National Leadership Grants for Museums

Sample Application MG-249353-OMS-21

Metropolitan Museum of Art

Amount awarded by IMLS:	$647,000
Amount of cost share:	$255,626

The project description can be viewed in the IMLS Awarded Grants Search:
https://www.imls.gov/grants/awarded/mg-249353-oms-21

Attached are the following components excerpted from the original application.

- Narrative
- Schedule of Completion

When preparing an application for the next deadline be sure to follow the instructions in the most recent Notice of Funding Opportunity for the grant program and project category (if applicable) to which you are applying.

NARRATIVE

Project Justification

The Metropolitan Museum of Art (The Met) requests a $647,000 National Leadership Grant (NLG) to calibrate and benchmark commonly used tests to identify safe storage, display, and transport materials and to make results available to museums, archives, and libraries worldwide. By developing methods to contextualize and benchmark such tests, The Met will build upon the achievements of its 2016 NLG award to provide tools for collection stewards to make more informed decisions in the testing and selection of materials scientifically proven to be safe for long-term use near cultural heritage objects. A database containing harmful chemicals and the minimum amounts needed to cause damage to collections, known as "damage thresholds," will also be created and provided free to the field via the American Institute of Conservation's (AIC's) Materials Testing Wiki, an online resource containing test data and general information about materials testing.

The universal test for assessing materials for use with all cultural heritage objects by institutions of all sizes is the "Oddy test".[1,2,3,4] In this test, the prospective material is placed in a sealed jar with water and three test strips made of lead, copper, and silver. The jar is aged in an oven for 28 days, and each metal strip is evaluated for level of corrosion caused by the material in question. With most collecting institutions lacking the capacity to conduct in-house testing, the field has, until quite recently, relied on personal experience, word of mouth, material safety data sheets (MSDS), conference presentations, and the occasional publication to inform material selection. The Met's 2016 grant focused on optimization of the Oddy test and the development of a new, related, paper test appropriate for organic-based artworks.[5] The publication of test results for more than 400 materials, one of the products of that grant, served as the impetus for multiple institutions to contribute results to the AIC's Materials Testing Wiki, bringing the total number of available material tests to nearly 2,500.[6] While this has become a widely used tool for selecting materials, due to the variety of test variants and the lack of benchmarking for standardization, interpretation of results into sensible materials usage recommendations is challenging.[3,7] The project proposed herein expands the scope of that work, strengthening the integrity of multiple materials tests and facilitating the standardization of other tests for the long-term benefit of collections everywhere. This advance has the potential to affect every collection-based cultural institution across the US and world.

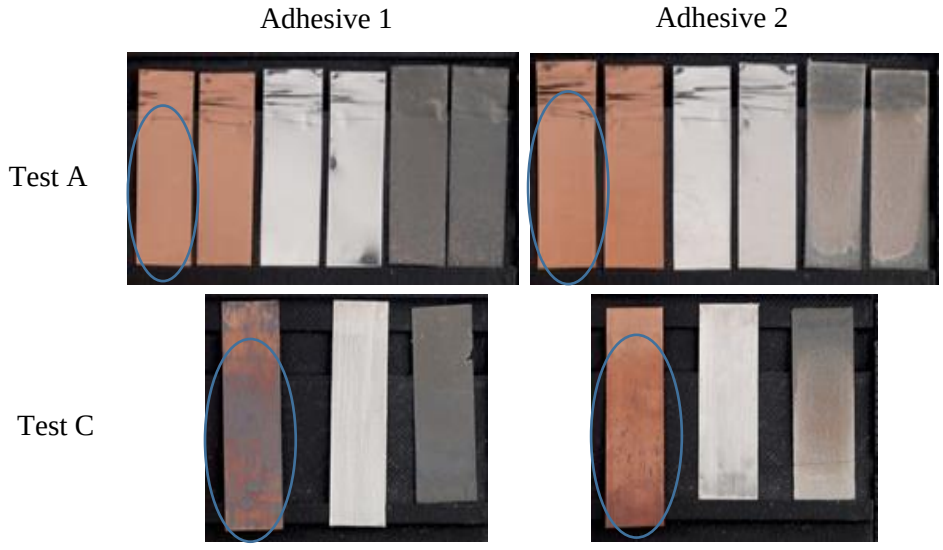
Nearly all other tests used in the cultural heritage field succumb to the same issue: that the line demarking when a material is recommended for use (passing the test) or not recommended (failing), is rarely defined with experiment-based information. While examples include long-used methods such as the Oddy test and spot or micro-chemical tests,[8] they also comprise more recently implemented chromatography-based volatiles analyses. The 2016 NLG supported the dissemination of volatiles analysis reports for hundreds of materials using solid phase microextraction (SPME) gas chromatography mass spectrometry (GCMS),[6] which allows for the identification of off-gassing chemicals from a prospective material. Other similar volatile analyses include direct thermal desorption (DTD) GCMS;[9] the Bundesanstalt für Materialforschung und -prüfung's (BAM's) BEMMA protocol,[10] which quantifies the amounts of harmful chemicals; and the recently developed paper test,[5] which uses a paper test strip aged with a prospective material to establish whether it is acceptable for use near art. In these and most other materials testing protocols, *the concentration of any one chemical or class of chemicals that is said to cause damage to collections or is enough to disallow the use of the material near art is based on subjective, often conservative, and experience-based rules rather than on a systematic and thoughtful assessment of what materials have been successfully and unsuccessfully used near collections.* The proposed process for developing a benchmarking procedure will generate highly useful information about the *amounts or*

concentrations of chemicals that are harmful to collections, making volatiles analysis results interpretable by both the testers and collections stewards.

The Oddy test serves as a key example of these issues. The unprecedented and copious sharing of Oddy test results on the AIC's Materials Testing Wiki since 2017 has allowed institutions and individuals with limited in-house testing resources to select construction, storage, and transport materials based on the results of others. It is notable that Torok et.al. found that 12 of 43 or nearly 30% of surveyed institutions did not conduct in house Oddy testing.[11] The widespread usage of the Oddy test Wiki page, which has become the sixth most visited by more than 5,600 visitors/year on that site (an increase from the 19th most visited page in 2017) is evidence of this trend. With 17 institutions contributing results using 16 significantly distinct test protocols, however, collections stewards are left guessing which protocol or institution is providing reliable information. This uncertainty is not only because some test protocols produce a wider range of corrosion than others when testing the same prospective material, but it is also because essentially *all* Oddy test coupon assessment protocols are based on tradition rather than experiment-based benchmarking or standards.

According to Torok's survey, at least 20 distinct protocols are in use at 31 institutions. The tests vary widely in their ability to maintain the water and volatiles being produced by the test material, which is just one of many differences that can lead to a range of corrosion results for the same test material (Figure 1 and Table 1). While evaluation protocols are not always disclosed in test procedures,[12] if the same coupon evaluation protocols are utilized for different test protocols, the results or recommendations for use of a material near cultural heritage objects can vary. This occurs because there is no basis for knowing whether a given test protocol is capable of detecting the minimum amount of a damaging pollutant, or for knowing whether the corrosion caused by that pollutant is being appropriately ranked in the context of the field's decades of experience using materials with collections.

Figure 1. Oddy test images from two different test protocols conducted on the same materials, showing significant differences in the type and amount of corrosion produced on the copper coupons. These tests have different sensitivities to the same pollutants. Benchmarking of the tests would allow those running the tests to document their sensitivity and allow the adoption of a better test, the modification of their test, or the modification of their rating protocols to account for the observed over- or under-sensitivity.



All Oddy variants base their rating levels of corrosion on traditional rather than on sensible benchmarking or a broadly accepted standard, where the metal coupons are categorized as Permanent (P), translating to materials that can be used indefinitely; Temporary (T) for up to six months; or Unsuitable (U), which are not recommended for use near cultural heritage objects. Examples of these materials include Obmodulan™ polyurethane board (P), some polyethylene boards (T), and plywood board (U). Typically, the first sign of corrosion defines the P/T border. The T/U border is much less well defined as "clearly visible corrosion".[3,4] At The Met, the T/U border has been based on the experience of running many tests, observing the corrosion patterns of each metal.[13,14,15] Again, as referenced above, differences between protocols can produce dissimilar sensitivities, resulting in notable variation in the amounts of observable corrosion for the same material. Thus, even if the same corrosion type is produced, different levels of that corrosion can lead to dissimilar use recommendations for the same material.

Table 1. Oddy test results for the same materials using two different test protocols, with different resulting use recommendations. Tape 1 is U and P, and Tape 2 and PVC board 1 are T and P. Notably, the PVC board tested here was recently used in museum showcases, causing rapid and significant tarnishing of collections.[16] For benchmarking of the Oddy test, the amount of sulfide present in this PVC board will likely become *Unsuitable* for use with collections rather than T or P, as these tests report.

	Tape 1	**Tape 2**	**PVC board 1**
Test A	**U** Cu: Slight red tarnish Ag: No corrosion Pb: heavy orange crystals	**T** Cu: No corrosion Ag: Very slight white haze Pb: Darkening overall	**T** Cu: No corrosion Ag: Yellow tarnish Pb: No corrosion
Test B	**P** Cu: Minor darkening Ag: No corrosion Pb: No corrosion	**P** Cu: Very slight darkening Ag: No corrosion Pb: No corrosion	**P** Cu: No corrosion Ag: No corrosion Pb: No corrosion

The Met proposes to address the lack of test benchmarking, which exists for nearly all material tests applied in the cultural heritage field, by developing an accessible and easily reproducible benchmarking procedure that will be applied to the Oddy and paper tests, standardizing the borders between P/T and T/U for both tests. This procedure will be based on the assessment of regularly used, no longer used, and generally avoided commercial materials and will utilize easily prepared chemical mixtures to allow for the generation and application of consistent and reproducible standards. While this proposal focuses on the Oddy and paper tests, *once developed, the chemical mixtures will be applicable far beyond the Oddy test, facilitating the benchmarking of other tests used to evaluate storage, display, or transport materials*. The process used to develop these benchmarking procedures will also allow the generation of damage thresholds for chemicals found through chromatographic volatiles analyses such as DTD-GCMS or those used in the BEMMA protocol, representing the beginnings of a significant advance in the use of analytical tools for the evaluation of storage, display, and transport materials.

The chemical analyses used to understand what chemicals in what amounts are off-gassing from the benchmarking materials will be used to develop a partial database reporting threshold levels of chemicals or classes of chemicals above which damage to art can be expected. This database will be made public on the AIC's Materials Testing Wiki page so that others can both contribute to it and use the data to inform materials selection in cultural heritage institutions. This database is a much needed resource, allowing the accurate and effective use of volatiles analysis tools for materials testing, informed by but eventually replacing surrogate tests such as the Oddy and paper tests.

The greatest challenge to benchmarking will be establishing which materials are appropriate and broadly accepted as safe for collections (P), on the border of safe and slightly harmful (P/T), and on the border of slightly harmful and harmful (T/U). Materials that are obviously P and U will easily be identified based on decades of conservator experiences, The Met's GCMS volatiles analysis and Oddy test data, and literature containing case studies of problematic or Unsuitable materials.[17,18] Identifying Temporary materials near the P/T and T/U borders, however, will be more challenging, requiring the identification of products that were once acceptable and are no longer used due to observed damage, products that are used despite showing a range of Oddy test results, or material categories that do not have Permanent options but have Temporary ones based on repeated use and testing. A steering committee consisting of conservators and conservation scientists has been assembled to develop strategies for tapping into the collective knowledge of the conservation field to identify and rank the acceptability of a range of materials for use near cultural heritage objects.

Steering Committee:
Sarah Melching – Director of Conservation, Denver Art Museum, CO

Jane Williams – Director of Conservation, Fine Arts Museum, San Francisco, CA

Laura Gaylord-Resch – Environmental Technician, Cleveland Museum of Art, Cleveland, OH

Pamela Hatchfield – Head of Objects Conservation, Emeritus – Museum of Fine Arts, Boston

Samantha Springer –Private Conservator, Portland, OR

Maria Fredericks – Sherman Fairchild Head of Conservation, The Morgan Library, New York City

David Thickett – Conservation Scientist, English Heritage Foundation, London, UK

Lisa Elkin –Director of Conservation, American Museum of Natural History, New York City

Jean-François de Lapérouse – Conservator, The Metropolitan Museum of Art, New York City

Once a range of materials between Permanent and Unsuitable are identified, the materials will undergo Oddy and paper testing as well as chemical analysis to establish what volatiles at what concentrations are causing corrosion on each coupon type, or degradation of the cellulose from the paper test. Because commercial materials are essentially uncontrolled and subject to formulation change or variation without notice, the goal will be to produce a benchmarking protocol based on easily reproduced chemical mixtures. The selection of chemicals used to produce corrosion on each metal type will be based on the volatiles analyses of the benchmarking materials as well as their commercial availability and costs. Oddy and paper tests of those or similar chemicals will be completed to verify that similar levels of corrosion and paper degradation as the source material are produced. For the Oddy test, a direct comparison of like coupons will be made by using electrochemical reduction to assess the amount of each corrosion type produced both by the material and the individual chemicals. The paper test includes the semi-quantification of paper degradation

through measurement of the glucose concentration via ion chromatography and level of oxidation via UV-Vis spectroscopy, which can be directly compared for both the test material and chemicals.

The development and use of a benchmarking protocol for the Oddy and paper tests will greatly improve the ability of collection stewards to choose materials for use near cultural heritage objects. Considering that the Oddy test is the primary decision-making tool used by collection stewards, it is important to note that material selections based on the Oddy test will still rely on a subjective and time-consuming protocol. It is clear that more rapid and objective tests are needed to improve the accuracy and rate at which materials can be tested. Volatiles analysis has been used to screen materials at a handful of institutions in the US and more prominently in Germany using the BEMMA protocol.[9,19,20,21] These use a range of analytical tools including GCMS, ion chromatography (IC), and high pressure liquid chromatography (HPLC) to identify and sometimes quantify the levels of acids, aldehydes, ketones, oximes, amines, esters, and other potentially reactive classes of compounds. The testers, however, much like those using the un-benchmarked Oddy test, have only circumstantially established rules and chemical intuition for recommending a material for use near cultural heritage objects. The Met will coordinate with BAM to conduct the BEMMA protocol on each of the benchmarking materials, and the Museum will conduct DTD-GCMS on each material. This in-depth chemical analysis of volatiles from each material will facilitate the selection of reactive chemicals for use in the benchmarking solutions and have the added benefit of beginning to benchmark the BEMMA test and other chromatography-based volatile organic chemicals (VOC) analysis techniques.

As The Met and other institutions develop and use a wide range of materials tests, it is clear that a community-based and approved benchmarking system has the potential to expand the list of materials that are acceptable for safe use with cultural heritage, while providing a scientific basis for eliminating the ones that are dangerous to collections. The Preventive Conservation Science Lab (PCSL) in The Met's Department of Scientific Research (DSR) is uniquely positioned to undertake this specialized work, having been awarded 2016 NLG support that made possible the development of the paper test and the testing and publication of Oddy and volatiles analysis results for hundreds of materials. While this previous award has allowed The Met to successfully identify gaps in knowledge for the field of materials testing, the proposed project expands on that work and aims to broadly enhance the integrity of testing protocols and establish damage thresholds of harmful chemicals for the benefit of cultural heritage collections worldwide.

Project Work Plan

Selection of benchmarking materials:

The selection of benchmarking materials, being the most subjective portion of the work, will be the most challenging and will require input from a broad range of community members. To accomplish this, The Met will work with the project's steering committee to establish viable methods and processes to engage with the conservation community. The project team will use at least two modes of outreach. Possibilities include conducting an online survey or call for information, hosting small-group online workshop sessions, and hosting an in person or virtual session at the AIC's Annual Meeting. For each of these methods, a similar set of questions will likely be posed, asking for experience-based information about materials that run the gamut on the Permanent to Unsuitable continuum and are or were regularly used in the conservation field.

A survey will be utilized to identify members of the community that are informed, willing, and interested in engaging on this topic as well as to collect viable information. A follow-up interview or invitation to join a small-group session will likely be required to ensure that the information provided

is interpreted correctly and appropriately evaluated. Participants will be asked to generate a list of materials, rating and ranking them for where they fit on the Permanent to Unsuitable continuum while documenting their justifications. This information, along with Oddy test and volatiles analysis data, will be utilized to finalize the rankings. Approximately 30-40 materials will be selected as the primary benchmarking set. Selection will focus on those at the P/T and T/U borders but will also include P, T, and U materials, ensuring that a range of degradation of the copper, silver, lead, and cellulose sensors can be expected.

Sourcing and testing of benchmarking materials:

The Met Museum will acquire sufficient quantities of each benchmarking material to minimize the need to repurchase for the duration of the grant, storing the excess in a freezer. Ideally, a single batch or production run will be used throughout the experiments for most materials. An exception will be materials that have historically produced a range of Oddy test results. Where possible, at least three different batches of these materials will be acquired from separate manufacturing sites, or at least separate suppliers.

Each material will be subjected to The Met's Oddy and new paper tests, as well as direct thermal desorption (DTD)-GCMS volatiles analysis, and the BEMMA protocol for volatiles. While The Met's DTD-GCMS test will allow for identification of individual chemical compounds, the BEMMA protocol, performed by BAM in Berlin, Germany will *quantify* the amounts of each chemical class. The combined data will be assessed and used to establish which chemical compounds in what quantities are most likely to cause the corrosion observed on each metal coupon used in the Oddy test.

Three to five chemicals believed to corrode each metal will be prepared in concentrations that were found to cause a particular level of metal coupon corrosion via the Oddy and/or paper test, and undergo individual testing using The Met's Oddy and paper tests. From these results a subset of chemicals will be identified for use in the final protocols.

To establish the concentrations of each chemical required for the benchmarking protocol, the amount of corrosion produced on the commercial material's Oddy coupons will be evaluated using electrochemical reduction. Using these chemical mixtures, The Met will aim to reproduce similar levels and types of corrosion each chemical is capable of producing. There are often multiple types of corrosion present on a particular coupon when exposed to the commercial material. The single chemical, however, will likely produce fewer types. The goal will be to identify the most abundant corrosion types from the commercial material's test and match it with the selected benchmarking chemical(s). The data from the electrochemical reduction of the Oddy coupons, paper test, DTD-GCMS, and the BEMMA analyses will be used to measure and establish both the levels of coupon degradation and the volatiles present. As needed, multi-angle x-ray diffraction of the Oddy coupons will be used to identify the phases or types of corrosion.

Project staff will aim to identify and analyze approximately 30-40 materials in the first six months of the grant period. Analysis of each material could yield as many as several hundred chemicals requiring further testing to identify which compounds are responsible for any corrosion. By sharing the resulting data and protocols, The Met will greatly enhance the reliability of materials tests that institutions worldwide rely on to aid in the selection of transport, storage, display, and construction materials; and promote a greater consensus among collections care professionals about which materials are dangerous to cultural heritage objects. To accommodate the volume of this work,

prospective grant funds would support two Ph.D. level Research Associates dedicated to the project over the course of three years, whose responsibilities are outlined below.

Key Personnel:

The Met team will consist of Eric Breitung (Ph.D., Research Scientist) as project lead, who will ensure the direction and timing of the research remains true to the proposal as well as providing guidance and mentorship. Catherine Stephens (Ph.D., Associate Research Scientist) will provide methodology guidance for volatiles analysis as well as establishing damage thresholds for individual chemicals, and Alayna Bone (B.A., Research Assistant) will provide Oddy test and ion chromatography training and conduct Oddy tests as needed. Two grant-supported Research Associates will provide support on all technical aspects of the proposed work including but not limited to literature searches, laboratory experiments, report writing, and publication. They will also conduct the outreach campaign to the conservation community, participate in steering committee and PCSL meetings, and have the opportunity to present their work at conferences. Additional details on their proposed responsibilities are available in the appended position description.

Grant funds would also support the contracted services of Wolfgang Horn, Senior Researcher at the Bundesanstalt für Materialforschung und- prüfung (BAM) in Berlin, who will provide key support by conducting the BEMMA protocol on benchmarking materials; and Samantha Springer, a Portland, OR-based conservator who will implement all updates and alterations to the AIC's Materials Testing Wiki pages to ensure broad and accurate dissemination of project results.

Planning and Implementation:

Planning, updates, and tracking of progress will occur at bi-weekly group meetings at The Met. Early in the project, the steering committee will help guide the outreach process with the conservation community. Once that is completed, the committee will continue to provide counsel through annual meetings on the progress of the project.

The Met will also present this work at annual Materials Working Group (MWG) meetings. The MWG is a community of collections care professionals united in developing guidelines and best practices for selecting, evaluating, and disseminating materials used in collection care. Its participants are highly engaged in this work and will provide substantive feedback on our process and methods.

Outreach and publication:

The final Oddy and paper test protocols will be reviewed by the steering committee and submitted for publication in peer reviewed scientific literature. In addition, summarized versions of the experimental protocols will be posted on the AIC's Materials Testing Wiki for any cultural heritage institution to use at no cost. A page dedicated to threshold levels for either individual, or if possible, classes of chemicals will also be posted on the Wiki, and we will work with BAM to introduce damage-based threshold levels into the BEMMA scheme. This information will greatly enhance the ability of collection stewards to translate data from rapid and quantifiable volatiles analyses into use recommendations for storage, display, construction, and materials near cultural heritage objects.

Upon publication of the benchmarking protocols, the AIC's Materials Testing Database[6] will be modified to include a clear demarcation for those tests that have been run and evaluated using the benchmarking protocols. In addition, The Met's tests conducted within the previous two years will be re-evaluated with the new benchmarking protocol and republished to provide approximately 200

benchmarked tests. With these additions, collections stewards can begin to utilize equally the results from a wide range of test contributors to the website.

Following the success of the International Materials Testing Symposium held at The Met in 2019,[22] which presented the state of materials testing in cultural heritage institutions to a crowded room of conservators, scientists, and technicians, grant funds would permit the Museum to host a follow-up symposium in the final year of the proposed project. All institutional partners will be invited to participate. Because this project will be of great interest to the broader conservation community, a video recording of the symposium will be disseminated afterward to allow those who cannot attend to view the presentations online. The 2019 meeting was hosted adjacent to the annual MWG meeting, also held at The Met. Assuming that in-person meetings are possible by then, this approach would also be taken for the 2nd International Materials Testing Symposium to facilitate broad attendance for an international community of collections care professionals.

Project Results:

Benchmarking protocols and VOC analyses:

The proposed project will result in two benchmarking protocols, one each for the Oddy and paper tests. Application of the Oddy test protocol will have the broadest impact on the field, as it is continues to be the most widely used test to inform collections stewards about the safety of various display, construction, storage, and transport materials. The benchmarking protocols will also facilitate the benchmarking of other materials tests and promote more accurate interpretation of dissimilar Oddy test protocols across the field. Because benchmarked tests should produce more similar and standardized results, fewer repeat tests will be necessary, and collection stewards will be able to access more reliable and readily comparable materials testing information. This will result in the adoption across the field of a broader range of safe materials that have been thoroughly tested and vetted by multiple institutions, increasing the longevity of millions of the world's cultural heritage objects through more thoughtful and informed collections care choices.

The paper test's benchmarking protocol will serve to establish the P/T and T/U borders for this test as well as highlight the differences in chemical types and concentrations that affect the cellulose sensor relative to the metals of the Oddy test. The implications here are significant, as it has been shown that the metals of the Oddy tests are not always reactive to the chemicals that cause paper degradation, but it is not clear which chemical or mixtures of chemicals are responsible for the differences. By establishing which chemicals can affect metals versus paper and in what concentrations, collections steward's will be able to consider the media being stored, displayed, or transported when making materials decisions.

The chemicals and concentrations found to define the P/T and T/U borders for both the Oddy and paper tests will also be applicable to chromatographic VOC analyses such as DTD-GCMS and the BEMMA protocol. To date, only a few reactive VOCs such as formaldehyde, acetic acid, and propionic acid have been investigated to allow informed threshold levels for use near cultural heritage objects,[23] leaving scientists to interpret VOC analyses with chemical intuition rather than experiment-based data.[9] An example of The Met's published SPME-GCMS data for hundreds of materials on the Wiki can be found in Supporting Document 4, where the first page shows how limited the field's knowledge is in this area. There we describe potential chemical reactions but cannot offer information about what concentration or chromatographic peak area is great enough to justify not using a material near collections.

The results from this work will add significantly to the list of VOCs for which the threshold levels for use near cultural heritage are established and will serve as a basis for adding to that list beyond the conclusion of the award. In fact, the long-term goal of The Met's PCSL is to use the Oddy and other materials tests to inform the more quantifiable, rapid, and objective VOC analysis techniques to the point where the Oddy and paper tests are no longer needed to make materials selection decisions. The work proposed herein is required for the conservation and scientific community to take the guesswork out of interpreting such data and, hence, guessing about material selection decisions.

Outreach and promotion:

As mentioned above, all relevant data and protocols will be published as is appropriate in peer-reviewed scientific literature and on the AIC's Materials Testing Wiki, where it will be available open source for anyone with internet access. The Met will, of course, implement the benchmarking test on its own protocol and continue posting test data on the AIC's wiki. In addition, The Met will offer to ship benchmarking solutions to up to 15 institutions or individuals that are actively sharing their results on the AIC's wiki.

Project updates will be presented at Materials Working Group meetings, where many who run the Oddy and VOC analysis tests convene to improve access to high quality materials test and selection information. The Met will also host a 2nd International Materials Testing Symposium in year three of the proposed grant to highlight the results of this work as well as the work of colleagues from institutions around the world to present the state of the field of materials testing for cultural heritage.

Training:

The proposed three year post-doctoral level positions would offer a rare training opportunity for two individuals to become experts in multiple materials testing and analytical techniques while working in a team environment at the only preventive conservation science laboratory in the U.S. Recruitment efforts will include outreach to ensure a diverse range of applicants, including those from underrepresented backgrounds. Ideal candidates will be expected to work collaboratively with each other and DSR staff. They will be included in all regular PCSL group meetings, where topics may include identifying materials for upcoming exhibitions, indoor air quality research, advances in the paper and Oddy test protocols, testing and improvement of display case design, integrated pest management (IPM), and other preventive conservation science issues at The Met. The PCSL has a growing list of collaborators and is currently working with scientists at Butler University, Case Western Reserve University, City University of New York, Abbott Laboratories, and Columbia University.

The Met has granted a one-year fellowship to a preventive conservator, who will work in the PCSL with Dr. Breitung as an advisor starting in September of 2021. She will work on a range of preventive conservation science projects, including vibration monitoring, our integrated pest management program, and pollutant monitoring in galleries. While her appointment is set for one year, the PCSL regularly accepts research fellows and interns, who participate in collaborative PCSL projects, creating a diverse, interactive, and exciting research environment.

As a global leader in scientific research on works of art, The Metropolitan Museum of Art would welcome IMLS' leadership support for this groundbreaking conservation science initiative, which we anticipate will yield broad, far-reaching benefits for museums both nationally and internationally. We would be honored to be among the 2021 National Leadership Grantees, and we thank you for your consideration of this proposal.

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The Metropolitan Musem of Art
IMLS FY 21 National Leadership Grant

Development of Damage Thresholds and a New Tool for Standardizing Materials Tests for Cultural Heritage Institutions

Schedule of Completion

	Project Year 1												Project Year 2												Project Year 3											
	2021				2022								2023												2024											
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Hire 2 Research Associates																																				
Establish Benchmarking materials via following activities:																																				
- Meet with steering committee																																				
- Distribute and evaluate electronic survey to conservation community																																				
- In person small group meetings with conservation community																																				
- Other activities as determined by steering committee																																				
Purchase and install freezer																																				
Order Oddy and Paper test benchmarking materials																																				
BEMMA and GCMS test benchmarking materials																																				
Assess results identifying key chemicals for study																																				
Purchase key chemicals																																				
Oddy and Paper test key chemicals at multiple concentrations																																				
Repeat key chemical selection as needed																																				
Repeat Oddy and Paper test of new key chemicals at multiple concentrations																																				
Conduct volatiles analysis (GCMS) on key chemicals at multiple concentrations																																				
Purchase and seek training on electrochemical stripping technique																																				
Conduct electrochemical stripping on benchmark material Oddy coupons																																				
Conduct electrochemical stripping on key chemical Oddy coupons																																				
Summarize data into benchmarking protocol for Oddy test																																				
Summarize data into benchmarking protocol for Paper test																																				
Summarize damage threshold data																																				
Publish Oddy, Paper, and Volatiles analysis data on AIC Wiki site																																				
Develop benchmarking page on AIC Wiki site																																				
Prepare and publish manuscripts for scientific and conservation literature																																				
Publish benchmarking protocols on AIC Wiki site																																				