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The Digitization Project of the Dead Sea Scrolls

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ABSTRACT

The digitization project of the Dead Sea Scrolls (DSS) was first conceived as yet another conservation effort to preserve the scrolls. The Israel Antiquities Authority (IAA) set out to develop a non-invasive monitoring methodology of their physical state, based on multi-spectral images. Once the IAA realized that they were going to create the best possible images to date and since all of the scrolls have been formally published, they decided to conduct a comprehensive digitization project in addition to developing a monitoring system. The IAA would image all of the DSS, including thousands of fragments, add their metadata, and put everything online, making it available to the public and the scholarly world alike in a way never before imagined.

The involvement of the IAA in the management, publication, documentation, and preservation of the DSS began with the organization's establishment in 1990. The IAA appointed an advisory committee of scholars to speed up the long overdue publication of the hundreds of DSS manuscripts. It also established a state-of-the-art laboratory dedicated solely to the conservation and preservation of the DSS. Besides the renowned, well-preserved scrolls from Qumran Caves 1 and 11, there are thousands of scroll fragments, the majority of which were retrieved from Qumran Cave 4, that belong to about a thousand manuscripts (Figs. 1–2).

The need of a dedicated conservation laboratory for the DSS arose because of their poor state of preservation. Beginning in 1947 and throughout the 1950s and 1960s, these 2,000-year-old manuscripts were discovered and retrieved from caves in the Judean Desert, in which they had been hidden, subsequently disturbing the environmental stability which had ensured their preservation for centuries.

Once retrieved from the caves, the scholars appointed to study them spread the thousands of fragments on long trestle tables in an effort to sort them out and ascribe them to different manuscripts. Every two pieces or more that matched were joined together with pressure sensitive tape. The joined fragments believed to belong to the same manuscript were then encased within glass plates. The stages of compilation and assembly of these plates were documented with infrared photographs (Figs. 3–4).

In the mid-1960s, the British Museum sent a conservator to prepare a number of the DSS for exhibition. The conservator was the first to remark that the pressure of the glass plates and the pressure sensitive tape were

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FIG. 1
An aerial view of the Qumran caves, from the east. (Courtesy of D. Tal, Albatross.)

causing damage to the scrolls and that the tape residue had penetrated the parchment and papyrus, resulting in their disintegration (V. Faulkes, unpublished notes). Just like scholars in the 1950s, the British conservator did what she knew best and employed British Museum leather dressing. Unfortunately, this caused further damage to the scrolls.

In the 1970s, yet another intervention was carried out by the Israel Museum in Jerusalem. Perspex glue and rice paper were applied to the scroll fragments and unfortunately caused some additional and, at times, irreversible damage to the DSS.

Finally, in 1991, the IAA established a designated conservation laboratory on the premises of the IAA in

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FIG. 2
A view of Qumran Cave 11. (Photo by A. E. Killebrew.)

FIG. 3
The Dead Sea Scrolls Scrollery in the 1950s with the taped scroll fragments arranged in plates on trestle tables. (Photo by N. Albina. Courtesy of the IAA.)

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FIG. 4
Najib Alnina taking infrared photographs of the scroll fragments in the 1950s. (Courtesy of the IAA.)

Jerusalem, to treat and maintain the scrolls, attempting to prevent further deterioration. The establishment of this facility was assisted by E. Boyd-Alkalay, the leading Israeli expert in paper and parchment conservation, as well as by an international team of world experts in the field of manuscript conservation and preservation, who were sponsored by the Getty Conservation Institute (GCI; Quandt, Stiber and Stanley Price 1993). Since then, five conservators, Lena Libman, Tanya Bitler, Tanya Treiger, Asia Vexler, and Yana Frumkin, have been recruited and trained to care for these extremely challenging manuscripts. A work protocol was drawn up, and a new era in the handling and managing of the scrolls began (Fig. 5).

The GCI also advised on the building of a climate-controlled storeroom to house the scrolls, where humidity and temperature would be monitored, and on a designated climate controlled storage facility to preserve the infrared negatives of the 1950s and 1960s, which are almost as invaluable as the scrolls. These infrared photographs reflect the state of the scrolls as they were found over 60 years ago, before the various interventions took place (Fig. 6).

One of the first undertakings of the team was a comprehensive survey of the current state of preservation of the scroll fragments. Later, the survey was expanded to include the eight scrolls in the Shrine of the Book, parts of which are exhibited at all times and most of which subsequently underwent treatment in the IAA DSS conservation lab as well (Boyd-Alkalay and Libman 1996).

Following the survey, the IAA conservators began the lengthy and ongoing treatment of the thousands of fragile manuscript fragments with the best-known, worldwide conservation procedures, ensuring that the preservation methods were reversible, to prevent any further inadvertent damage. This includes addressing the damage caused unknowingly by the previous interventions of the 1950s, 1960s, and 1970s. When possible, the pressure sensitive tape and other adhesive materials are removed and replaced by materials currently accepted in the field of conservation (Fig. 7; Boyd-Alkaly and Libman 1997).

As access to the DSS grew, worldwide interest created a demand for their exhibition. The IAA began to exhibit the scrolls in the mid-1990s. The first venue was the US Library of Congress. Its Preservation Directorate aided the IAA in devising capsules in which the travelling scrolls were encased to ensure their climatic stability during transportation and exhibition. Each venue is required to provide climate-controlled showcases and monitor light exposure. Also, after three moths of exhibition, the DSS must "rest" for several years (Figs. 8–9).

The Dead Sea Scrolls Digitization Project

The conservation and preservation of the scrolls is a continual process due to their extreme brittleness and the need to make use of the most up-to-date, state-of-the-art conservation methods. After 20 years of extensive work, the IAA decided to reassess its own conservation efforts and address some unresolved issues. To this end, the IAA began to collaborate with the Italian Ministry for Cultural Heritage and Activities and the Institute of the Pathology of the Book in Rome.

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FIG. 5
The conservation laboratory as it looks today at the IAA's premises in Jerusalem.
(Photo by Shai Halevi. Courtesy of the IAA.)

This collaboration was led by Dr. Alessandro Bianchi from the Italian Central Institute for Restoration. Subsequently, an international group of experts, led by Doris Hamburg, director of Preservation Programs at the National Archives and Records Administration in the US, came to Israel for a reassessment workshop (Hamburg et al. 2014).

The IAA also consulted with Professor Stephen Weiner, a specialist in biomineralization and microarchaeology from the Weizmann Institute of Science in Rehovot, Israel, who was the first to suggest the use of spectral imaging for monitoring the well being of the scrolls. Imaging has been a mainstay of textual study for decades. There are two possible goals for the imaging of texts—scholarly and scientific. Imaging for scholarly purposes is concerned with the legibility of texts that have become unreadable due to damage caused by age, environment, and handling. Imaging for scientific purposes entails the use of images to monitor the physical state of deteriorated texts. Thus, the digitization project began as yet another conservation effort.

Following Prof. Weiner's advice, the IAA approached Dr. Greg Bearman, then a principal scientist at the Jet Propulsion Laboratory at the California Institute of Technology in the US and an expert in spectral imaging. Dr. Bearman had previously experimented with spectral imaging in the mid-1990s with a few DSS fragments in an attempt to aid in their decipherment (Bearman and Spiro 1996).

During the celebration of the 60th anniversary of the discovery of the DSS in November 2007, the IAA convened an international committee of experts from Israel and abroad to evaluate the most advanced imaging technologies available as well as the leading programs for the management of large databases. The committee recommended the initiation of a large-scale digitization project, including the development of a monitoring system for the DSS, and the creation of high-quality color and advanced near-infrared images. Given that all of the DSS have been published, the IAA made it a priority to upload the digitized scroll images online, along with their metadata, transcriptions, translations, and bibliography, finally allowing free access to the scrolls by the public and scholars alike.

In August 2008, the IAA set up a designated studio and led a pilot project, under the direction of Dr. Bearman

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FIG. 6
The IAA climate-controlled storage vault for the DSS. (Photo by S. Halevi. Courtesy of the IAA.)

and Simon Tanner, director of King's Digital Consultancy Services in King's College London. As a result of this testing of equipment and methods, it was decided that:

- images would be captured at 600 dots per inch or higher;
- all fragments would be shot at a fixed height for consistency; and
- images would be in 48-RGB for color and 16-bit grayscale for infrared imaging.[1]

Following the pilot project, the IAA set out to raise the funds necessary for the imaging project. But, by the time the IAA was ready to commit to the project, a new spectral imaging system was suggested: the MegaVision system. It combines the creation of high-quality color images and advanced near-infrared images in a single imaging station. The IAA team worked with MegaVision for over a year to develop quantitative calibration methods and to demonstrate that the system would meet the preservation needs of the DSS. In addition, its "best possible images" would also improve the legibility of the texts, thus opening new horizons in scholarly research.

In January 2011, the digitization project began with the high-resolution scanning of all the infrared negatives from the 1950s–1960s, as well as all other negatives taken by the IAA to date. About 5,000 negatives and transparencies were scanned at 800 pixels per inch, using the highest quality optical lenses. As a result, images of the DSS can be enlarged to three times their original size, without losing any information and no pixilation (Fig. 10).

In July 2011, MegaVision informed the IAA that the system, which was assembled especially for the DSS, was ready. The Santa Barbara Museum of Art in California kindly hosted a final pilot for the scrolls. In the allotted space, an exact mock-up of the IAA studio was set up. For three full days, images were taken, data analyzed, and work procedures practiced. The system was then dismantled and finetuned for delivery.

In August 2011, Ken Boydston, the owner of MegaVision and the developer of the system, Dr. Wiliam Christens-Barry, creator of the LED multispectral lighting technology, and Dr. Bearman, now an IAA consultant for imaging technologies, came to Israel to mount the system in the designated studio. Two photographers, Yair Medina and Shai Halevi, of Jerusalem Art Graphics were chosen to operate the system and joined the team for two intensive weeks of set-up and training (Fig. 11).

A work procedure was formulated, whereby the plates of the scroll fragments were first prepared for imaging by the IAA conservators.[2] Then, the plate was imaged in a designated workstation for which the team tailored an automatic system to read the image and give every fragment a unique number, which enabled the integration of each fragment number with the plate's data, drawn from the IAA State Collections database and uploaded to the MegaVision system in preparation for the imaging (Fig. 12).

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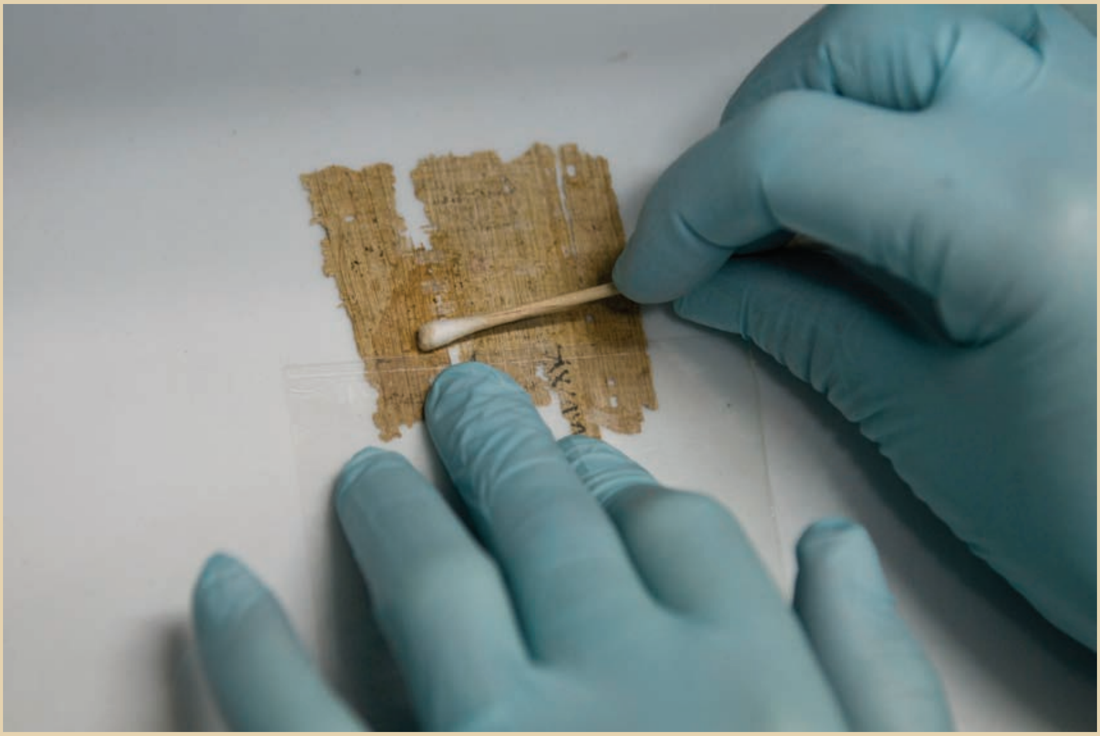

FIG. 7
The careful removal of residue left from the pressure-sensitive tape from the 1950s with a cotton swab from a papyrus fragment. (Photo by S. Halevi. Courtesy of the IAA.)

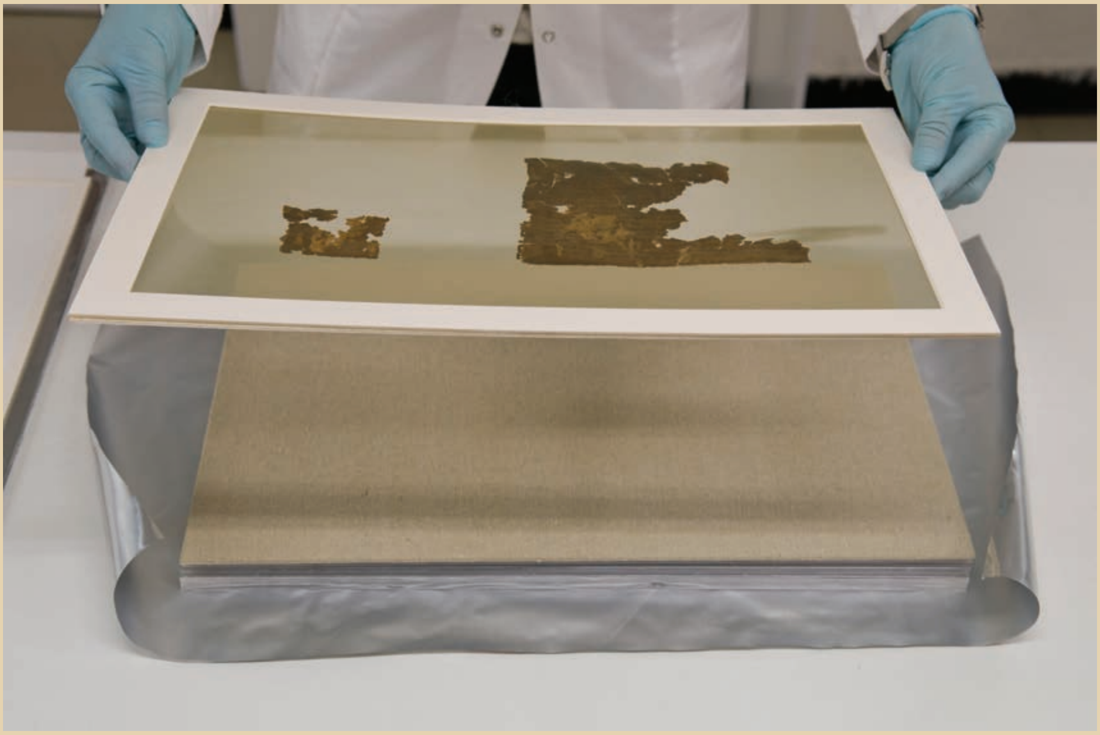

FIG. 8
An IAA conservator preparing a scroll fragment for exhibition. (Photo by S. Halevi. Courtesy of the IAA.)

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FIG. 9
The DSS in their current climate-controlled showcases at a DSS exhibition in New York. (Photo by M. Peyton. Courtesy of the IAA.)

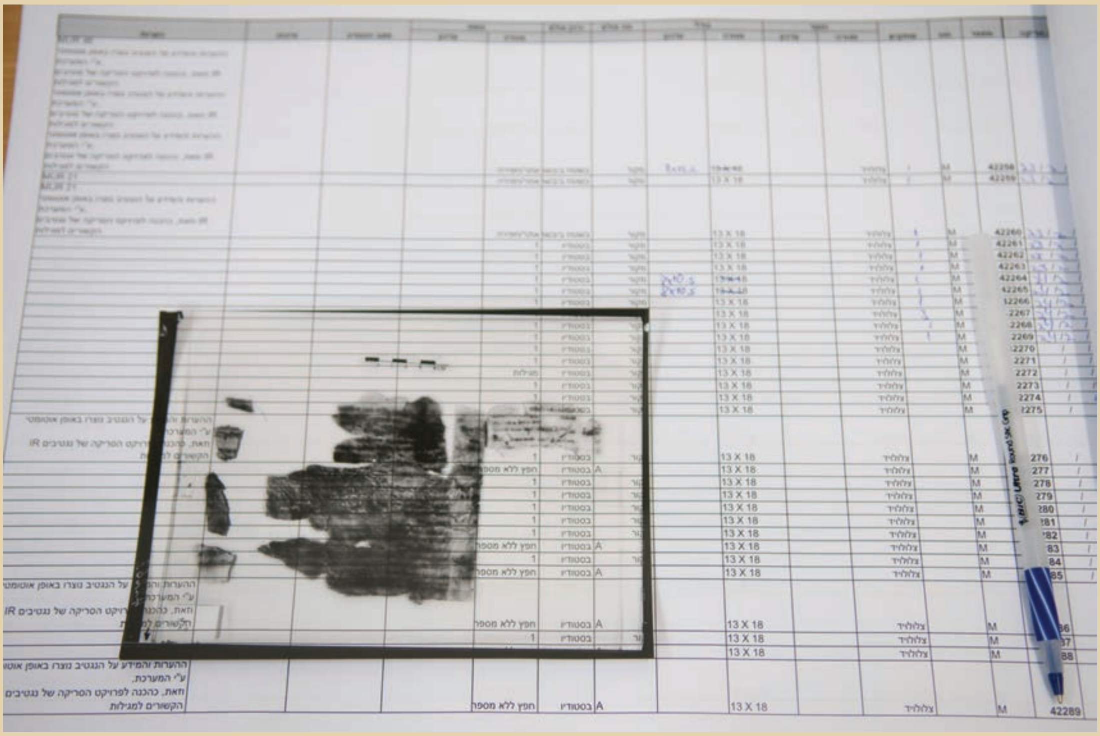

FIG. 10
A negative of the DSS that was scanned for the digitization project. (Photo by S. Halevi. Courtesy of the IAA.)

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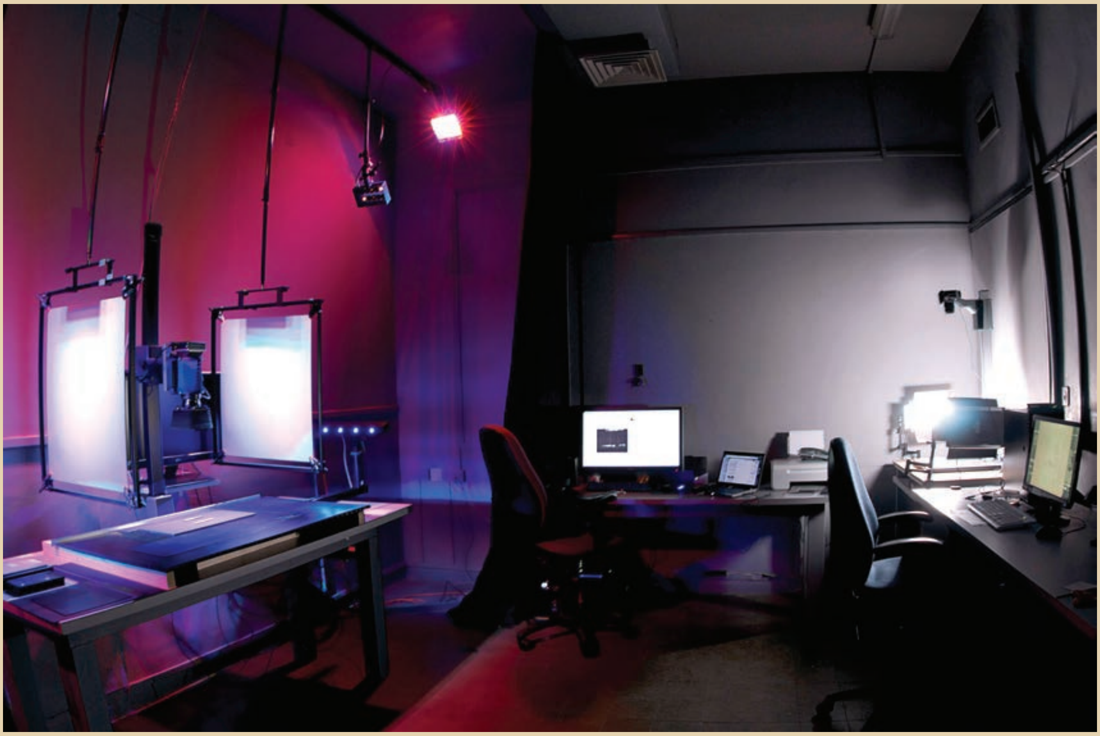

FIG. 11
The MegaVision imaging system. (Photo by S. Halevi. Courtesy of the IAA.)

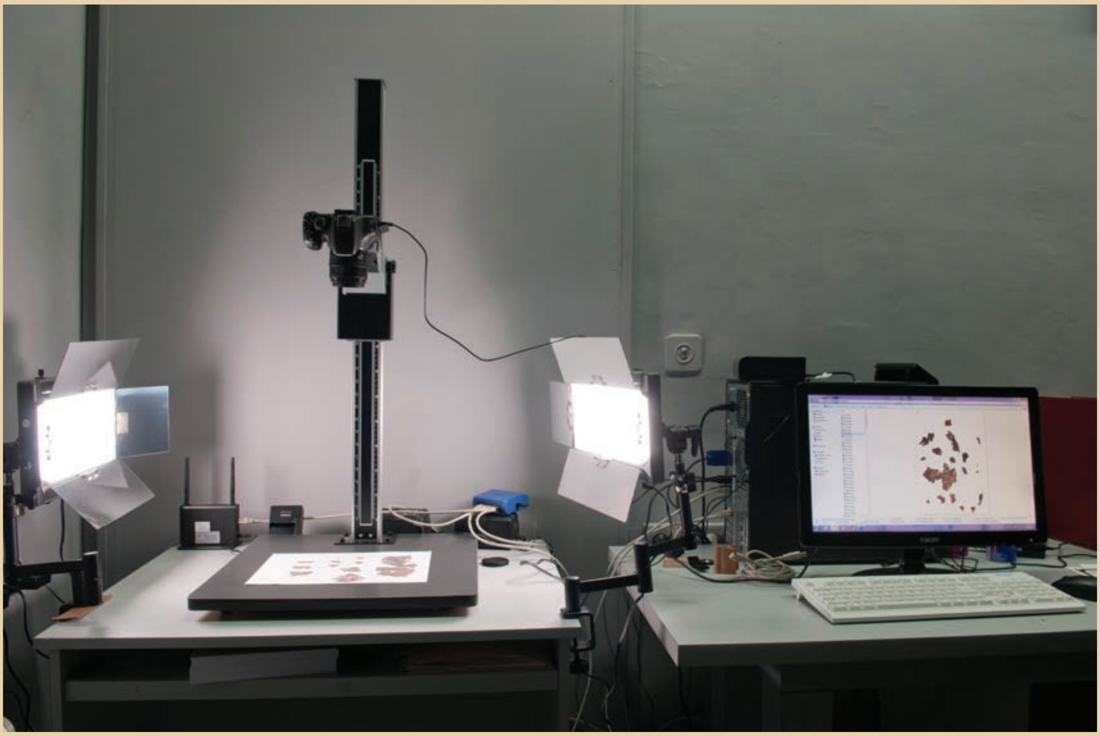

FIG. 12
The designated workstation for numbering the scroll fragments. (Photo by S. Halevi. Courtesy of the IAA.)

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The Imaging System

There are many ways to obtain spectral imaging data—wavelength scanning, image scanning, interferometry, and even methods that obtain the spectral data all at once (Bearman and Levenson 2003). Technology was selected to allow for conservation monitoring and high-resolution color and near-infrared images of the DSS.

The team decided on spectral illumination with narrow-band LEDs coupled with a 39-megapixel monochrome digital camera. The 12 high-power LEDs provide more than enough light when imaging a large field of view (approximately 5 ft by 7 in).[3] Every fragment was imaged on both the recto and verso in 28 exposures, creating a file of 56 monochrome exposures per fragment. The system then generated a 57th file of a color image combining all visible wavelengths. The resolution of the files is 1,215 pixels per inch at a 1:1 ratio, capturing approximately 4 gigabytes of information per fragment. Since the field of view was fixed and relatively small, many of the fragments underwent tiling and stitching (e.g., Plate 978 of 11QPsalms[a], which is made up of 22 tiles [Fig. 13]).

The four panels of LED lights were arrayed with two panels on each side, one with visible LEDs and the other with near-infrared. Plastic sheet diffusers were hung between the LED panels and the copy-stand base that spread the illumination pool across the camera field of view and reduced hot spots. To prevent the illumination pool from moving, the LED panels were attached to the ceiling and the camera stand was bolted to the table, which in turn was bolted to the floor.

Given that these images were primarily created for developing a non-invasive monitoring methodology for the physical state of the scrolls, the system was calibrated daily, weekly, and monthly. The color targets also helped the system calibrate the values of each wavelength to provide high-fidelity color (ΔE76 ~ 1) for documentation and reproduction as well as the monitoring data (Fig. 14). Thus, the system's features allow for:

- Taking accurate, high-resolution color images, using the seven bands in the visible spectrum and creating a color image with a calibrated CIE mini-color checker chart from X-rite for the proper transformation matrix.
- The highest band used (924 nm) producing a high-resolution infrared image that increases legibility for scholars.
- All of the images for any one image session or spectral cube being naturally co-registered across wavelength. There are no chromatic or lateral image shifts, or refocusing. A newly designed 120-mm lens with broadband color correction across the visible and near-infrared spectra makes this natural registration possible.
- Taking low-angle raking illumination (~20°) images provides shadows and contrast that show surface topography.
- This "one-stop shopping" enables us to accomplish all of our goals with a single imaging station, increasing throughput and reducing handling.

Spectral Imaging

Imaging spectroscopy provides a spectrum for each pixel of an image; it reports on *what* (spectroscopy) is *where* (imaging). The team uses multispectral imaging, which is a version of spectral imaging. This method provides a powerful means of classifying and segmenting images along with data visualization tools. It allows the tracking of changes in the pigments of paintings and other colored objects and in text substrates, such as parchments or papyri, as well as inks. The spectrum is the physicist's tool for analyzing unique chemical compositions, allowing her to analyze and classify the scene based on spectral differences. Figure 16 is an example of reflectance spectra that also maps color into spectra since the two are intimately related (Fig. 15).

Figure 16 shows how a spectrum is acquired with imaging spectroscopy. Imagine taking *n* images of the same scene, each at a different wavelength, and stacking them up like a deck of cards. Then, stick a needle through any one pixel and plot the reflected signal against wavelength. That plot is the pixel's spectrum. These data sets are called image cubes, since they have three dimensions, (x, y, λ). In our case, we have 12 wavelength data points so the cube is approximately 5,400 by 7,200 by 12 pixels. Software is used to look for other pixels in the image with the same spectrum and classify them into bins,

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FIG. 13

A spectral image of the Psalms Scroll (11QPsalms[a]), merging the color image with the near-infrared image. (Photos by Y. Medina and S. Halevi. Courtesy of the IAA.)

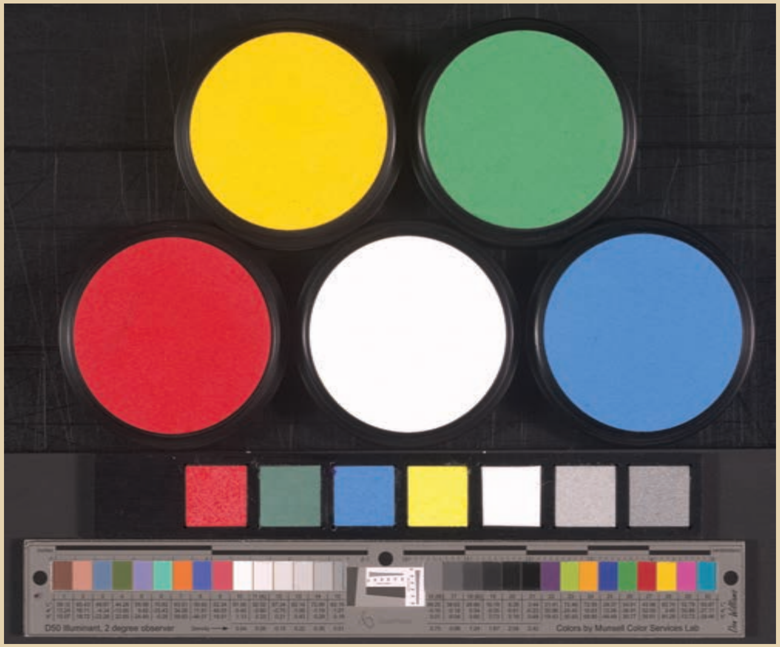

FIG. 14

An image of the three color targets used for calibration. The 2-inch circles are the NIST traceable reflectance standards. (Photo by S. Halevi. Courtesy of the IAA.)

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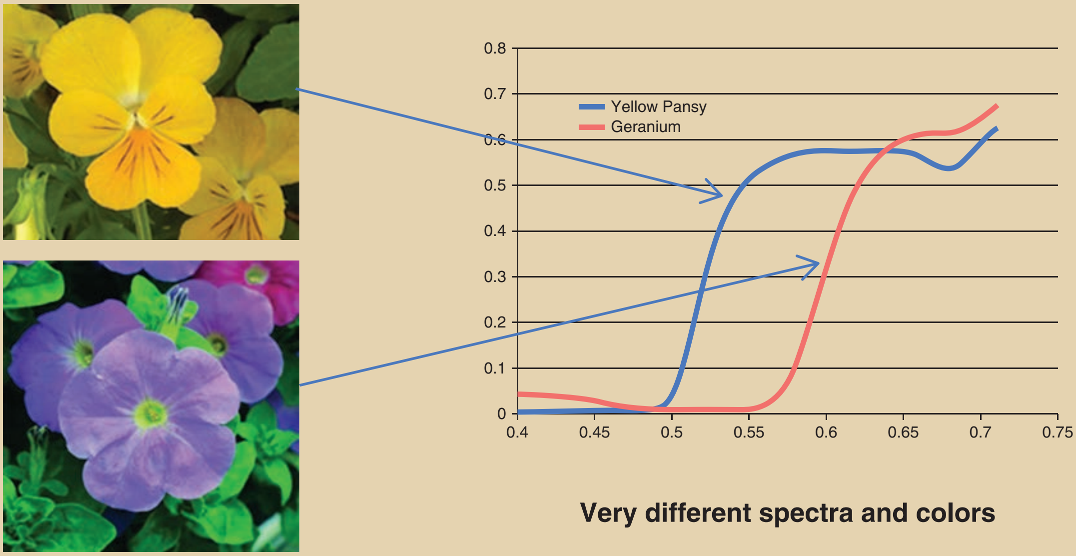

FIG. 15

Reflectance spectra of two flowers, showing how different colors are related to different spectra. The geranium is purple, containing both blue (the bump between 400–450 nm) and red, which starts to turn on around 550 nm. Remember that objects look yellow since they reflect yellow and absorb all other wavelengths. (Images and graph by G. H. Bearman.)

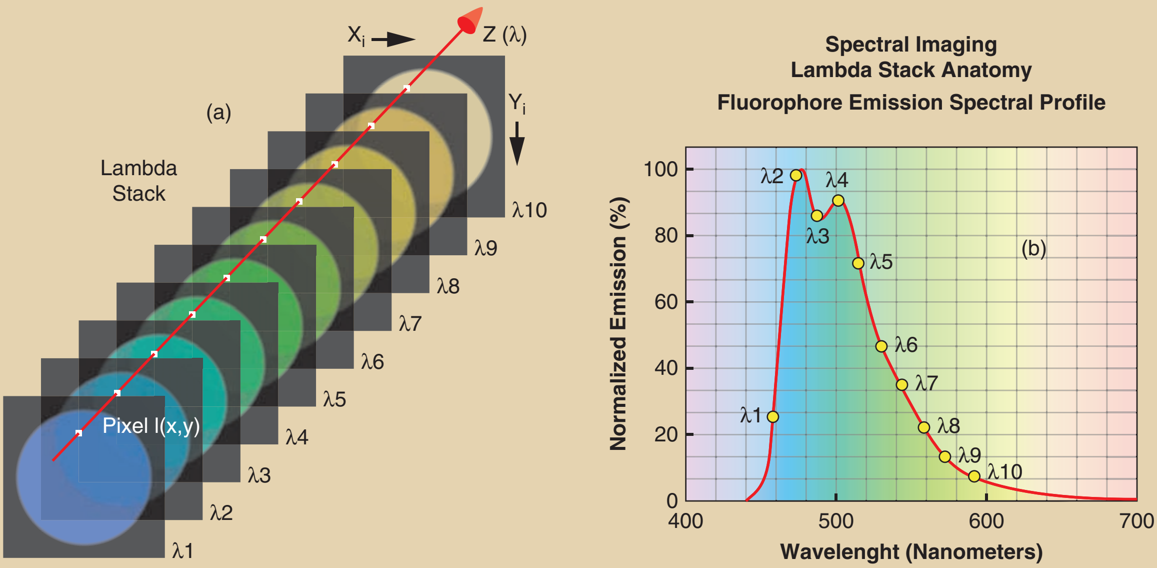

FIG. 16

A 3D spectral image cube. There are two dimensions to the cube (x, y) from the image itself and a third one from the measured wavelength. (Illustration by G. H. Bearman.)

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each containing all the pixels with the same spectra. The spectral bins can correspond to minerals, trees, or ink.

As shown in Figure 17, imaging spectroscopy is to color imaging as color imaging is to black-and-white imaging. Spectral imaging uses hundreds of "colors"—some visible, some not—rather than just the three standard colors of red, green, and blue. These extra "colors" contain a lot of information.

Spectral imaging requires careful calibration in order to be useful. Calibrated systems offer a range of advantages for research and conservation, including easy comparison of data across groups and objects;[4] development of libraries of absolute spectra of pigments, inks, papers, parchments, etc.; and use of spectral libraries for image segmentation, image processing, and comparison of objects.

Spectral Imaging of the Dead Sea Scrolls

Many of the scroll fragments are difficult to read, either completely or in degraded areas. It has long been known that near-infrared photography of ancient texts could often improve legibility. Already in the 1950s and 1960s, the photographs of the thousands of scroll fragments were taken with infrared film. (Bearman, Pfann and Spiro 1998). Experiments with spectral imaging of the DSS in 1993–1994 helped expand our understanding of the physics of near-infrared photography. It showed that legibility issues are driven entirely by contrast between the ink and parchment. In a legible text, the ink and parchment have very different reflectance spectra in the visible spectrum, where the human eye and traditional film photography work. For an illegible text, since the ink and parchment have similar reflectance spectra in the visible spectrum, the contrast between them cannot be seen with the naked eye (and regular camera); thus, the text is not readable (Bearman et al. 1993; Bearman and Spiro 1996; Bearman and Christens-Barry 2009; Chabries, Booras and Bearman 2003). However, in the near-infrared spectrum, starting typically above approximately 700 nm, the reflectance increases the contrast between the parchment and ink, making the text legible (Figs. 18–19; Bearman and Spiro 1996; Faigenbaum et al. 2012).

Monitoring reflectance is a natural way to detect changes in the fragments. The team will monitor changes in the parchment substrate, as this drives the transition from legible to illegible. The aim is to detect degradation *before* its effects become visually recognizable. While the cause of such changes is unknown, it probably reflects chemical or physical-chemical phenomena. At the same time, monitoring reflectance also looks for changes in the ink, which the automated software developed for the digitization project does just as well.

This project aims to eventually correlate observed changes with chemical or structural changes in ink, parchment collagen, or surface chemistries (Manfredi et al. 2012). It is clear from images of the scrolls that they are a heterogeneous collection—a single fragment can have both easy-to-read areas and darkened, illegible ones.

The scrolls are heterogeneous in another way, namely in cross-section. The surface and interior may have different properties and different aging processes, all proceeding at different rates. Reflectance monitoring is a surface methodology, but our research group has also begun to apply other analytical methods and spectroscopies to the scrolls, such as x-ray fluorescence, Fourier transform infrared spectroscopy, and Raman spectroscopy, in order to correlate the surface with the interior and to understand chemical and structure changes in the parchment and ink.

Conservation Monitoring

A number of DSS fragments with various conservation issues including delamination, gelatinization, and organic and non-organic residues have been selected for periodic imaging and analysis. For conservation monitoring, spectral image cubes of these fragments were taken at regular intervals and multivariate methods were employed to interrogate the data for changes over the entire image in an automated fashion (Marengo et al. 2011). Multivariate techniques, such as Principal Component Analysis (PCA) or Cluster Analysis, which are able to extract systematic information from complex datasets, have already been applied in the field of cultural heritage. Statistical Process Control can be used to

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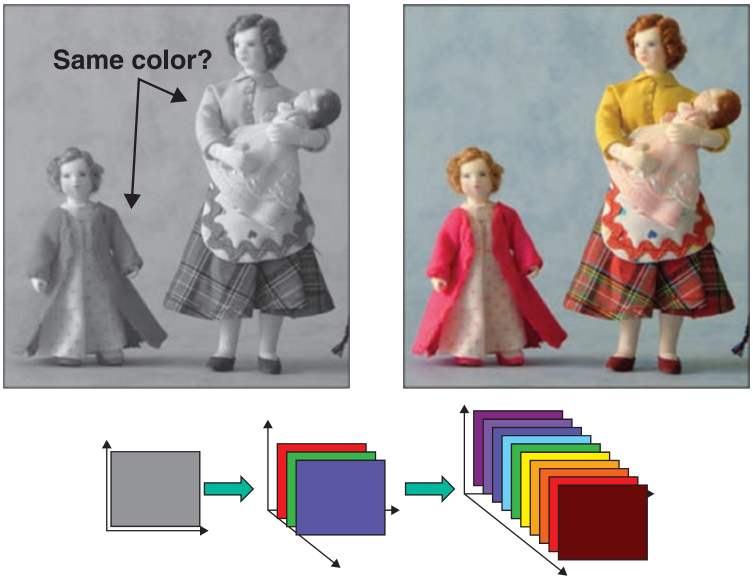

FIG. 17
In the black-and-white image on the left, it is unclear if the dresses are the same color. The color image on the right shows they are not. The bottom image shows how spectral imaging uses "colors." (Illustration by R. Levenson.)

investigate degradation processes, as has already been demonstrated in the monitoring of the conservation state of wooden objects and canvas painted with inorganic pigments and analyzed by Raman and infrared spectroscopy (Marengo et al. 2005a–b; Marengo et al. 2003). Mathematically, the team applied a PCA to the *before* data and then projected into that PCA space the *after* data, using Shewart control charts to flag pixels that have moved more than the system noise in PCA space. A pixel that will change needs attention. This method builds statistical models and control charts as if the scroll fragment were an industrial process to be monitored by quality assurance and kept under control.

It is critical to measure the natural variability (noise) of the imaging system by acquiring and measuring many multispectral images (cubes); the larger the variance, the less sensitive the method. It is known that even repeated images of the same object taken sequentially under the same conditions are not the same. A number of factors create variability or noise between images: shutter lag, shutter jitter, photon noise, electronic noise, illumination changes, and even cosmic rays. Clearly, for this method to work, the imaging system must return accurate, repeatable, and calibrated reflectance spectra. The system must be able to detect even small changes and false positives, changes must be avoided in data taken over time.

To facilitate the imaging process as much as possible, calibrated, absolute reflectance image cubes were used. The team corrected for variables such as illumination gradients and illumination intensity variation, so that each time an absolute reflectance cube was produced, the data can be meaningfully compared with our multivariate methodology. Reflectance relative to a National Institute of Standards and Technology (NIST) traceable white standard was measured and values between [0,1] were obtained.

The Spectral Data Quality

Spectral data quality and image registration were the main drivers for the success of this approach. The team looked at spectral data in two ways: measurement of the illumination LEDs' performance separately and extensive measurements of the calibrated target. The system calibration also addressed absolute reflectance (accuracy) and stability and reproducibility (i.e., even if the team had systemic errors that prevented them from hitting the calibration values, how stable and reproducible was the system [precision])? Since the team was interested in changes, reproducibility was more important.

The lighting system was very stable. Variations in the LEDs' central wavelength were approximately

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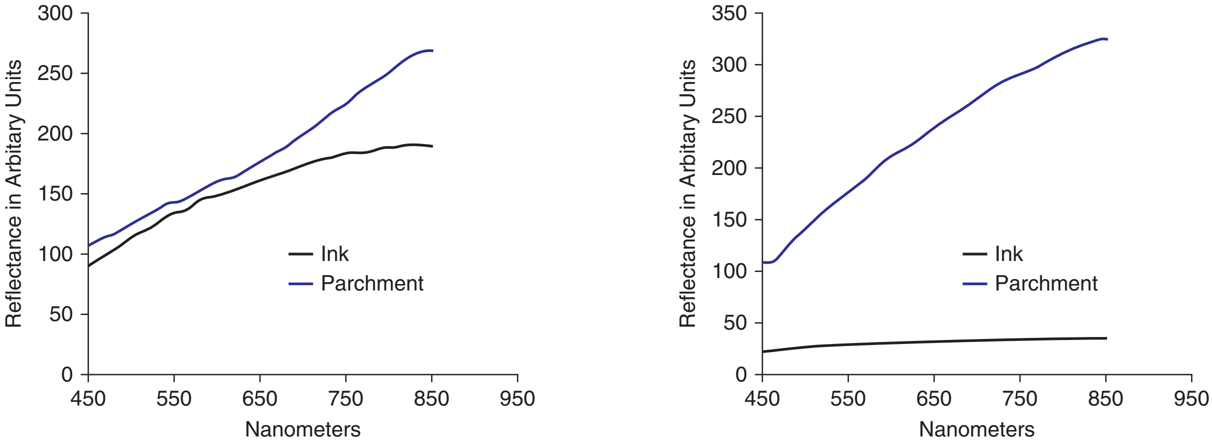

FIG. 18

Reflectance spectra of two DSS fragments. The fragment on the left is easy to read both with the eye and in a black-and-white image, while the one on the right only becomes visible in the infrared. (Graphs by G. H. Bearman.)

FIG. 19

The Ten Commandments Deuteronomy scroll (4QDeut^{n}) spectral image in near-infrared at 924 nm. (Photos by Y. Medina and S. Halevi. Courtesy of the IAA.)

0.05%, variations in the bandwidth were approximately 0.24 %, and power variations approximately 1%. Power changes were always calibrated out from a standard white. What made this approach work was that where the target was placed and how the LED panels were arranged were irrelevant. The team got the same absolute reflectance results within an error that was quantifiable. Four separate calibrated targets were used to test repeatability and absolute results. Each image had two targets in the field of view, so that the team could always extract/reproduce color and calibration data from each image.

Calibration Results

Repeatability was measured in several ways. The targets were moved around in the field of view and the reflectance for different imaging locations was measured. Figure 20 shows the ratioed reflectance for three locations of the green Labsphere target; since the values are so close, the ratios are plotted to illustrate the differences. For all of the color targets, the uncertainty in repeated measurements is approximately 0.025 while the measured absolute reflectance targets were typically ± 0.034 of the NIST standard values (not shown).

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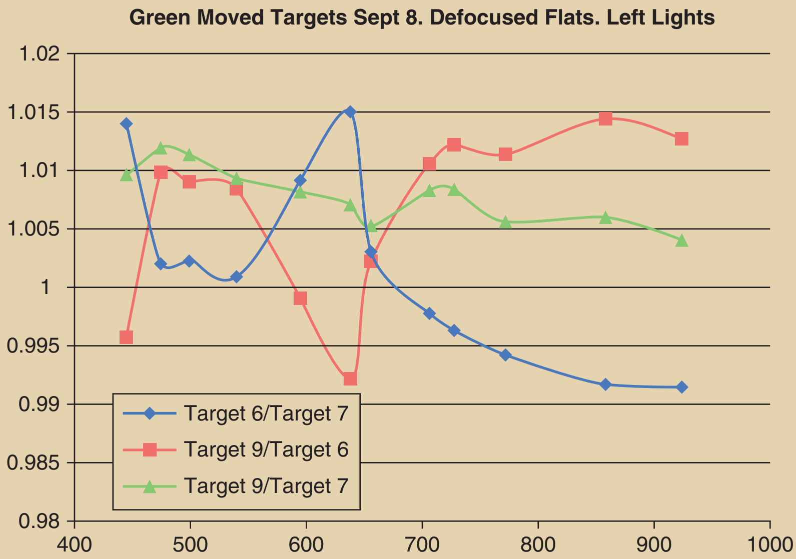

FIG. 20

Measured reflectance for three locations of a target within the field of view. In general, they are right, middle, and left across an approximately 7-inch field of view. (Graph by G. H. Bearman.)

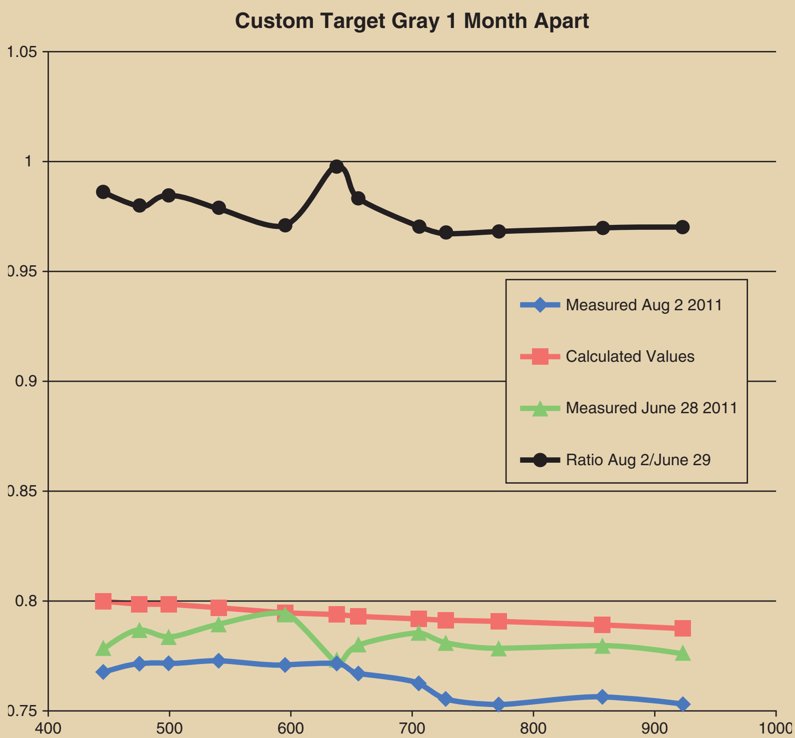

FIG. 21

Measured values of a custom grey target taken over a month apart. The system was disassembled, moved to another city, and reassembled again. (Graph by G. H. Bearman.)

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Perhaps the best way to look at the stability and reproducibilty of the system is to look at data taken on different occasions and under *very* different conditions. Figure 21 presents target data taken on June 29, 2010 and August 2, 2010 for a custom gray target. In this case, the system was taken down and reassembled in another location (another city). Although all of the components were different (LED illumination angle, resolution, focus, exposure times, etc.), the team obtained the same values within approximately 0.025 absolute reflectance units.

Color Space as Spectral Proxy

With this imaging system, the team created very high-accuracy color images, much better than with a Bayer color-filter camera, by sampling at more wavelengths (Berns 2006; Imai, Berns and Tzeng 2000). Seven visible color bands, along with the XRite color target, were used to calibrate color and create the transformation between LED image planes and color spaces, such as L*a*b* (see *Multispectral and Colorimetric Imaging System* US Patent 20110176029 A1). The measured color differences (∆E76) are about one-quarter to one-third that of a high-end, Bayer camera digital back, which is a significant improvement over current color camera performance. The measured target color data helps monitor the system's stability and quantitation since the L*a*b* color space is a weighted convolution of the spectra with the CIE XYZ values. Over the last year, the team measured weekly variations in ∆E76~0.5, which is well below the level visible to the human eye.

Image Registration

Image registration is critical because misregistered pixels between imaging sessions could show up as spectral changes, indicating variation in the fragment. The team method was first tested on an artificially aged parchment, which was forcibly changed with elevated relative humidity and temperature, and showed detection of changes via spectral imaging and control charts before they became visible (Marengo et al. 2011).

The method used required registering and comparing the same pixel for each imaging session. An extensive series of images were taken sequentially to investigate methods for image registration in order to determine registration errors, measure their effect on the sensitivity of the method, and for false positives. Since it was not possible to repeatedly locate and image a fragment on the spatial scale of a pixel (approximately 20 microns), the burden fell on the software. Registration errors showed up most easily at the edges of the fragments and text.

This method could also be applied to a host of cultural heritage objects such as paintings, illuminated manuscripts, or wood icons. Perhaps more importantly, this basic methodology is extendable to other imaging methods applied to conservation monitoring.

The DSS Digitization Project—A Collaborative Initiative

As discussed above, one of the major goals of the IAA's DSS Digitization Project is to promote and develop non-destructive means to monitor and track the well being of the scrolls. To this end, the IAA established national and international collaborations.

The development of a monitoring method based on spectral images of the scrolls was undertaken by the IAA's consultant for imaging technologies, Dr. Bearman, and the University of Eastern Piedmont, Italy, where Marcello Manfredi with his advisor, Prof. Emilio Marengo, developed the monitoring system as his PhD dissertation. Within the same collaboration, a project concerning the aging of parchment was carried out at the Preservation Directorate's Research and Testing Division of the US Library of Congress and headed by Dr. Fenella France.

The artificial aging of parchment to improve our understanding of its aging processes continues alongside with non-destructive analysis and characterization of the physical properties of the parchment and ink of the DSS, with PhD student Yonah Maor and her advisor, Prof. Zeev Aizenshtat, in a partnership with the Institute of Chemistry at The Hebrew University of Jerusalem, Israel.

A team from Tel Aviv University, Israel, headed by Nahum Dershowitz and Lior Wolf have taken steps towards computer-aided research of the DSS. They started with image binarization and are developing two ways of achieving high-quality binary images of the scrolls (Lavee 2013).

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Another major goal of the project is making the digital images of the scrolls and their content accessible online to all in a number of languages and formats. This was made possible through collaboration with the Google Research & Development Center in Israel. As stated by Shuka Dorfman, IAA General Director, "we are establishing a milestone connection between progress and the past to preserve this unique heritage for future generations" (Gaudin 2010). Ultimately, the objective is to upload all the scroll images and metadata, including transcriptions, translations, and bibliography, allowing free access to anyone in the world.

With this goal in mind, the IAA created an advisory committee of scholars that worked with the team's in-house scholars, Dr. Shani Tzoref and Oren Abelman. They work closely with IAA IT team to improve and modify the data in the IAA State Collections' database for integration into the website, based upon databases compiled by Prof. Emanuel Tov (2010).

For the bibliography, the IAA is working with The Orion Center at The Hebrew University of Jerusalem, which is developing and updating a site dedicated to the bibliography of the DSS and associated literature, including keywords and primary texts. The aim is to link the DSS images to the relevant bibliographic entries and vice-versa in order to facilitate research on the scrolls.

Following the initial launch of the Leon Levy Dead Sea Scrolls Digital Library website by Google in December 2012 (www.deadseascrolls.org.il), an updated version of the site was launched in February 2014 with 10,000 new multispectral images, improved metadata, additional manuscript descriptions, images, and a faster search engine. The IAA intends to update the site periodically by loading new spectral images and manuscript descriptions, and by revising data concerning the scroll fragments to reflect ongoing research. Eventually, transcriptions and translations of the texts as well as interactive tools for scholarly research will be added.

The Dead Sea Scrolls are a universal cultural heritage. As such, the IAA is committed to safeguarding the scrolls, preserving them for future generations, and sharing them with the public and scholarly community worldwide.

PNINA SHOR is an archaeologist who has been with the IAA throughout her career, first as a field archaeologist, then as head of the department for the treatment and conservation of artifacts. In 2010 she established and is heading the unit dedicated to the DSS.

MARCELLO MANFREDI is a researcher at the University of Piemonte Orientale in Italy. He received is PhD in chemistry sciences in 2014 and his research interests center on the development of non-invasive methods for the monitoring and analysis of cultural heritage surfaces.

GREG H. BEARMAN was a principal scientist at NASA's Jet Propulsion Laboratory at the California Institute of Technology until 2008. He is currently a consultant to the IAA on imaging technologies. He has applied a number of modern imaging technologies to cultural heritage, especially ancient texts.

EMILIO MARENGO is a professor of analytical chemistry at the University of Piemonte Orientale in Italy. His research areas span from environmental and cultural heritage chemistry to food safety analysis, proteomics, process control, experimental design, and chemometrics.

KEN BOYDSTON is president of MegaVision, which developed and installed the first professional commercial digital camera for studio use in 1990. MegaVision continues to advance the state of the art in professional, industrial, medical, and scientific digital photography. He has participated in MegaVision's technical development since its founding in 1983 and has contributed to numerous innovations and advances in the art of digital imaging.

WILLIAM A. CHRISTENS-BARRY is the founder of Equipoise Imaging, LLC, and originator of the narrowband illumination approach to the spectral imaging of manuscripts. He specializes in optical measurement, imaging, and analytical techniques and participates in many cultural heritage studies of historically important texts and objects.

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Notes

A major lead gift from the Leon Levy Foundation has enabled the IAA to embark on this unique project. Substantial funding has also been provided by the Arcadia Fund. The Yad Hanadiv Foundation, the project's constant supporters, granted the initial contribution.

1. For a comprehensive report of the results, which was sent for review to three independent experts in the field of advanced imaging technologies, see Tanner and Bearman 2008.
2. The procedure described here is still used today as the team continues to process the fragments.
3. For use of a similar system, see Easton, Christens-Barry and Knox 2011; and Easton et al. 2010. The team uses 12 bands at wavelength λ (445, 475, 499, 540, 595, 638, 656, 706, 728, 772, 858, and 925 nm).
4. This is critical for works by the same artist/scribe or texts/collections located at different venues.

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