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Application of High-Resolution Multispectral Imaging Systems for the Very-Long-Term Monitoring of Degradation Over Time of Photographs, Paintings, Fabrics, Documents, Books, and Other Cultural Heritage Materials

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High-resolution multispectral imaging provides periodic full-image area, non-destructive and zero-contact monitoring over both short and very long periods of time of cultural heritage materials, including photographs, paintings, fabrics, documents, books, tapestries, and other works of artistic and historic importance with very large data sets consisting of up to ten thousand or more discrete colorimetric data points for the short-term and long-term monitoring of full-tonal-scale – generally nonlinear – colorimetric changes (including in the UV and IR regions), in a fully time-integrated manner, that may take place over time in the full image area and in the support material (front and back). Multispectral imaging can accurately monitor rates of degradation of optical brightening agents (OBAs) and can quantify gradual yellowish or other stain formation in photographs, including albumen prints, polyethylene coated (RC) papers, and other materials.

Multispectral imaging provides the ability to monitor glazed works periodically during exhibition without the necessity of removing glass or plastic sheets from their frames while the works remain on the wall. Likewise, works

housed in anoxic frames may be monitored over the long term without opening the frames. Irregularities in image deterioration and/or staining brought about by localized variations with photographic materials and their chemical processing, washing, contamination during drying, or as a result of selenium, sepia, gold, or other chemical toning treatments, coating and varnish layers, laminates, and other steps employed in the creation and finishing of the work, integrated with the inevitably non-uniform contact with mounting, framing, and storage materials over time, and the effects of exposure to non-uniform lighting, environmental and “micro-climate” temperature and relative humidity conditions, can be assessed and compared over long periods of time in all areas of an image – including within very small image details.

Representative times currently required for a MegaVision camera-based high-resolution capture of an object are: 1 minute and 16 seconds for 16 sequential image captures with 16 different waveband illuminants (with no filter wheel captures), with an integrated lux exposure of 0.12 lux/hour (equivalent to <10 seconds of display at 50 lux), and 3 minutes and 15 seconds for 26 sequential image captures with 26 different waveband illuminants (capture time includes 10 filter wheel captures for a more comprehensive OBA degradation analysis), with an integrated lux exposure of 0.33 lux hour (equivalent to <1 minute of display at 50 lux).

High-resolution multispectral camera captures provide extremely accurate color images that are superior to RGB captures. These images can be used to automatically generate lower-resolution RGB images for cataloging, websites, publications, posters, and other uses. These high-resolution images can also readily be used to make color-accurate facsimile prints for exhibitions and study. Multispectral imaging employed as a routine part of the acquisition and accessioning process provides a “time-zero” set of high-resolution spectral data for every object that can then be used for very-long-term monitoring.

This presentation will consider the formidable technical challenges of very-long-term monitoring in the context of the now more than 2,000-year-old Dead Sea Scrolls in Israel, and the ongoing programs to systematically multispectrally capture each scroll and scroll fragment, monitor, and preserve the delicate parchment scrolls and scroll fragments. During the coming hundreds or many thousands of years into the future, every single part of a multispectral imaging system and the associated computers, software and data storage systems, calibration targets – and our understanding of color science itself – will repeatedly become obsolete and must be replaced with new systems. Strategies that will ensure a continued high degree of accuracy relative to the original measurements are proposed.

Without a comprehensive multispectral monitoring program, conservators and other institutional caretakers will have little or no quantitative data concerning what has actually been happening to their collections as they age over time, and with the understanding that comes with that quantitative information, of how degradation may be slowed or halted by changes in display and loan policies, by the use of humidity-controlled refrigerated and sub-zero freezer preservation, and by other means, some of which are yet to be developed.

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library's greatest accomplishment using its new technology, but several other projects are in progress. The imaging device, for instance, found thumb and fingerprints on the Gettysburg Address using infrared light, and library researchers are seeking to determine whether they are President Abraham Lincoln's…" "[Library of Congress Preservation Director, Dianne van der Reyden] said the research and discoveries illustrate why it's so important to keep and protect original documents. The erased 'subjects,' she said, could have been detected only from Jefferson's original draft."

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22) “Special Exhibit: Dead Sea Scrolls, A New Traveling Exhibition from the Israel Antiquities Authority,” Ronald Reagan Presidential Library and Museum (U.S. National Archives and Records Administration), 40 Presidential Drive, Simi Valley, California 93065 U.S.A., November 22, 2024 – September 2, 2025. Fully integrated, light-induced and dark-storage changes, and changes caused by moisture, airborne pollutants and by other factors that may occur during this exhibition are being monitored using high-resolution multispectral imaging.

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Their Time – 54 Years: From 1971 to 2025 – The Only Collection of Its Kind in the World," Henry Wilhelm and Carol Brower Wilhelm, Wilhelm Imaging Research, Inc. (WIR), 2025 (2,936 pages). During the 54-year period that this collection has been assembled, multiple test target designs have been used, as well as a succession of different densitometers and spectrophotometers. In addition, a number of different older and no longer supported Apple Macintosh and Windows PCs have and are currently being used to run the in-house written Mac and PC software data collection and analysis programs, all of which now pose a variety of data migration difficulties. In anticipation of this, the decision was made to start collecting the full spectral data from 380 to 730nm in 10nm increments for 800-patch neutral, cyan, magenta, yellow, red, green, and blue color scales so that the raw spectral data could be used with any current or future color change analysis system. This system was implemented in 2000. In addition, beginning in 2004, sets of measured test targets are being preserved unchanged in subzero, humidity-controlled freezer storage at -20°C (-4°F) for use for future reference and for calibration of future multispectral and other, yet unknown, measurement instruments and color change analysis systems. Test targets stored in the dark under ambient room conditions are also being monitored for research projects and this has presented a number of practical difficulties because of changes in measurement instruments over time. For example, a major research project at WIR in 2021 that involved hundreds of test targets focused on light-induced yellowish stain formation, targets exposed to light in the course of various accelerated light exposure tests and then placed in the dark where many papers developed high levels of yellowish stain over periods of months or years.

http://www.wilhelm-research.com/WIR_Reference_Collection/The_Wilhelm_Analog_and_Digital_Color_Print_Materials_Reference_Collection_1971_to_2025_v26_(2025-02-01).pdf

Author Biographies:

Henry Wilhelm

Henry Wilhelm is the Founder and Director of Research at Wilhelm Imaging Research, Inc. Through its website, the company publishes print permanence data for desktop and large-format inkjet printers, silver-halide color papers, digital presses, UV-curable ink printers, dye sublimation ink printers, and other digital processes. WIR developed test methods have become the worldwide de facto standard for print permanence evaluation and are currently being used by Epson, HP, Canon, HP Indigo, and other OEMs. Wilhelm Imaging Research also provides consulting services to museums, archives, and commercial collections on sub-zero cold storage for the very-long-term preservation of still photographs and motion pictures. In 1979, Henry Wilhelm was one of the founding members of the AIC Photographic Materials Group (PMG). Wilhelm has authored or co-authored more than 30 technical papers presented at conferences sponsored by the Society for Imaging Science and Technology (IS&T) and the Imaging Society of Japan (ISJ) in the United States, Europe, and Japan. With contributing author Carol Brower, Wilhelm wrote “The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures,” published in 1993. The complete 758-page book is available in PDF/A form at no cost from <www.wilhelm-research.com>. Since the book was posted online in 2003, more than one-half million copies have been downloaded worldwide. In 2011 Wilhelm received an Honorary Doctor of Science degree from Grinnell College for his research on the preservation of photographs.

Ken Boydston

Ken Boydston is the President and Chief Color Scientist of MegaVision, Inc., based in Ventura, California. Boydston led the development of the high-resolution MegaVision Multispectral Imaging and Analysis System, which was introduced in 2007 and, with Boydston’s collaboration. The system has been used to image, to monitor with very large colorimetric data sets, and conduct forensic analysis of the Dead Sea Scrolls in Israel and many other national and world cultural heritage treasures, including:

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6) Léon Bonvin Watercolors (Walters Museum)
7) Oxyrhynchus Papyri (Oxford University)
8) Declaration of Independence (United States Library of Congress)
9) Selected pigment studies (Getty Museum of Art, Los Angeles, California)
10) Palimpsest collection and other manuscripts (St. Catherine's Monastery)
11) Dead Sea Scrolls (Israel Antiquities Authority)
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13) Artists' works: Monet, Picasso, Delacroix, Michelangelo, Gauguin, others (Santa Barbara Museum of Art, Santa Barbara, California)
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15) Various papyri and manuscripts (State Library of Austria)
16) Vercelli Book (Museo del Tesoro del Duomo)
17) Codex Vercellensis (Museo del Tesoro del Duomo)

18) Vercelli Mappamundi (Museo del Tesoro del Duomo)

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