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Digital Archiving of Civil War Graffiti for Research & Access

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Abstract

Historic properties face challenges preserving and maintaining their physical heritage, as well as digitally sharing and accessing their history in a virtual environment. They are now utilizing new advanced imaging methods to research their cultural heritage artifacts. Recent advanced imaging in historic Civil War-era houses demonstrated the integration of imaging techniques and data to support conservation of these structures and research into their history and contents. New technical systems, including the latest narrowband multispectral imaging systems and higher resolution cameras, raise major challenges in not only the integration of new technologies, but also the ability to store, manage and access large amounts of data. Integration, preservation, access and collaboration with the image data from this program requires implementation of standardized digitization and data archiving practices.

Non-Invasive Imaging Program

This research program is evaluating new methods for analyzing and preserving Civil War and post-war era materials and graffiti and making it accessible for digital research. Archiving these data for public access and interdisciplinary collaboration requires facilitation of user-friendly and cross-platform access and retrieval for the large volumes of data generated by the imaging.

This program encompassed two projects to provide narrowband multispectral imaging of the walls of two historic structures that are covered with the text and drawings of Union and Confederate soldiers during the US Civil War. Large areas of text and drawings remain intact in each house, but have suffered environmental and alteration damage. This program built on prior multispectral imaging of objects to apply similar technologies and methods to the assessment, conservation and environmental mitigation of interior surfaces with difficult to see text, drawings, paints and residues. This capitalizes on technical advances in the development of integrated multispectral imaging systems for cultural heritage research.[1] These systems have been used to provide new information from manuscripts, artwork and other objects, sometimes in conjunction with other imaging techniques such as x-ray fluorescence (XRF).[2] Applying these systems and workflows to research into walls and structures required a shift from a stable imaging system mounted on stands with horizontal portable objects below, to moving the integrated imaging system itself around in front of vertical permanent structures. It also required development of new methods for cataloguing wall regions that are compatible with metadata schemas and file naming used for catalogued collections objects with discrete features or parts.

The goal of this program is not just to assess the optimum technology, but also the most appropriate workflow and protocols needed for effective analysis and documentation of structural interiors. These include image and metadata management so conservators and scholars can store and preserve data for online collaboration and analysis. This research program is providing image data and analyses needed to:

- implement new methods for assessing and preserving interior surfaces with in-situ advanced imaging;
- identify techniques for preservation assessment and long-term monitoring, analysis and mitigation;
- demonstrate the application of new technologies to guide preservation of and research.

Historic Structures

Civil War-era Historic Blenheim in Fairfax City, Virginia, USA is a c.1859 Greek Revival-style brick structure 17 miles west of Washington, D.C. The Brandy Station, VA Graffiti House is one of the few dwellings built before the American Civil War to survive intact in a village 60 miles southwest of Washington DC. These houses are notable for the Civil War-era graffiti covering their walls.

The legibility of the graffiti on the walls varies based on how the writing dried into the original fresh uncured surface. Walls in both houses were subject to subsequent modifications, treatments and damage, similar to the broad range of conditions faced by other historic structures and objects. The graffiti includes names, drawings, names of units, and other inscriptions. These offer unique concentrations of Civil War soldier graffiti on the plaster walls, as well as years of water, earthquake and other structural damage and repairs (Fig. 1). To date these have only been available for research by visiting each location and studying the walls in person.

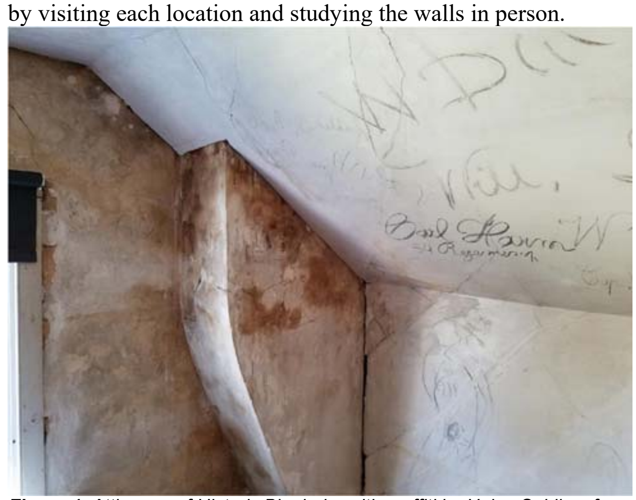

Figure 1. *Attic area of Historic Blenheim with graffiti by Union Soldiers from the Civil War and environmental damage to the walls and chimneys.*

Narrowband Multispectral Imaging

The two Civil War-era houses have varied amounts of graffiti in different areas – similar to approximately 45 other houses of this era with still extant graffiti. Historic Blenheim has extensive graffiti, plaster repairs and damage in eight rooms on two floors and the three attic areas. The Brandy Station Graffiti House has extensive graffiti covering 10 walls in three adjacent rooms. Imaging of each required balancing schedule, cost and performance goals to meet the requirements of the funding stakeholders. R.B. Toth Associates LLC conducted the imaging in both structures in collaboration with staff from each house. M.B. Toth could safely access both structures via car, so both organizations were able to sponsor this nearby program while observing COVID travel and health restrictions.

Conservators and staff identified and prioritized key regions of interest (ROI) on the walls of Historic Blenheim based on the preservation and scholarly interest. About 45 of these ROI were imaged on 15-19, 21 and 23 December 2020 (First Floor and Attic) and 9-11 February 2021 (Second Floor, following conservation removal of wallpaper). This multispectral imaging at over 300 pixels/inch (ppi) supported conservation research and scholarship under a National Park Service, National Center for Preservation, Technology, and Training (NCPTT), Preservation Technology and Training Grant. This followed experimental multispectral imaging of ROI on the First Floor on 19 June 2019.[3]

Survey multispectral imaging of the Brandy Station Graffiti House took place on 1 and 2 April 2021, with funding from the Brandy Station Foundation. The limited funding, a shorter schedule and less graffiti-covered wall area with larger drawings and text dictated imaging original wall areas at a lower resolution of 150 ppi.

In both houses a commercial system with an achromatic Phase One 100 megapixel (MP) iXG camera captured multispectral images illuminated by light emitting diodes (LEDs) in 16 narrowband wavelengths. The Phase One camera and filter wheel were set up in each room on a 3-degree of motion tripod with two illuminators on adjustable light stands on either side of the camera (Fig. 2). The system was controlled from a USB tethered Windows 10 laptop, where the data was stored. The Equipoise Imaging LED light panels were placed approximately 30-45 inches on each side of the camera axis at a wall incidence angle approximately 45º from the optical path, but distances varied based on location and adjoining walls.

Figure 2. Multispectral imaging setup in Brandy Station Graffiti House with 100MP camera, filter and two narrowband light panels

Space limitations sometimes required manually positioning an illumination panel above the camera, and in some locations (e.g. in a closet area), only one compact illumination panel could fit in the available space, with exposures adjusted accordingly. Imaging took place in darkened rooms with windows covered with aluminium foil to avoid broadband illumination. All images were taken with a constant aperture of f/8 to ensure that the ROI was in focus and sharp images were produced. The ISO value was adjusted between 200 and 800 to improve efficiency while balancing the acceptable single-to-noise (S/N) ratio in captured images.

Focus was established with broadband illumination provided by the ambient light in the imaging room or the green LED emission at the midrange of the wavelengths. Once established, focus was left unchanged during capture of a full spectral image stack (365, 385, 405, 420, 445, 475, 505, 535, 590, 635, 660, 700, 735, 780, 870, 940 nm) to eliminate magnification changes and mis-registration that could occur due to focal adjustments. Exposure durations for each wavelength were set in the controlling software to ensure the image histogram was adequately filled for a good S/N ratio. Images contain a reference ruler and standard color chart affixed to the lower left of each scene whenever surfaces allowed, with the ROI designation affixed to the ruler for quality control and image verification.

To capture fluorescence from the walls, images were filtered with long-pass filters that pass wavelengths longer than 515 nanometers (nm)(green and above) and 590 nm (red and above) mounted a minimal distance directly in front of the camera lens. This provided good visualization and analysis of the characteristic spectra of substrate, colorant, and contaminant materials.

Accurately designating the location of ROIs on specific walls required establishment of a spatial standard, especially since neither house is aligned to cardinal compass points. A lettering and numbering system was developed to designate image locations and facilitate image planning and analysis with a standardized spatial reference system for both houses (Fig. 3). This system was used for each structure to create standardized image filenames and location metadata that offered immediate reference to specific wall areas.[4]

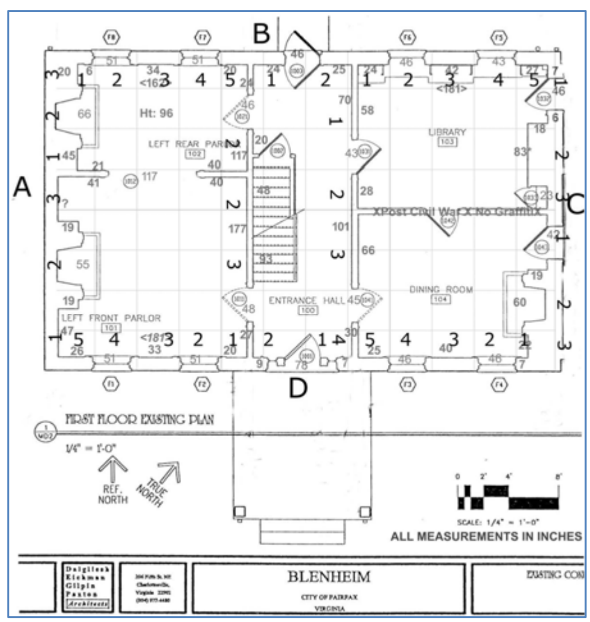

Figure 3. Historic Blenheim First Floor spatial standard used to alphanumerically designate regions of interest

Advanced spectral imaging of ROIs is being combined with Fiber Optic Reflectance Spectroscopy and other analysis of specific points in Historic Blenheim to assess surface responses to specific wavelengths of light that can be correlated with the 16 wavelengths captured in the images. The imaging with the current generation of LEDs and camera also demonstrated the ability to conduct narrowband imaging in low ambient light levels with sufficient spectral differentiation and response for research and analysis, in addition to imaging near-total darkness.

Data Management and Open Access

The Historic Blenheim and Brandy Station graffiti data sets comprise a core content set of registered digital images of each ROI imaged. They contain folders with multispectral image data from a stack of 21 images of each wall ROI, with each image captured using a different illumination and/or filter. The Historic Blenheim data set comprises 120 image stacks with 8,744 files that total 477 Gigabytes of data. The Brandy Station data set comprises 27 image stacks that total approximately 100 Gigabytes of data.

All data are being stored in a George Mason University (GMU) digital archive in accordance with accepted data management and archiving standards.[5] All image data, metadata and documentation will be made accessible online from publicly available servers. This will offer a free and open public resource under Creative Commons 0 "No Rights Reserved" license for download and use. All the multispectral image data are being hosted as flat files that will be linked from the organizational websites. The image data are standardized to support transfer to institutional online repositories.[6]

For each region of interest, the data set provides captured registered TIFF images with metadata, as well as digitally processed images of key ROIs. These were converted to 16-bit TIFF format and transferred to webservers at the Roy Rosenzweig Center for History and New Media (RRCHNM) at George Mason University for storage and access, along with thumbnail jpeg images. These images are being retained by RRCHNM as archival images for hosting online, and can be viewed with most image viewers.

These images were converted from the Phase One proprietary .IIQ format to 16-bit .TIF format with Phase One's Capture One Software and the "linear scientific" curve. Images were not flattened due to the ever-changing positioning of the camera and lights for each ROI, preventing capture of a white sheet image for each setup.

The core data set includes:

Captured Image data. These are "stacks" of approximately 20 individual images, each captured at a different wavelength of light and/or filter. Each stack and its accompanying metadata in a json file is contained in a folder named for the ROI.

Computer Processed images. These images have been digitally produced through the application of computer algorithms to combine and enhance captured images to enhance visibility of manuscripts artifacts and text. All processed images are TIFF or jpeg images, or AVI video clips of a series of processed images.

Each multispectral capture image folder includes descriptive metadata in a json file giving details of the image capture for the project, scene and stack of images and processing methods used to generate integrated images from the various captured images. The metadata are included in json files with each captured stack, as well as a summary json file for all imaging on each project. These jsons can be read with any text editor. The metadata in these jsons follow the Archimedes Palimpsest Metadata Standard[7] for multispectral images, now updated as the KU Leuven Narrow Band Multi-Spectral Imaging Metadata Standard.[8]

The captured images file names are standardized with six fields plus an extension. The initial three fields are based on the spatial standard to match the short forms of the project name (House), scene name (Room), and image stack name (ROI). The fourth field consists of a three digit number, indicating the illumination light wavelength (in nanometers), plus a plus a single letter identifier for the **R**ed or **G**reen camera filter. Examples for captured images are: *Project_Scene-Stack-<wavelength and filter>_<index number>_R.tif* For the "Blenheim" NCPTT project, this yields: *Blenheim_Room-ROI-<wavelength and filter>_<index number>_R.tif*

A representative image in the Historic Blenheim front parlor (Room 101) of the wall (Wall A) to the left of the fireplace (Section 1), in an area to the top left (area a), taken with 940 nm (IR) lights with no filter, which is the 14th shot, yielding: *Blenheim_Rm101-A1a-940N_014_R.tif* Processed images are amended under this naming convention to indicate the type of processing employed.

Image files are being made available online through a local instance of the Omeka S content management system (CMS), developed at RRCHNM using a Dublin Core Metadata Element Set. This required a metadata schema for describing vertical objects like graffiti on walls, an endeavour for which there are currently no accepted international standards. At a minimum, the schema developed for this project needed to: define the spatial relationship of the digital image to the wall area(s); describe the wall area and content in objective terms; detail the image content and the processes used to create it; and identify the metadata standards used to create the record. When available support permits, this schema will be published and all data will be made freely available online from the GMU server.

The Omeka S in development at https://historicblenheim.org divides the content by floor, room and section (Fig. 4). While each image is available separately, they are grouped by type in sets on this site. Each set is named by the room, region, section and type of image, either the raw capture images or processed ones. This allows a researcher to quickly access imagery for a specific area of interest in the house or to search a specific type of image. To continue testing the schema, the titles and image names all reflect the previously discussed conventions for consistency across all the platforms. Transferring the files from a Google drive set of files highlighted the requirement for standardization, as the same image could be stored in three to five folders for initial access, creating redundancy when downloaded. The current metadata associated with the images is rights and production based, using the Dublin Core Metadata set.

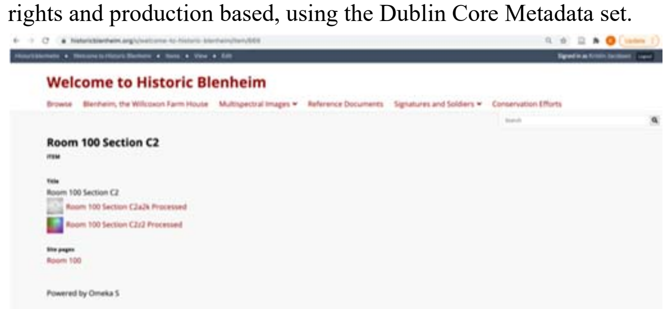

Figure 4. *Historic Blenheim images hosted by GMU with Omeka S CMS*

Image Processing and Research Support

Digital image processing was used during and following imaging to reveal and enhance any no longer visible or minimally visible texts and residues. This was the first step in the technical assessment of and research into the ROIs. During this digital processing, the imaging team worked in collaboration with scholars and conservators to try to reveal any features that may have resulted from the initial production of the images from regions of interest and text. They also highlighted areas of interest to support the conservation and preservation of the structures.

A semi-automated "Paleo" ImageJ tool developed by Bill Christens-Barry of Equipoise Imaging LLC ingested image stacks and performed normalization and statistical processing of the stack. This used principal components analysis (PCA), a statistical technique to help identify and distinguish unique features in image stacks. This aided visual recognition of faint content that would otherwise be undetected. PCA was used to create monochrome and false color "pseudocolor" output images that could provide additional insight into features on the Interior walls (Fig. 5).

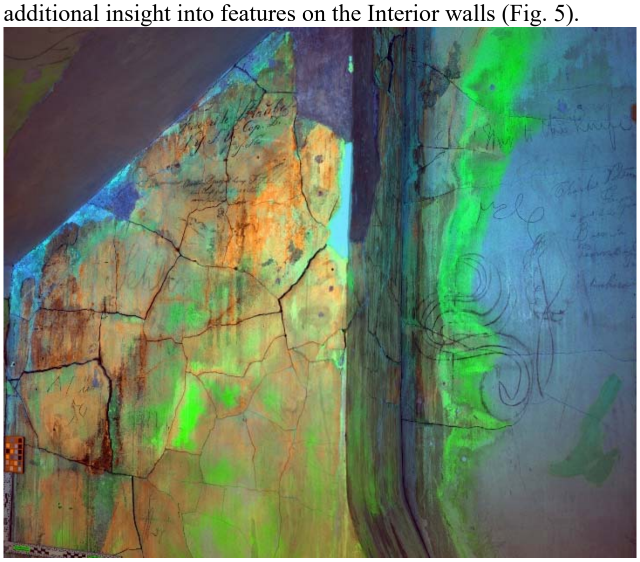

***Figure 5**. PCA pseudocolor image of water-damaged section of attic wall with graffiti in Historic Blenheim produced with semi-automated digital processing*

Technology Assessment

The technology, data and methodologies from this program supports the preservation and study of Civil War-era and subsequent historical structures by providing the preservation and scholarly communities with new technologies and methodologies for in-situ materials research and analysis. The advanced narrowband multispectral imaging produced standardized multispectral images with the data structure needed to support digital preservation and access of all the images. With publication of the metadata schema and open access to all the data, the program will be able to contribute to the standardization of metadata for vertical cultural heritage like graffiti, murals and archeology materials.

The compact LED illumination panels with integrated diffusers and the robust camera and filter wheel allowed initial setup of the full system in about an hour and a half. A key challenge in imaging wall structures with a system adapted from one normally used on a stable mount for imaging portable objects was the transition of the tripod-mounted camera and filter wheel and the two illumination modules on their stands from region to region. This required movement of the entire mounted system for each image, which took significantly more time than handling objects below a permanently set up system. Not only did the system components have to be moved about on their supporting hardware, but about a dozen data, control and power cables also had to be moved about and kept plugged in. This required shutting down the system regularly after a series of moves to untangle cables and check connections, which despite best efforts could become unplugged, prompting a "system timing error" and thorough check of all plugs. A mobile rig with more fully integrated camera, filters, illumination panels into a single structure would help refine and speed up this process.

Another issue was the need to mount the system at heights from 12-80 inches above the floor to image upper or lower areas of walls. At times this required mounting about 15 pounds of expensive optical and illumination equipment at a significant height above the floor (fortunately the imaging operator is 80 inches/2 meters tall). A flexible mount allowing movement of the imaging system vertically and laterally as a unit would offer greater structural integrity and more robust connectivity for rapid movement and imaging at different heights and locations.

The fragility of the wall surfaces made it difficult to properly mount the ruler and standard color chart in all images. The latter was important to provide a standard for comparison of different plasters, residues and carbon writing media from different ROIs and images.

The latest generation of compact LED illumination panels and 100 MP camera sensor offered the ability to image from close up as well as greater standoff distances with good illumination of the entire scene. Imaging with the light panels more than about a meter away from the wall resulted in some exposure drop-off at the edge of the scene in IR images. This offered flexibility for good illumination of large areas when dictated by the size and height of walls. The large wall areas also required a performance/schedule trade-off depending on the subject matter and time (and funding) available. In an optimum situation with plenty of funding and time, images with a resolution of at least about 300 ppi seem to best support scholarship (Fig. 6), but some small scripts could be more difficult to discern in lower resolutions. The latest generation of 150 MP camera sensors could help alleviate this issue by providing higher resolution images of the same imaging area, although with larger data sets.

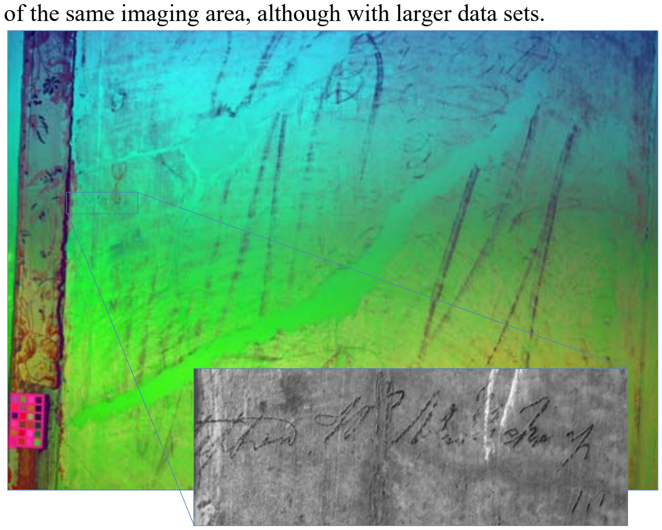

***Figure 6**. PCA processed greyscales image of Stephen W. Millichamp signature under much larger pseudocolor image of "Welte" signature in Room 102 Wall C*

Research Utility

The images produced during this program provided additional information for both conservation and scholarship, in particular in shorter and longer wavelengths than viewed by the human eye. The captured and processed images proved useful for both scholarship and conservation at different resolutions, although the ability to read smaller scripts benefitted from higher resolution. Scholars preferred higher resolution and the longer wavelength and processed images to better see text and drawings. They could then correlate the names they could now read in the images with other archival records available about the soldiers.[9]

Fluorescence images from the shorter UV, Violet and Blue wavelengths (365, 385, 410, 420 and 450nm) with the green (515 nm) and red (590 nm) long-pass filters gave good indications of different plasters and damage. Images captured in the IR wavelengths (740, 850 and 940 nm) provided better visibility of carbon-based writing media through surface contaminants. In many cases these captured images provided good visibility into features of interest, eliminating the need for image processing (Fig. 7).

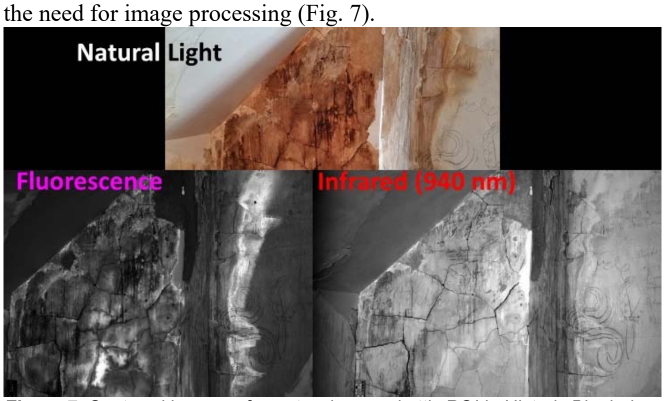

***Figure 7**. Captured images of a water-damaged attic ROI in Historic Blenheim in natural light, short wavelengths with filters, and infrared 940nm light*

Interpreting historic graffiti on historic Civil War-era house walls is challenging due to the subsequent covering of the walls with paint and wallpaper over a 130-year-period of time. The scraping of walls to remove some graffiti, earlier paint layers, and or wallpaper also has hindered the legibility of the words and images. Along with conservator-removed wallpaper and paint layers to reveal graffiti, the multispectral imaging is a valuable tool to further scrutinize the walls by taking images with both visible and non-visible light. The ability of these methods to work with a selected ROI and enhance the visibility with narrowband light imaging and digital processing supports scholarly research. It allows the scholars to heighten the legibility of letters, markings, shadows to better interpret the original graffiti. Matching these findings with soldier databases and other common drawings and images from both Civil War graffiti sites and general Civil War drawings and writings, offers scholars unique opportunities to see better what is beneath the paint.

Multispectral imaging has served as a useful tool to support the conservation of manuscripts produced from paper and parchment.[10] Thesa me technologies and techniques applied to multispectral imaging studies of inks, dyes, residues and damage in these materials apply to studying walls for preservation. Conservators looking for residues and disturbed areas seemed satisfied with lower-resolution images of broader areas. They are also challenged by the various coverings of the historical graffiti on the historic house walls. Changes in temperature on walls due to fireplace use, prolonged cold, water and earthquake damage, cracks from house settling, modern updates of plumbing and heating systems (from wood and coal fires to modern HVAC), and decorative treatments all created challenges for preservation of wall surfaces. Multispectral images offers conservators' visual analyses of the walls to better assess materials and make recommendations for further conservation treatment. Along with better understanding of chemical and paint treatment, the multispectral imaging also reveals shadows of wallpaper patterns from earlier time periods.

Multispectral imaging in both houses provides new insights for both scholars and conservators. The Brandy Station Graffiti House images offer not only the first full digital cataloguing of graffiti covered wall areas, but also more details from prior conservation treatment and overlapping text and drawings on the walls (Fig. 8). This allows researchers to better visualize details in some drawings and text, as well as plaster patches.

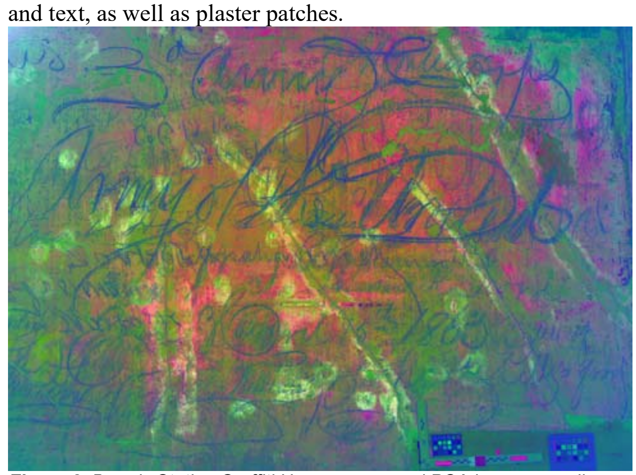

***Figure 8**. Brandy Station Graffiti House processed PCA image revealing conservation patches and better defined text on walls.*

With further research, imaging in narrowband light and other energy levels may be beneficial in revealing covered underdrawings and underpaintings on the surface of historic houses.

Conclusions

This imaging program at Historic Blenheim and the Brandy Station Graffiti House not only demonstrates the value of the multispectral imaging technology and work processes, but also the potential utility of these systems in analyzing important structures and surfaces. This includes moving the equipment up and down stairs of various widths, setting up and imaging in tight spaces, and imaging varied surfaces, such as the angled attic ceiling at Historic Blenheim and curved wall in the Brandy Station Graffiti House. Addressing the imaging and data management challenges raised during this program will enhance the study of similar structures and surfaces.

Twenty years ago, very little was known about the material characteristics of historic plaster and its fluorescence - its ability to fluoresce under short wavelengths and absorb long wavelength light that penetrates into the surface. This advanced imaging at different narrow wavelengths of light provides increased understanding of wall materials, allowing conservators and scholars to better characterize the walls and fill in their historic record. The large amounts of image data may yield even more information as digital processing technologies and computer power advance, with more people able to review the images. This public-private partnership for in-situ narrowband multispectral imaging shows promise in using the latest commercial technologies to support both scholarly research and conservation, with large amounts of image data now available for assessment and study. Advances in imaging applications for forensics, national security and medicine offer cross-disciplinary advances in technologies and methodologies that could enhance the ability to visualize features in cultural heritage objects that are not seen in natural light.

The results of this multispectral imaging and analysis provide digital resources for scholars and conservation personnel to meet a wide range of research needs. This will support development of appropriate conservation techniques for the interior walls of historic structures and scholarly research into heretofore nameless soldiers. It will build upon not only the plans, standards and practices of prior multispectral imaging projects, but also follow-on advanced imaging projects in other structures and institutions around the globe.

This multispectral imaging and research program provides more insights into the history and preservation of historic structures. The standardized multispectral data can be used to analyze the walls in comparison with other structures and standard samples. It can also support optimization of spectral analysis and potential follow-up research with additional technologies, such as XRF elemental analysis. This promotes greater participation in historic preservation programs and activities, providing new knowledge through research. Broad data access will support research into features and residues of importance for conservation and scholarship.

The narrowband multispectral imaging in Historic Blenheim and the Brandy Station Graffiti House with effective data management offers a model for the use of digital, non-invasive technology to reveal, conserve and preserve historic information on walls and surface elements impacted by a range of environmental events and human activities.

Acknowledgements

The success of this imaging program was only possible with the expertise and dedication of personnel who have devoted their time and energy to the preservation of these historic structures. Each of them contributed to these projects with their own unique skills: scholars, conservators, historians, curators, data administrators, funders, scientists, managers and others.

This imaging program relied on the dedicated support of staff and volunteers with the City of Fairfax at Historic Blenheim and the Brandy Station Foundation at Graffiti House. Civil War expert and battlefield guide Jim Anderson first realized the potential and local availability of R.B. Toth Associates' multispectral imaging to contribute to these unique visualization challenges, and put the key players in contact with each other. Dr. Bill Christens-Barry of Equipoise Imaging LLC in Ellicott City Maryland provided software and hardware for these projects.

Conservators Mary Jablonski and Stephanie M. Hoagland of Jablonski Building Conservation, Inc. not only provided invaluable input about preservation issues, but also scheduled the second floor wallpaper removal in time to allow imaging of the newly revealed wall areas. Research and open access was only possible with the support of the City of Fairfax and Brandy Station Foundation. City of Fairfax Mayor David L. Meyer, Office of Historic Resources Director Susan Inskeep Gray, and other staff and volunteers supported the Historic Blenheim project.

With George Mason University's data management and planning supported by God's Will Katchoua, these data can all be safely digitally "preserved" for future online access. This imaging program was made possible with the financial support of the National Park Service NCPTT and its Grant P20AP00313, the City of Fairfax, and the Brandy Station Foundation.

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