scarce and was too costly. Bhoj patra, as birch-bark is known in Hindi, is supposed to be very sacred and even today many religious mantras (sacred hymns) are written on it and kept in the temples, as well as at home, for spiritual use.
Many of the early birch-bark manuscripts have been destroyed and lost forever. Even then large collections are available in some museums, libraries and archives. The National Archives of India, New Delhi has a considerable collection of ancient birch-bark manuscripts. A good number is available in the collection of the Akhil Bharatiya Sankrit Parishath, Lucknow. The Sri Pratap Singh Museum, Srinagar also has a sizeable collection. Birch-bark manuscripts are found in several houses of Kashmir, where people keep them as holy scriptures. Unfortunately, birch-bark materials are more susceptible to damage and deterioration. The INTACH Indian Council of Conservation Institutes, Lucknow through its various units, has been very active for the preservation and conservation of these types of manuscripts.
Given in the following pages are some of the innovations introduced in techniques used and issues involved.

Birch-Bark

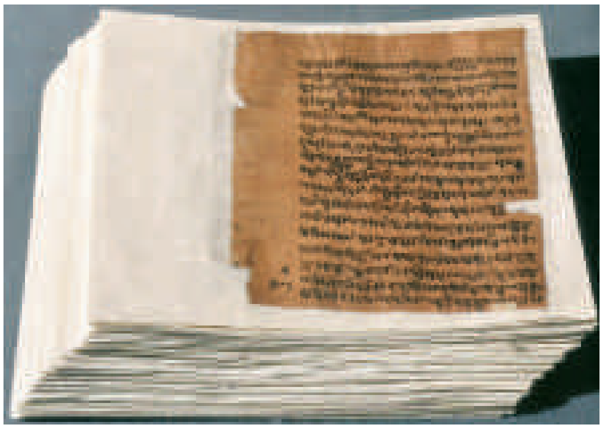
Origin

Birch is a moderate size tree, growing to a height of about 7 meters, and is found in the mountain forests of the Himalayas. The inner bark of the birch tree was used for writing. The outer bark after peeling from the tree is discarded and the inner bark, which also peels off easily, is almost paper thin, very supple and flexible. It was first of all dried in the shade, an oil was applied over it and was then polished with a smooth and hard stone like agate. It was then cut to the required size and written upon with pen and ink. Written sheets were kept between two wooden panels for protection.



Deterioration

Physically birch-bark is not a very strong material. Old birch-bark sheets become weak very quickly and start to disintegrate. Furthermore, birch-bark sheet is not a single layer; it has a multilayed structure, in which 3 or 4 or even thinner layers are fixed together with a type of natural gum and also joined with brownish nodes in the form of streaks. In due course of time the natural gum joining the individual layers disintegrates and the layers start to separate, but they continue to be joined at the nodes. This phenomenon makes the conservation procedure rather complex and difficult. If the component layers were separated out completely, they could be stuck together again with a fresh adhesive, but since they continue to be joined at various intervals on account of nodes, introducing new adhesive is not easy.
There is some inherent chemical property of birch-bark, which prevents the growth of insects and fungi on it. Experiments conducted at the National Research Laboratory for Conservation of Cultural Property, Lucknow indicated that even in very humid atmosphere fungi did not develop in birch-bark samples.



Properties of Birch Bark

The physico-chemical properties of birch-bark were the subject of intense research by O.P. Agrawal and D.G. Suryavanshi. During these studies, first of all 'water – absorption rate' of birch-bark was measured and it was found that it was very low. That is the reason birch-bark does not get stained easily. Nevertheless sometimes some accretions are present on the surface, which need to be removed. So experiments were conducted to examine the effect of various solvents, like ethyl alcohol, acetone, carbontetrachloride, ether, etc., on birch-bark. It was found that most of the organic solvents had some effect or the other on the birch-bark. These solvents leached out some parts of the sheet and in several cases changed its appearance also. In some cases birch-bark acquired brown colour.
Mixtures of these chemicals were also tested and they also produced several problems. None of them was found suitable for cleaning of birch-bark. On the contrary they produced an adverse effect.

From these experiments we learnt a lesson that organic solvents should never be used to clean birch bark manuscripts. We also experimented with water and water-based solutions.
Water did not harm the birch-bark in any manner except the ink. O.P. Agrawal and D.G. Suryavanshi also tested the effect of alkaline and acidic solutions on the materials of birch-bark. Even dilute acids and alkalies were found to be injurious to the material. Alkalies did more damage than acids did. It was concluded from these studies that birch-bark manuscripts should never be deacidified.
Experiments were also conducted to examine the suitability of adhesives for fixing of separated layers of sheets. Methyl cellulose or carboxy mythyl cellulose gave very good results. Gum prepared with tamarind seed juice was very successful. To prepare this gum, tamarind seeds, which have a brownish shell, are slightly roasted, the brown shells are removed and the seeds are pounded to small pieces and soaked in water overnight. A sticky juice emits, which is strained and boiled for 30 minutes. The concoction is passed through a muslin cloth to remove coarse particles and used as a gum. It has a unique property of being very flexible.

Conservation Procedures

As in the case of any other object, examination of manuscripts is an important part of conservation. During examination, one is to assess whether the component layers are fixed or are separating out. The condition of the edges of the birch bark is equally important for its safety.
Although, fungi and insects are normally not found in birch-bark manuscripts, one should ascertain their presence or absence.
We should also note the presence or absence of stains.
For removal of stains, water solution is the best option. It is better to leave a stain in the sheet rather than use any type of organic solvent. Our studies have indicated that organic solvents cause damage to the bark.
As mentioned earlier fixing of separate layers of birch-bark sheet is the most tedious problem in conservation. It has already been mentioned that a birch-bark sheet is composed of several layers, which when fresh and new, are fixed to each other with a natural gum and sort of ‘stitched’ together with ‘nodes’. With time, and on account of various deteriorating factors, they separate out and also become fragile. In order to give them a strength, it is essential to paste the sheets to each other afresh. However, it is not possible to do so unless they are completely separated. There lies the difficulty, because the nodes hold all the layers of a sheet firmly together and any attempt to separate them may result in severe damage to the layers. In some instances where the bond of the nodes was not very strong, it was possible to separate out the layers, and refix them with a fresh adhesive.
In some manuscripts, constituent layers are opened only at the edges, and we could treat them by applying the adhesive between the layers with a fine brush, and then let them dry between blotting sheets under pressure.
Sometimes, the birch-bark sheets are very fragile and therefore some new support has to be provided to them. The following techniques have been employed to achieve this objective:

1. Placing the documents between two glass plates and sealing them from all the four sides with tape. However, the glass plates are too heavy and cumbersome to store. At best the technique could be adopted for small pieces of birch-bark, as was done recently by the National Research Institute for the Protection of Cultural Property, Tokyo for the conservation of birch bark fragments collected from the Bamiyan site in Afghanistan. Microscope slides were employed to mount the birch bark fragments. The mounted slides were placed in plastic storage containers with Styrofoam in between to make them secure. The device served very well for small pieces of birch-bark, but will not be of much use for full-size documents. Glass plates could be put to use if there are only one or two documents to mount.
2. Lamination between silk gauze with starch paste as adhesive. The famous Gilgit birch-bark manuscripts in the collection of the National Archives of India, New Delhi were restored by this technique. We have observed that silk gauze becomes brown, and also brittle, in a few years time.
3. Introducing a new durable material between weak layers of the birch-bark to impart to them new strength and support. This technique is possible only if the layers can be separated from each other completely. We have used it for some important manuscripts.
4. Lamination between transparent tissue paper or cellulose acetate foils.
5. Encapsulation between transparent polyesters sheets is another method. However, large-scale restoration is rather impractical by encapsulation.

Future Research

Much more intense research is required in the methods of restoration of birch-bark manuscripts. Some issues are:

i. Cleaning system. We have seen that organic solvents are harmful to birch-bark. Then what should be used?
ii. Develop a method for the separation of individual layers of birch-bark sheet, in order to consolidate them individually and paste them together.
iii. Alternatively, find consolidating solution which would penetrate through the various layers and bind them together without separating them.
iv. Strengthening of birch-bark sheets. None of the present method seems to be wholly satisfactory.
v. With age, birch-bark loses its flexibility and starts to break at the edges. How to restore its flexibility is a big question.

These are research issues and should perhaps be taken up by the National Research Laboratory for Conservation of Cultural Property, Lucknow, which has all the necessary infrastructure and expertise in this area of research. The execution of preservation of sizeable collections could be undertaken by the network of conservation centres of INTACH, which are located in various parts of India.

About INTACH Conservation Centres

In 1984, there was a unique happening in the field of conservation of cultural heritage in India, and that was the establishment of the Indian National Trust for Art and Cultural Heritage (INTACH). With its head quarters at New Delhi it acts as a pressure group with the aim of documentation and conserving India’s rich and varied built, as well as moveable art heritage. Soon after its establishment a conservation centre was established at Lucknow in 1985 with the objective of providing services for the conservation of varied types of art materials, including paintings, paper manuscripts, textiles, sculptures, bronze images, birch-bark and palm-leaf manuscripts, etc. At the time when it was established there was no conservation facility in the non governmental sector. The Governmental centres were mainly responsible for the preservation of collections in the Government institutions and as such there was no organization to look after the collection of privately owned museums, libraries, archives and temples and churches. With the establishment of the INTACH Conservation Centre at Lucknow this need was fulfilled to a great extent.

Encouraged by the success of the Lucknow Centre INTACH established a Centre at New Delhi in 1990. This Centre was specializing mainly in the conservation of oil paintings. Now its scope has widened and it undertakes restoration of other types of objects like paper manuscripts and textiles as well.

Very soon in 1993, the third Centre of INTACH was founded in Bangalore in collaboration with an eminent art institution, namely Karnataka Chitrakala Parishath. This Centre was established to conserve the needs of South India. It was conserved with conservation of canvas paintings, miniature paintings murals, paper and palm-leaf manuscripts, etc.

In 1995, yet another Art conservation Centre was established in Bhubaneshwar to cater to the needs of eastern part of India. It conserves various types of art materials, and has specialized in conservation of palm-leaf and paper manuscripts. The State of Orissa is famous for its palm-leaf manuscripts which are found in hundreds and thousands in museums, libraries, archives and even in villagers' houses. Villagers keep these manuscripts as sacred text and will not part with them at any cost. The Orissa Centre with the support of Norway Agency for Development (NORAD) organized a number of workshops for training in preventive conservation as well as curative conservation. Several training programmes were conducted, with participants coming from India as well as from other countries of Asia.

In the same year in 1995, yet another Centre for conservation of paper manuscripts was established in the Rampur Raza Library, Rampur, (U.P) in the State of Uttar Pradesh, India.

A Centre came up at Jodhpur in 1996 with the specialization in wall paintings, miniature paintings, wooden objects, etc.

Subsequently conservation centres were founded in Tripunithura, Kerala specializing in conservation of wall paintings and at Jaipur for conservation of paper manuscripts.

It was being felt by INTACH that two main metropolitan cities of India namely, Kolkata and Mumbai were without any conservation centres. To meet this need, an Art Conservation Centre specializing in oil paintings, paper paintings was established at Kolkata in 2004.

In the same year, an Art Conservation centre was established at Mumbai in collaboration with the Bhau Daji Lad Museum.

The Indian Council of Conservation Institutes was formed as a Division of INTACH to look after and to guide all these Centres, which have been established as a network of units spread in all parts of India. At present all of them are not concerned with conservation of birch-bark and palm-leaf manuscripts, but given an impetus they could easily do this type of work as well.

Conclusion

It would thus be seen that during recent years much progress has been made towards conservation of birch-bark manuscripts, a very important part of India's cultural heritage. But, much still needs to be done to solve various problems which are present. These are important issues, which need to be addressed very seriously and thoroughly.

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News

Blue Shield actions for safeguarding heritage in Haiti Press Release, 22 March 2010

The Blue Shield reasserts its solidarity with the Haitian authorities and population as well as all National and International Organisations working to help the injured and homeless and rebuild sustainable infrastructures vital for the Haitian people's survival.
Culture being a core component of Haiti's social fabric, protecting and rescuing the country's heritage is essential for its recovery. In this perspective, the Blue Shield, through its constituent organisations and its National Committees around the world, has been taking unprecedented action since 12 January 2010 in order to assist the Haitian authorities, cultural associations and stakeholders as well as the Haitian population in their effort to defend and restore Haitian heritage. Haiti can count on the BlueShield member organisation's expertise and support with regard to archives, audiovisual documents, libraries, monuments and museums.

Actions taken by the Blue Shield since 12 January

The various member organisations of the Blue Shield have swiftly reacted to the Haitian disaster and have made every effort to prepare the current action phase, by taking the following preparatory steps:

Damage and needs assessment

Through the member organisation's local networks, personal contacts and field missions, the Blue Shield followed the lead of the Haitian authorities by conducting thorough evaluations of the damage suffered by Haitian cultural heritage and the best ways to assist the Haitian authorities, institutions and associations in their efforts to rescue Haitian heritage. This effort together with the expertise of the Blue Shield's constituent bodies has made the organisation a favoured source of information on Haitian cultural heritage issues for NGOs, governments and International organisations.

Circulation of information

The Blue Shield has made all information gathered available to the international communities willing to help the Haitians in their efforts to rescue their heritage. In addition to traditional means of communication, the Blue Shield has set up a dedicated website, as well as a Facebook page and a Twitter thread.

Coordination with Haitian and international communities

The Blue Shield met the Haitian Minister of Culture, Mrs Marie Laurence Jocelyn Lassegue and her team on 16 February and assured her of its full support and determination to collaborate with the Haitian authorities. Moreover, the Blue Shield is coordinating its actions with its members' National Committees, ISPAN (Haiti's Institute for the Protection of the National Heritage) and the Haitian Crisis Unit "Patrimoine en Danger", set up following the earthquake by heritage and cultural association members to coordinate heritage safeguarding actions.
The Blue Shield and all its member organisations have actively taken part in the creation of the UNESCO International Coordination Committee (ICC) for Haitian culture and have given full support to the steps UNESCO has taken to ensure that culture and heritage issues will be taken into account fully in the United Nations' efforts to reconstruct Haiti, in particular during the forthcoming 31 March meeting in New York City.
The Blue Shield is also in contact with OCHA (UN Office for the Coordination of Humanitarian Affairs) and other relevant organisations to prepare its actions in Haiti.

Preparing action plans

Through its website, the Blue Shield has so far collected more than 700 application files from volunteers all around the world covering all heritage fields. Each constituent organisation also directly appealed to its members to volunteer their expertise.

Blue Shield actions in progress

The Blue Shield is coordinating the actions of its members where possible in order to strengthen their impact. As the recovery efforts vary for each type of heritage item, each member organisation is also taking additional steps. The following joint actions were resolved:

Marking cultural sites with the Blue Shield emblem

As a response to the urgent problem of demolition and bulldozing of buildings of cultural value and/or content, the Blue Shield produced 250 weather-resistant signs (30x50cm) with the following inscription in English, French and Haitian Creole:
Cultural Property
Protected by the Convention of The Hague, dated 14 May 1954
www.blueshield-international.org

These signs are currently being distributed to the Blue Shield's local partners, ISPAN and the Crisis Unit "Patrimoine en Danger" to mark relevant buildings and sites.

Offering the international community a Damage assessment and project follow-up tool

The Blue Shield has enriched its dedicated website with pages devoted to each identified cultural site. They can be used by the Haitian and international authorities and NGOs to track projects and avoid overlap. Fifty pages are already published, based on data collected and status reports from the Blue Shield member organisations. They can be accessed under:
http://haiti2010.blueshield-international.org/directory

Sending of building engineers

Architects and building engineers will be sent for the emergency evaluation and reinforcement of damaged buildings. This will make the evacuation of items in museums, libraries and other heritage buildings possible.

Creation of a Cultural Recovery Centre for the treatment of cultural items

The Centre will include facilities for urgent repairs and restoration of archives, books or museum objects that might be rescued from the rubble and damaged buildings. It will be used for hosting international volunteers and other NGOs willing to participate in Blue Shield-related actions, and provide working and training facilities for Haitian volunteers.

The Blue Shield has had the opportunity to cooperate with the Haitian organisation FOKAL (Fondation Connaissance et Liberté or Open Society Institute) to establish this Centre on a 3,000m^2 field near the airport, thanks to "Haiti Habitat" and in close cooperation with Bibliothèques Sans Frontières. Blue Shield member organisations are planning how the site will be organized with tents, electricity and secure storage, in coordination with Bibliothèques Sans Frontières and FOKAL, who have already purchased and placed nine 40 ft. containers on site. MINUSTAH should provide security for the site and UNESCO is interested in funding the fencing of the premises.
The Cultural Recovery Centre will be equipped with more containers for temporary storage of rescued cultural goods and relevant equipment to treat cultural property.

Contact Information:
Blue Shield secretariat: secretariat.paris@blueshield-international.org

The actions of the Blue Shield can also be followed on:
Our website: http://www.blueshield-international.org
Our Facebook page: Haiti 2010 Blue Shield Solidarity
Our Twitter thread: blueshieldcoop

Publications

Proceedings: "CULTURAL HERITAGE on line. Empowering users: an active role for user communities", 15-16 December 2009, Florence, Italy

Fondazione Rinascimento Digitale is delighted to announce that the official Conference Proceedings are now available on the website, at: http://www.rinascimento-digitale.it/conference2009-proceedings
IFLA-PAC was one of the supporters of this conference.

Contact:
Fondazione Rinascimento Digitale
Nuove Tecnologie per i Beni Culturali
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Events and Training

Announcements

LIBER Annual Conference 2010: "Re-Inventing the Library. The challenges of the new information environment", 29 June-2 July, Aarhus, Denmark

LIBER will hold its 2010 Conference entitled "Re-Inventing the Library. The challenges of the new information environment" from 29 June to 2 July in Aarhus (Denmark).
LIBER2010 is being kindly organised by the State and University Library in Aarhus. Please visit the Conference website at http://www.statsbiblioteket.dk/liber2010/liber-2010 for further details.

Important dates:
Deadline for early registration: 30 April 2010
Final registration deadline: 14 June 2010

The programme is available at: http://www.statsbiblioteket.dk/liber2010/conference-programme
Papers and posters will focus on four areas:

1. *The Library in the context of e-Science*
2. *The Library in the context of e-Education*
3. *Making collections digitally available*
4. *Library Management*

Contact:
If you have questions relating to the organisation of the 2010 LIBER Annual Conference, please contact the organizer at info@liber2010.eu.
If you have questions regarding registration or accommodation, please contact the Conference Secretariat, KongresKompagniet, at liber@kongreskompagniet.dk.

76th IFLA General Conference, IFLA Preservation and Conservation Core Activity and Section Open Session on "Preservation and Sustainability", 10-15 August 2010, Gothenburg, Sweden

The IFLA PAC Core Activity and IFLA Preservation and Conservation Section are coorganizing a session on the topic of **Preservation and Sustainability** at the WLIC 2010 in Gothenburg.

The general theme for the conference is **"Open Access to Knowledge – promoting Sustainable Progress"**. Environmental sustainability is a much-debated topic and there are fears that extreme weather situations will become more abundant in the future. Today, it is evident that floodings, fires and hurricanes are a major threat to library collections and should such events increase in numbers, or occur in unusual places, measures have to be taken to safeguard library collections.
Energy may become more expensive in the future and the control of in-house climate is dependent on the use of energy for heating, de-humidifying and cooling – crucial factors for long-term stability of library materials. How may higher energy prices, or the switch from one energy system to another, have an effect on the long-term preservation of library collections? These are all relevant questions within this topic. Risk factors involving digitally stored information may need to be addressed.

The programme will be on line very soon: consult PAC web page (http://www.ifla.org/en/pac) and the conference website (http://www.ifla.org/en/ifla76) for further information.

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Rare Books and Manuscripts & Preservation and Conservation Sections Satellite Meeting: "New techniques for old documents. Scientific examination methods in the service of preservation and book history", 16-18 August 2010, Uppsala, Sweden

Within this theme, papers shall focus on scientific techniques such as DNA, infrared spectroscopy, imaging techniques and micro X-ray fluorescence. All these techniques may be used in conservation treatments and material bibliographic issues such as the determination of animals for leathers, provenance through DNA-analysis, measuring paper strength, examination of pigments and inks for palimpsests and other documents, and ICR (Intelligent Character Recognition) for the recognition of handwritten text.
The programme should be soon on line on IFLA website.

Venue:
Uppsala University, Sweden

More information at:
http://www.ifla.org/en/events/preservation-and-conservation-section-satellite-meeting

Primera Conferencia Iberoamericana de Bibliotecas Nacionales Digitales, 7-9 Septiembre 2010, Santiago, Chile

La Biblioteca Nacional de Chile con el patrocinio ABINIA y UNESCO, está organizando la Primera Conferencia Iberoamericana de Bibliotecas Nacionales Digitales: "Bicentenario, Desafíos y tendencias del patrimonio digital", que se realizará los días 7, 8 y 9 de septiembre de 2010, con el objeto de conocer, compartir y discutir las problemáticas del patrimonio digital en el ámbito de las bibliotecas nacionales.

La conferencia propone reflexionar y discutir sobre los procedimientos de manejo, gestión y preservación de documentos digitales a través del conocimiento de las experiencias de los países líderes en materia de desarrollo e implementación de las tecnologías de la información y comunicación. Por ello, esperamos contar con representantes de todas las Bibliotecas nacionales de Ibero América, así como también especialistas de nivel internacional en los temas propuestos.

El programa se desarrollará a partir de seis ejes temáticos:

- Políticas y estándares de digitalización
- Patrimonio nacido digital
- Preservación digital

- Acceso: herramientas de administración de colecciones digitales
- Aspectos jurídicos: depósito legal electrónico y propiedad intelectual
- Proyectos cooperativos: metadatos e interoperabilidad.

Adicionalmente se realizarán cada día talleres y exposiciones de distintos proveedores de herramientas y servicios digitales, la que posibilitarán conocer la oferta de recursos que entrega la empresa privada. Además se contempla realizar visitas de carácter cultural a instituciones relacionadas con el patrimonio bibliográfico chileno.

Contacto:
conferencia2010@bndechile.cl

IIC Congress 2010: "Conservation and the Eastern Mediterranean", 20-24 September 2010, Istanbul, Turkey

The International Institute for the conservation of works of arts (IIC) 2010 Congress will focus on the conservation of moveable and immovable heritage in or from the Eastern Mediterranean. This will include material held in collections around the world, the care and conservation of works of art, artifacts and sites, and the preservation of architecture, all reflecting the influences that have made this region one of the world's richest centres of heritage.

The conference will bring together the international professional community to present and exchange ideas, to debate conservation practices and cutting-edge research, to consider exciting new developments and thought-provoking challenges, and to make new connections between this region and all corners of the world.

An impressive range of over 40 speakers is lined up to report on contemporary thinking, current research and examples of best practice. Topics will include:
- Site and urban conservation and management
- Conservation and research of textiles, sculpture, leather, and manuscripts
- Conservation of painted interiors and decorative surfaces
- Conservation of mosaics, wall paintings and tomb art
- Reviews of conservation history and techniques

Conference venue: Sabanci Centre

Programme and Registration
The programme and all the details regarding registration can be found on the Congress website at:
http://www.iiconservation.org/congress/

Contact:
iic@iiconservation.org

Report

IFLA International Newspaper Conference, "Digital Preservation and Access to News and Views", Indira Gandhi National Centre for the Arts (IGNCA), 25-28 February 2010, New Delhi, India

By Else Delaunay,
IFLA Newspaper Section

The Conference was organized jointly by the IGNCA, the IFLA Newspaper Section and IFLA PAC Core Activity, and directed by Dr Ramesh C. Gaur, head of the Kala Nidhi Division, IGNCA.

Around 220 delegates attended the Conference among which several participants from the Indian newspaper industry (ex. *Times of India, The Hindu, DNA…*). Eminent speakers from national libraries, newspaper libraries and archives in the USA, the UK, France, Germany, Finland, Australia, Bangladesh, South Africa, Singapore and India delivered some 40 presentations. Before the opening of the Conference the printed volume of 29 conference papers was handed over to each delegate.

In his keynote Reinhardt Altenhoener, German National Library Frankfurt, said that newspapers worldwide carry a whopping 400-500 billion items everyday. "The tricky bit is copyright issues and the overlap between e-paper and online news." It is not feasible to collect all material. "It's a challenge to evaluate what to preserve," he said.

The New Delhi conference focused as much on collection, preservation, and access of digital news and newspapers as it did on these same activities for traditional printed newspapers. For news is created and produced digitally, even for print newspapers. The discussions throughout the Conference moved round issues such as physical preservation and conservation of newspaper hardcopies and microfilm master negatives (considered as a last resort), policy issues and methodologies, copyright problems, selection of items to preserve, digital preservation of both traditional and born digital newspapers, online newspapers, newspaper as digital resource, and 24X7 digital access to newspaper. Various issues concerning digital archiving of newspapers and the reading habits of users in the digital era were also explored.

As pointed out by Dr Ramesh Gaur the present era is one of transition, a crucial point for the world's newspaper industry, from traditional newspapers to digitally produced news. This results in new opportunities and challenges to face and to overcome in order to be able to cope with these challenges of digital production and distribution. Institutions, librarians, researchers and archivists worldwide must share all these tasks with the object to discover new practices and necessary innovations.

During the Conference the various tools and technologies for digital preservation were introduced and discussed. National libraries and State public libraries were asked to share technical resources and digital archiving software with smaller libraries, including newspaper libraries. IFLA Newspaper Section was asked to develop a digital archiving software package that would help newspaper libraries and other organisations in preserving news resources.

The Conference resulted in a number of recommendations for the future action development within newspaper libraries. There was a strong wish: to create a forum of professionals from Indian newspaper libraries in order to list their development needs; to come out with a state-of-art report on newspaper libraries in India; to insist on the need for an online directory of newspaper libraries worldwide.

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IFLA Newspaper Section also decided to prepare a report on the status of newspaper library systems and establish a framework for launching a national level programme for centralised digital preservation of news information resources in India.

The Conference ended with a valedictory address by Jawhar Sircar, secretary of the Union Ministry of Culture, who also put forward the need to set up a professional forum with all the stakeholders involved in preservation and provision of access to news resources: create national standards and benchmarks for effective and best use of various resources including grants and funds from the government. Jawhar Sircar appreciated the pertinence of the Conference, in particular for all organisations which preserve and provide access to news resources.

The Conference director as well as the delegates agreed the meeting was very successful in achieving its objectives. It was indeed a platform for media librarians to exchange ideas and experiences.

The Conference was very well reported in many Indian daily newspapers.

Conference website:
http://www.ignca.nic.in/ifla2010/ifla2010.htm

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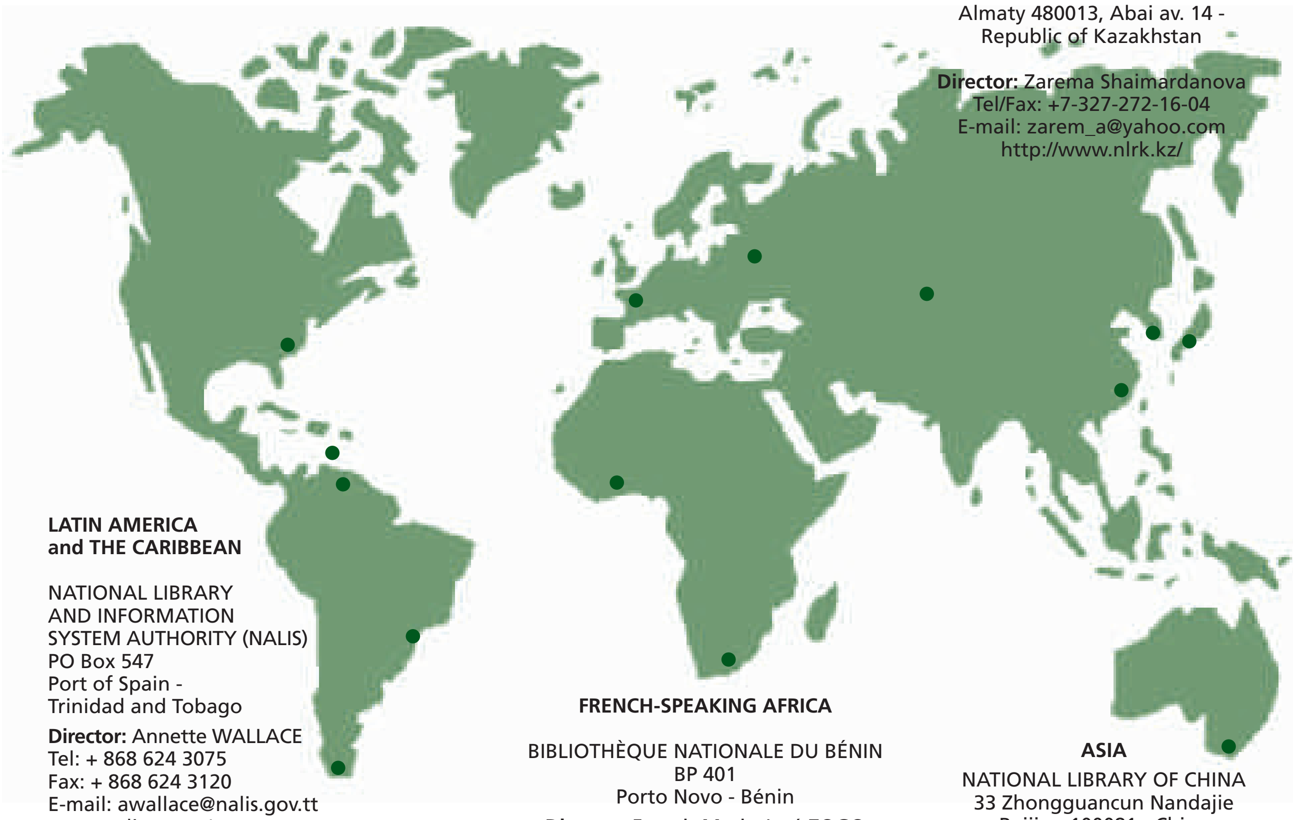

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