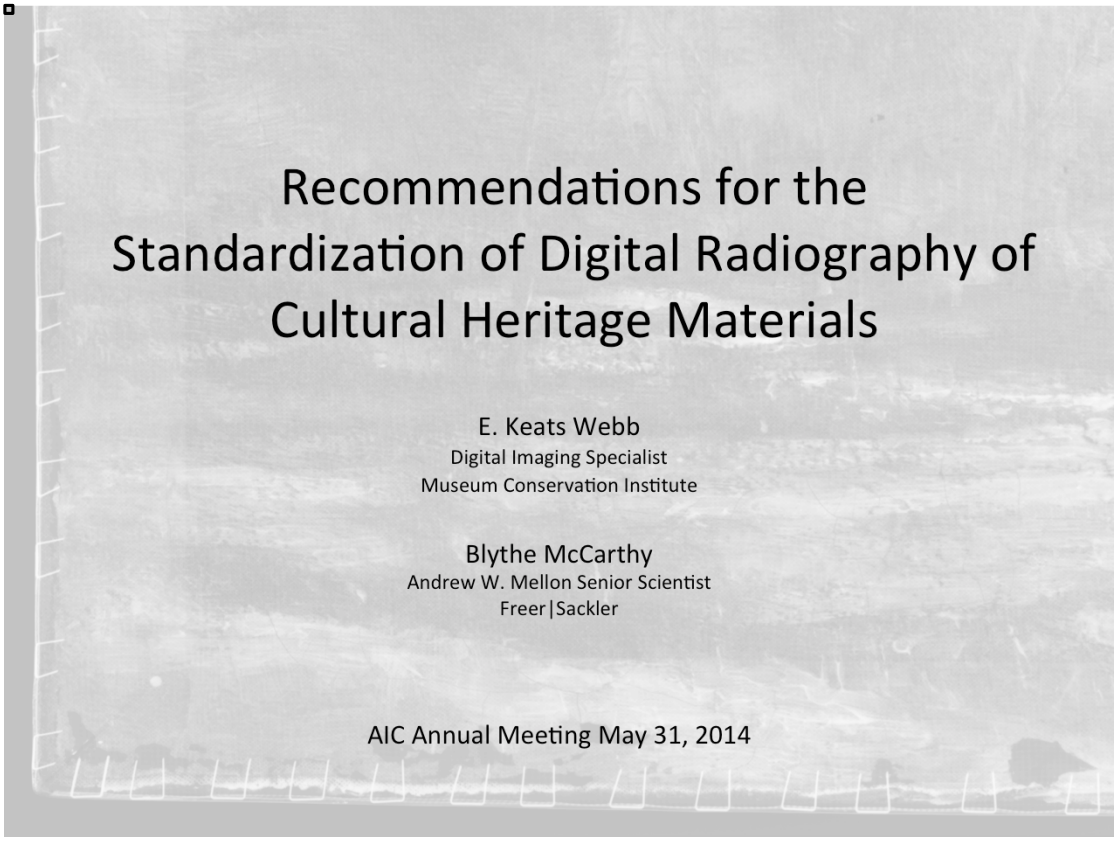


E. Keats Webb[1], Blythe McCarthy[2]

[1]Digital Imaging Specialist, Museum Conservation Institute, Smithsonian Institution
[2]Andrew W. Mellon Senior Scientist, Freer Gallery of Art & the Arthur M. Sackler Gallery, Smithsonian Institution

Presented at the RATS session
42nd Annual Meeting of
The American Institute for Conservation of Historic and Artistic Works (AIC)
San Francisco, CA, May 27-June 1, 2014

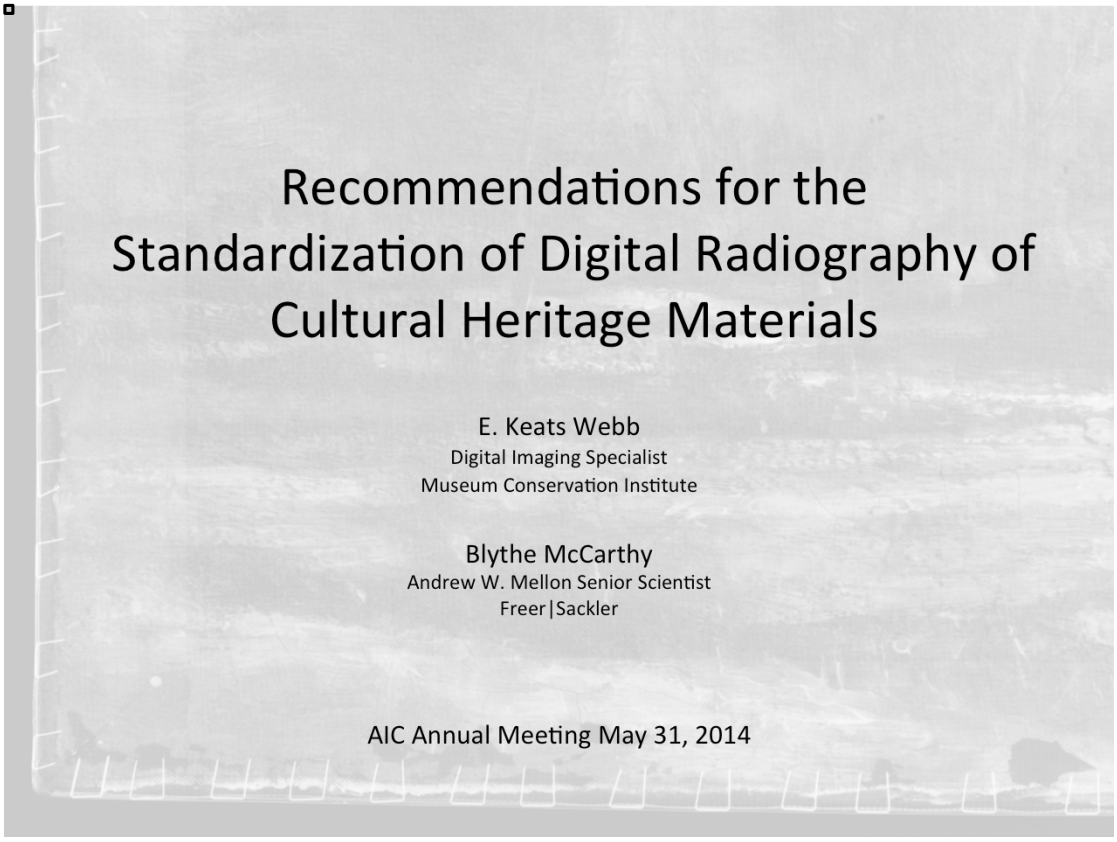
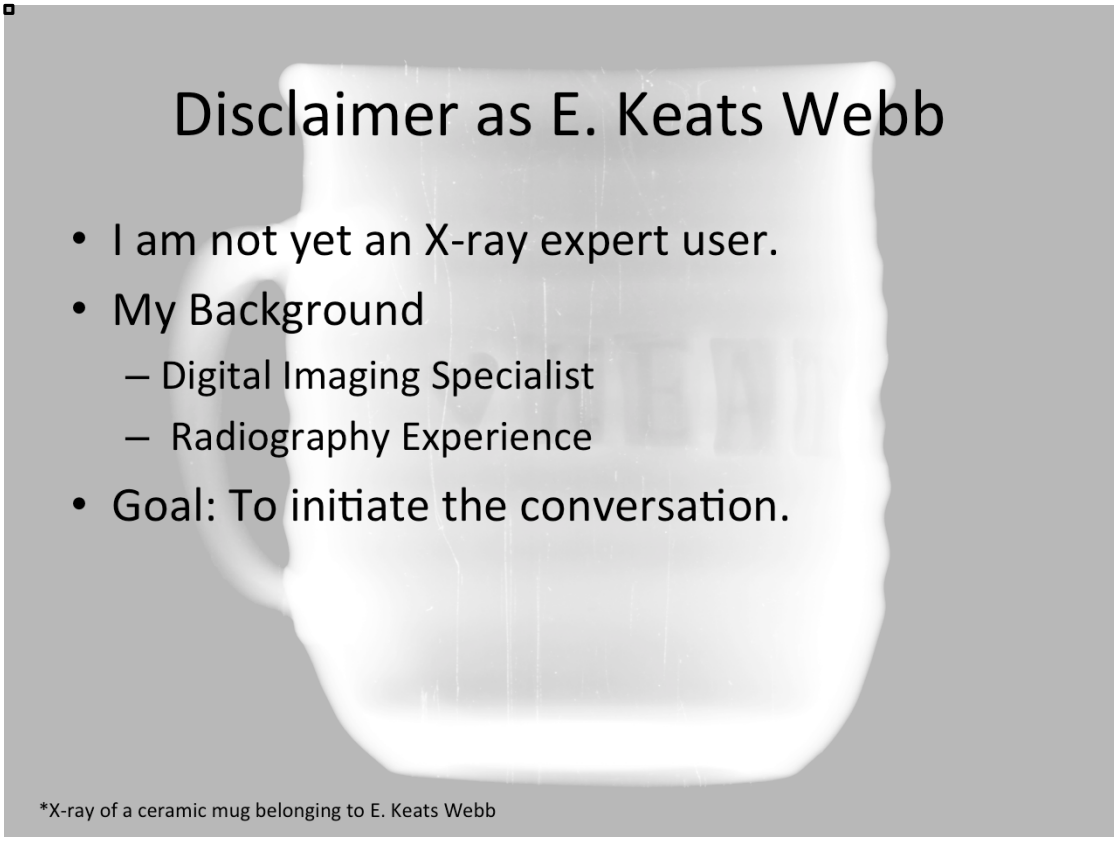


Image: X-ray of a landscape painting by FW Rogers used as a study piece for various techniques at the Museum Conservation Institute (MCI) from the personal collection of Mel Wachowiak.

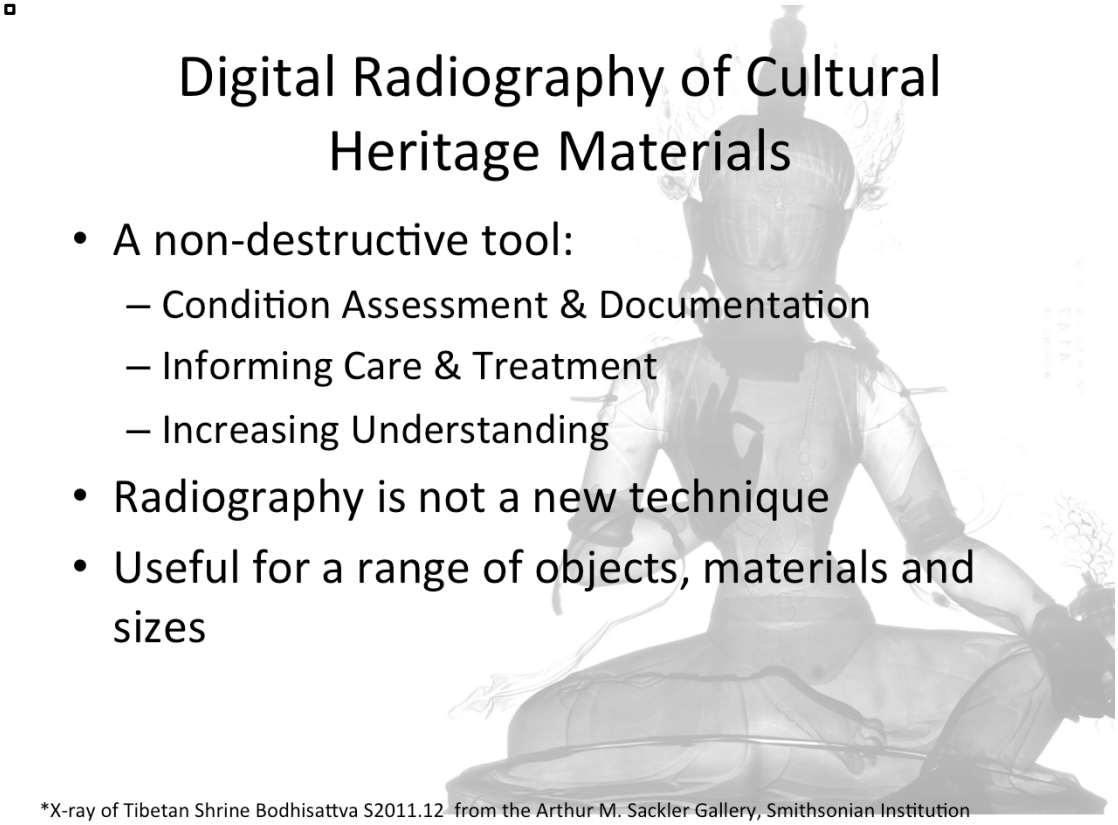


I want to start this paper by telling you a little bit about myself. I do not want anyone to get the wrong impression that I am claiming to be an expert digital radiography user.

My background is as a Digital Imaging Specialist at the Smithsonian's Museum Conservation Institute (MCI) using a variety of scientific and computational imaging techniques for the conservation and research of cultural heritage materials. Digital radiography is one of my newer techniques.

When I was hired in 2012 as an employee with the title of Digital Imaging Specialist, I was assigned to work towards the revitalization of the digital radiography program at MCI. In the fall of 2012, I completed training at General Electric (GE) for Nondestructive Evaluation (NDE) for digital radiography. After the training, I visited various conservation and research labs to learn more about digital x-ray in the context of cultural heritage.

With the lofty title of "Recommendations for the Standardization of Digital Radiography of Cultural Heritage Materials" my goal is to initiate the conversation about standardization of digital radiography of cultural heritage materials. I initially had the time and resources to support the community in this way.



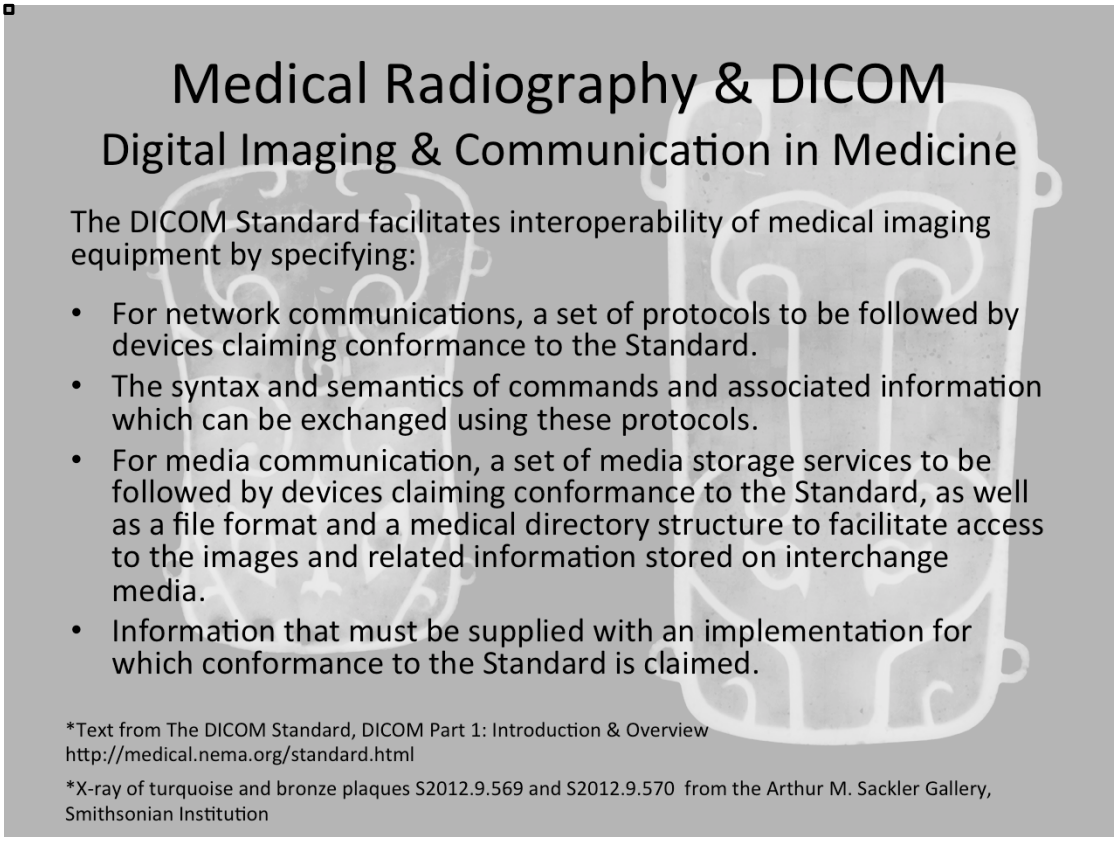
*X-ray of Tibetan Shrine Bodhisattva S2011.12 from the Arthur M. Sackler Gallery, Smithsonian Institution

Similar to digital photography, digital radiography of cultural heritage materials is used as a non-destructive tool for condition assessment and documentation, informing the care and treatment and increasing the understanding of an object.

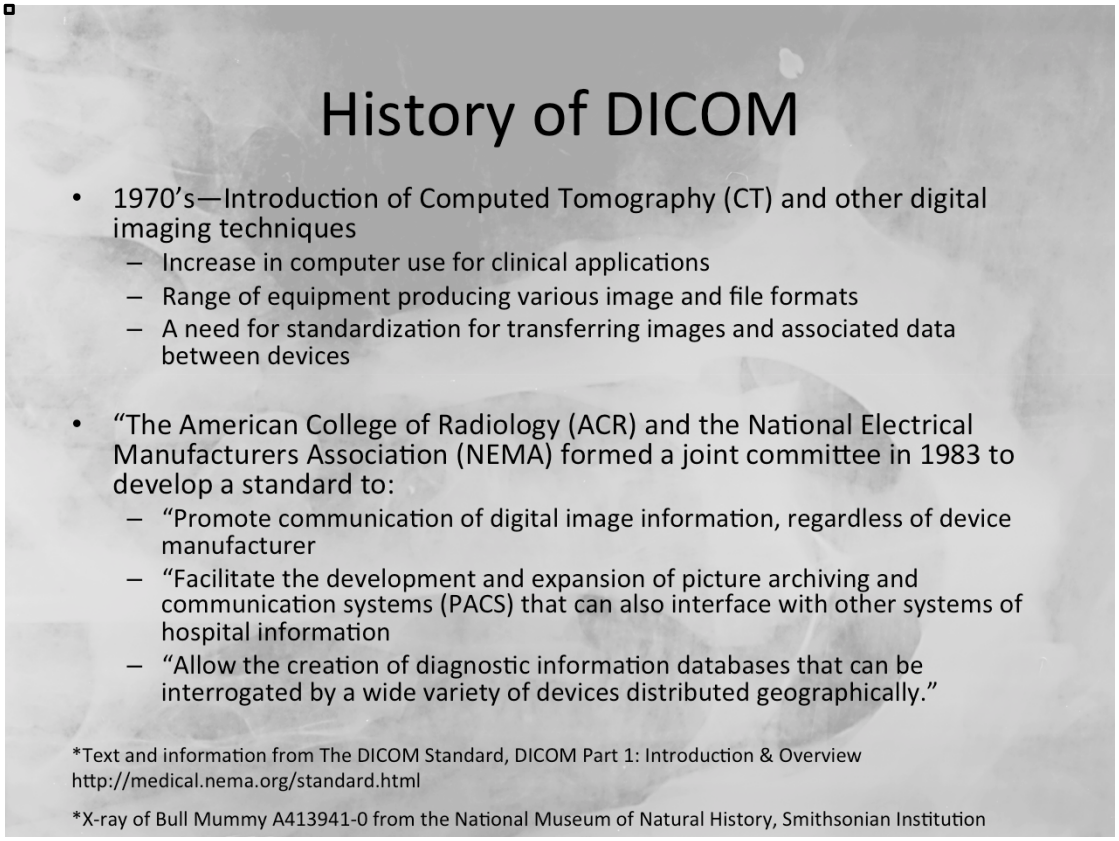
Radiography is not a new technique for documenting and analyzing cultural heritage objects. According to Janet Lang and Andrew Middleton in "Radiography of Cultural Material", radiographs were taken of archaeological artifacts including mummies shortly after the discovery of x-rays by Rontgen in 1895. The technique has seen growth in the past few decades for the examination of cultural heritage materials.

Depending on the source and energy, it can be used on a wide range of objects and materials.

Similar to other analytical techniques used in research and conservation of cultural heritage objects, digital radiography has been heavily developed by medicine and industry.



In medical radiography there is a standard known as Digital Imaging & Communications in Medicine or DICOM.



With the introduction of computed tomography (CT) followed by other digital diagnostic imaging modalities in the 1970's, and the increasing use of computers in clinical applications, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) recognized the emerging need for a standard method for transferring images and associated information between devices manufactured by various vendors. These devices produce a variety of digital image formats.

The American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) formed a joint committee in 1983 to develop a standard to:

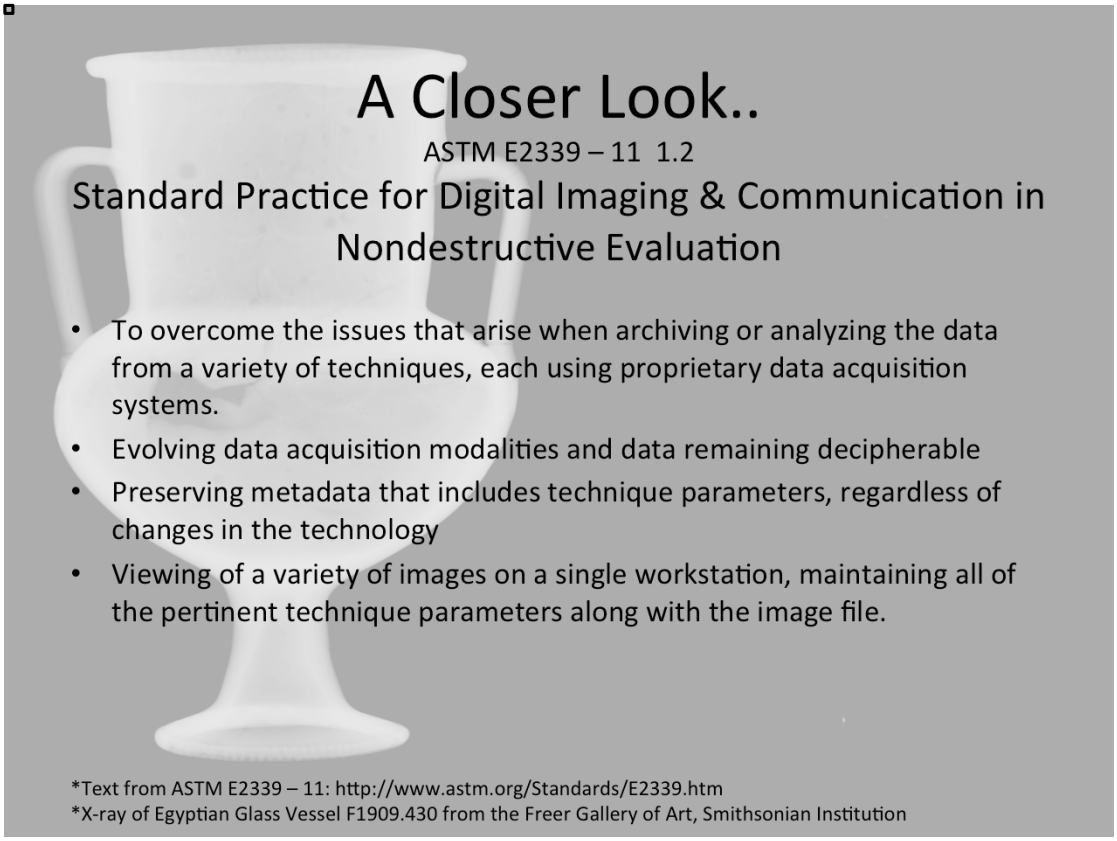
- Promote communication of digital image information, regardless of device manufacturer
- Facilitate the development and expansion of picture archiving and communication systems (PACS) that can also interface with other systems of hospital information
- Allow the creation of diagnostic information data bases that can be interrogated by a wide variety of devices distributed geographically.

Industrial Radiography & DICONDE

Digital Imaging & Communication in Nondestructive Evaluation

- Industrial Radiography includes aviation, transportation, energy and defense
- ASTM E2339 – 11 DICONDE Standards
  - 1.1 This practice facilitates the interoperability of NDE imaging and data acquisition equipment by specifying the image data in commonly accepted terms. This practice represents a harmonization of NDE imaging systems, or modalities, with the NEMA Standards Publication titled DICOM…
  - 1.2 This practice has been developed to overcome the issues that arise when archiving or analyzing the data from a variety of NDE techniques, each using proprietary data acquisition systems. As data acquisition modalities evolve, data acquired in the past must remain decipherable. This practice proposes an image data file format in such a way that all the technique parameters, along with the image file, are preserved, regardless of changes in NDE technology. This practice will also permit the viewing of a variety of image types (CT, CR, Ultrasonic, Infrared and Eddy Current) on a single workstation, maintaining all of the pertinent technique parameters along with the image file.

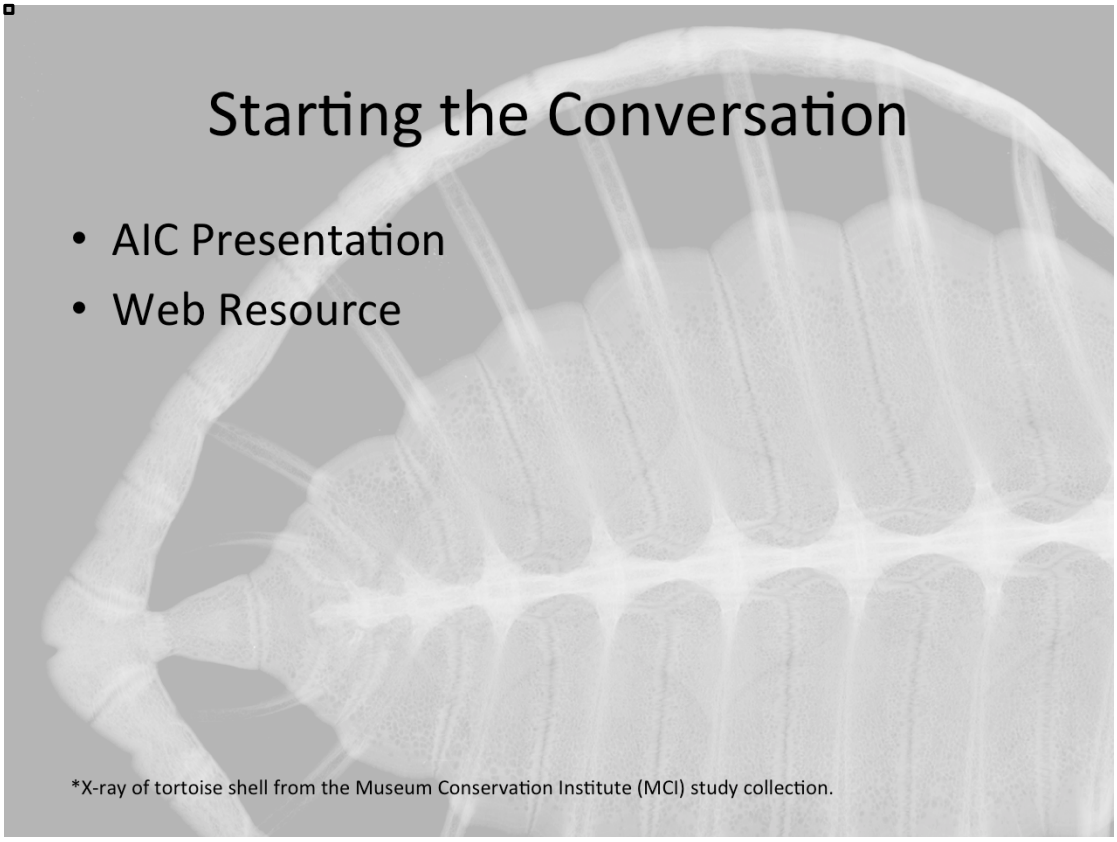
*Text from ASTM E2339 – 11: http://www.astm.org/Standards/E2339.htm
*X-ray detail of Tibetan Shrine Bodhisattva LRN 7563 from the Freer|Sackler Galleries, Smithsonian Institution



These are similar issues to what we deal with in digital radiography for cultural heritage: archiving and analyzing, the evolving of data acquisition modalities, and preserving metadata.

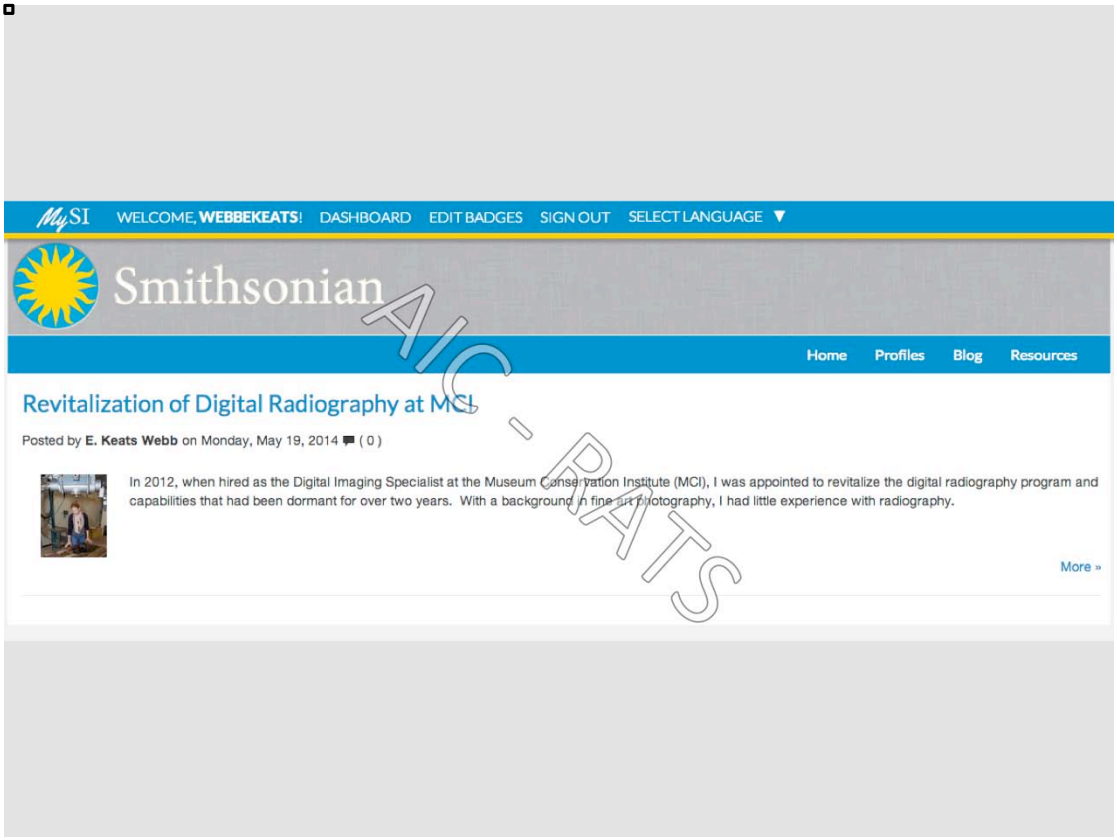
We need to standardize digital radiography for cultural heritage imaging.

How do you know your system is working? How do you know that the quality of your x-ray is such that you are seeing everything that is there, and that what you don't see really is absent?

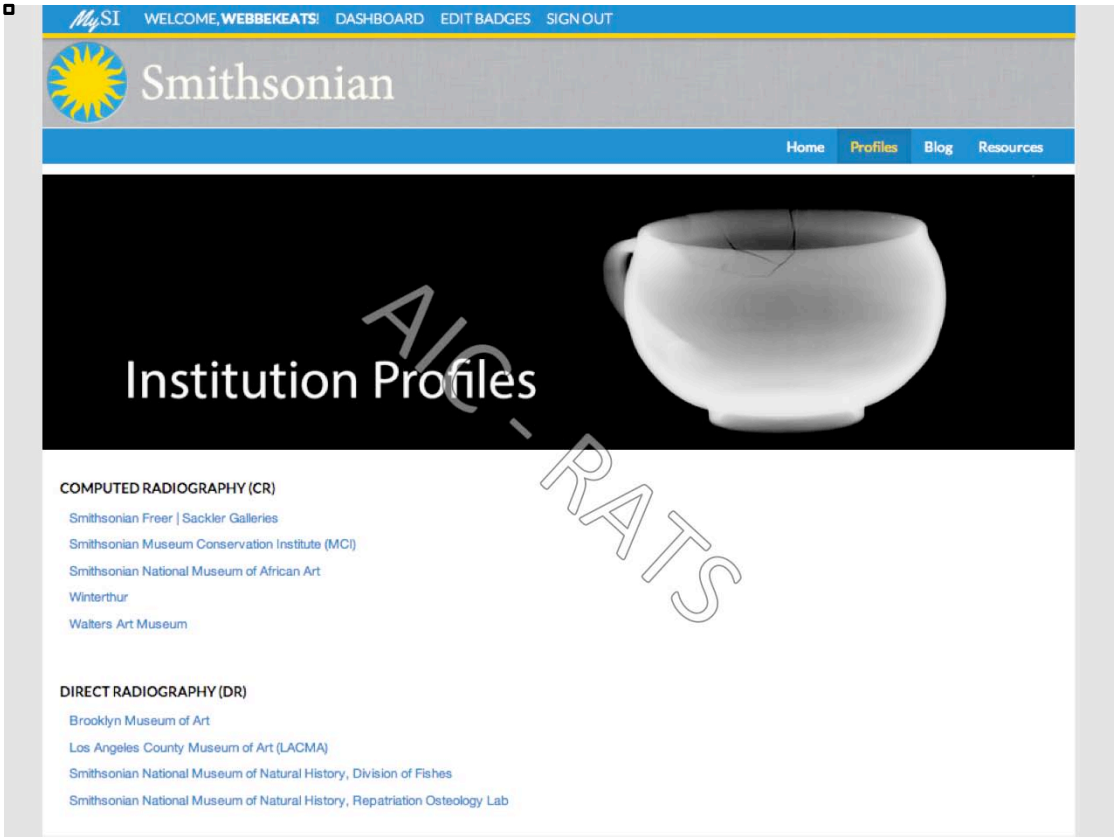


We have established that there is a need for standardization for digital radiography of cultural heritage materials, so now we need to start the conversation. The presentation of this subject at the 2014 AIC annual conference was a start to this conversation, as is a web resource that I created.

I have created a web resource for cultural heritage professionals working with digital radiography to pull together resources and encourage the conversation about standardization: http://my.si.edu/DigitalX-ray.



The website has a blog that will include guest bloggers discussing recent projects, challenges, trouble shooting, and anything and everything relating to digital radiography of cultural heritage materials.



The site also includes a page with profiles for institutions that have digital radiography capabilities.

Smithsonian
Museum Conservation Institute

Date: April 7, 2014

X-ray Contact: Keats Webb, Digital Imaging Specialist
webbekeats@si.edu

X-Ray Source
Philips MG320 Constant Potential X-ray Unit
(40-320kV, 1-9mA, 1.5mm & 4mm focal spot)

Scanner/Detector Specifications & Software
Pegasus CR50P scanner
GE Rhythm Acquire & Rhythm Review

Examples of Objects X-rayed
(sizes & materials)
Paintings, a large animal mummy, argillite objects, beaded belts, plastic aircraft models

Processing & Software
Using a combination of software and processing workflows.
-Rhythm Review (GE software for viewing and processing)
-Adobe Photoshop CS4 & CS6
-Lucis Pro 6 with Adobe Photoshop CS4
-Stitching--Nip2, Microsoft ICE, and Photoshop

Archiving & Metadata
-Archiving original DICOMs exported from Rhythm Acquire software and also archiving "original image" TIFF exports from Rhythm Review software and edited/processed TIFFs and JPEGs.
-Archiving to a network drive within the Institution.
-Metadata--still working on a good solution for this.

Additional Comments
Large lead lined room with sliding door allowing larger objects (like a bull mummy) to be x-rayed.

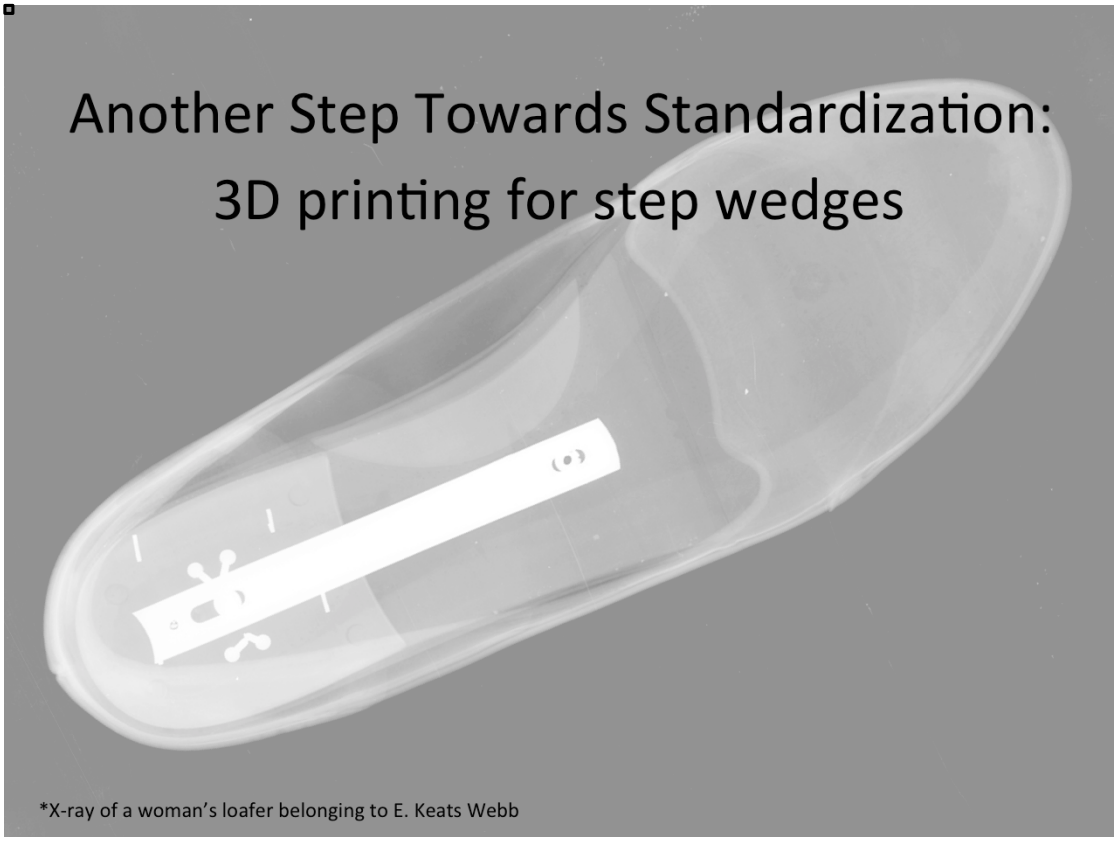
Image of X-ray Source

Image of Scanner & Workstation

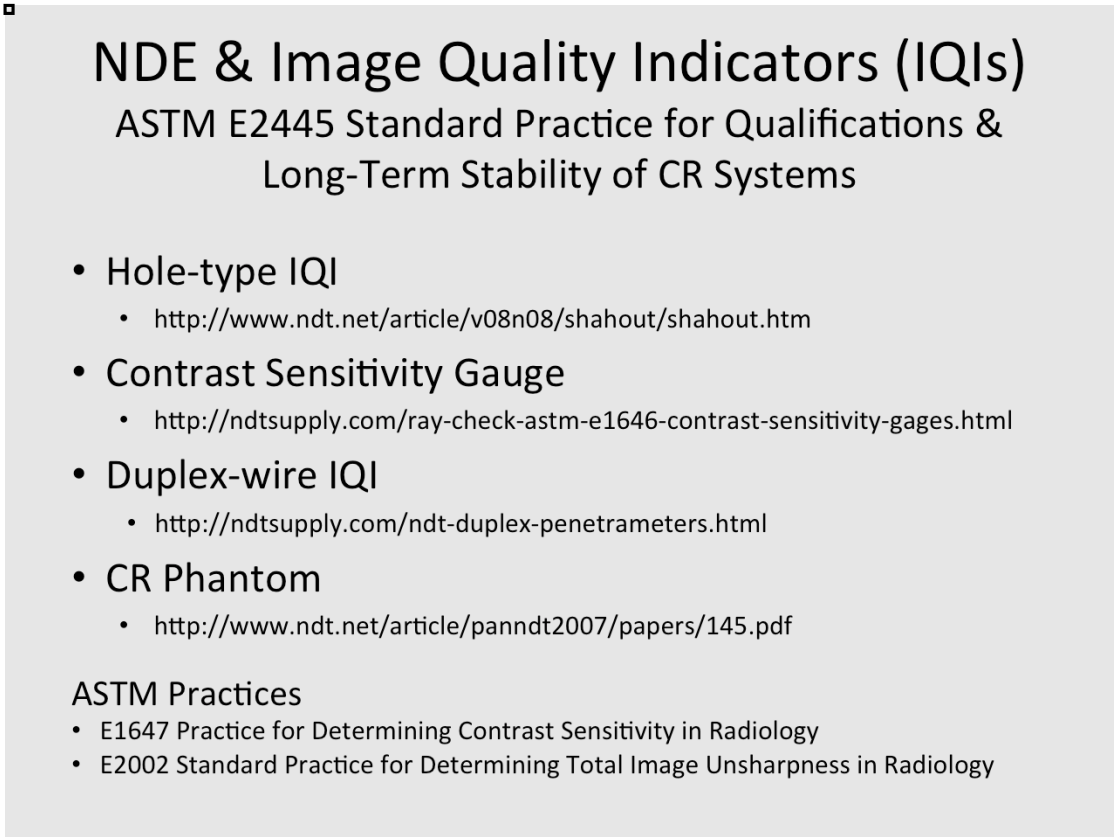
The intent of these profiles is to allow users to reach out to others who may be using similar equipment or working with similar materials so that they may discuss, collaborate and troubleshoot together.

The final page is a list of resources for digital radiography. The page currently includes articles and books, but I would be happy to add links, technical notes/white papers, and other resources that will help us do our work better.

Participation is the key to the success of this web resource. It can only be as good as the contributions and participation of the community.



An example of taking steps towards standardization is Blythe McCarthy's work with 3D printing for step wedges.



Examples of Image Quality Indicators (IQIs) for NDE radiography:

Hole-type IQI

- T equals the thickness of the material of the IQI. The three holes on the indicator have the diameter of T (thickness of the indicator), 2T (twice the thickness) and 4T (four times the thickness). The holes that can be resolved in the x-ray image indicate the image quality of the exposure.
- Illustration from http://www.ndt.net/article/v08n08/shahout/shahout.htm

Contrast Sensitivity Gauge

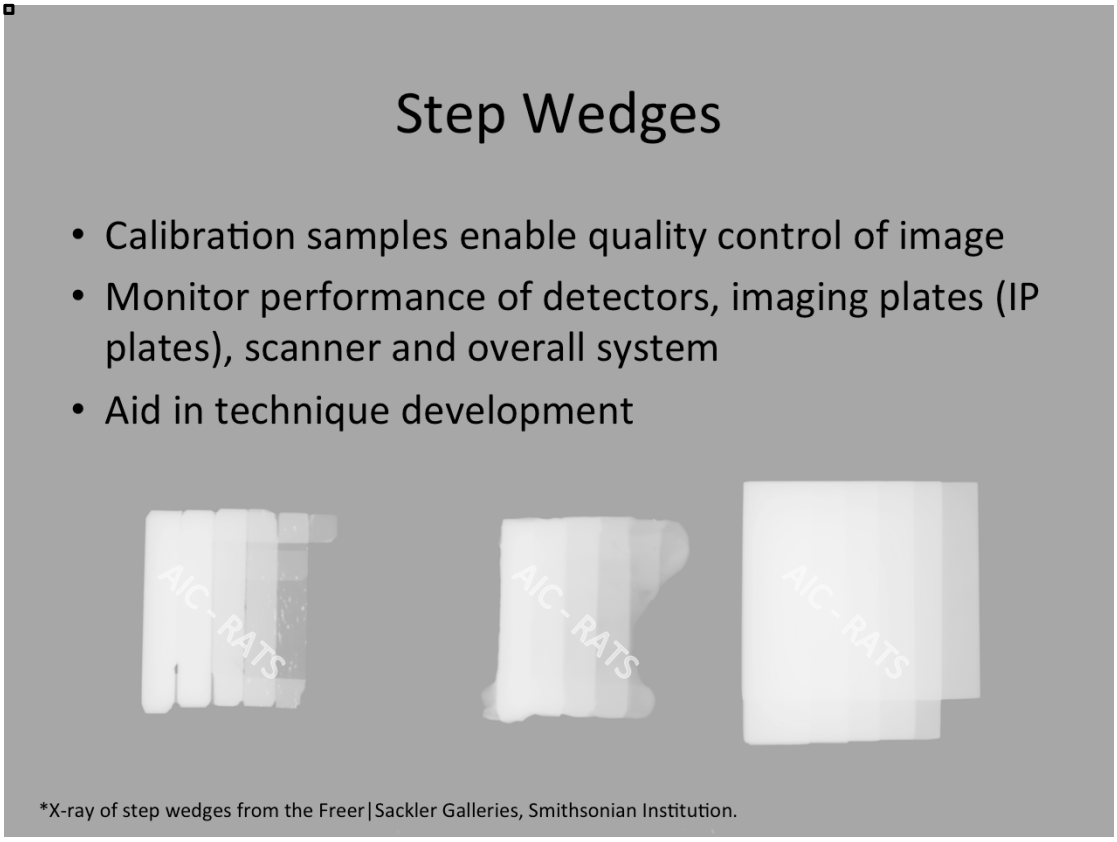
- These gauges have varying thicknesses of partial holes that represent 1%, 2%, 3,% and 4% transmission so you can check the sensitivity of the contrast in your image. This gauge measures contrast sensitivity independently from the imaging system's spatial resolution.
- Illustration from http://ndtsupply.com/ray-check-astm-e1646-contrast-sensitivity-gages.html

Duplex-wire IQI

- This IQI evaluates image unsharpness. The distance of the wire pairs is the thickness of the wires. As the unsharpness increases the line pairs begin to merge.
- Illustration from http://ndtsupply.com/ndt-duplex-penetrameters.html

- CR Phantom
  - A kit that incorporates several test objects that are included in ASTM E2445 so that they can be shot with one exposure.
  - Illustration from http://www.ndt.net/article/panndt2007/papers/145.pdf

These are not inexpensive standards and some must be composed of the same material that is being evaluated. Within cultural heritage digital radiography it can be hard to obtain a standard for each of the materials that might be imaged.



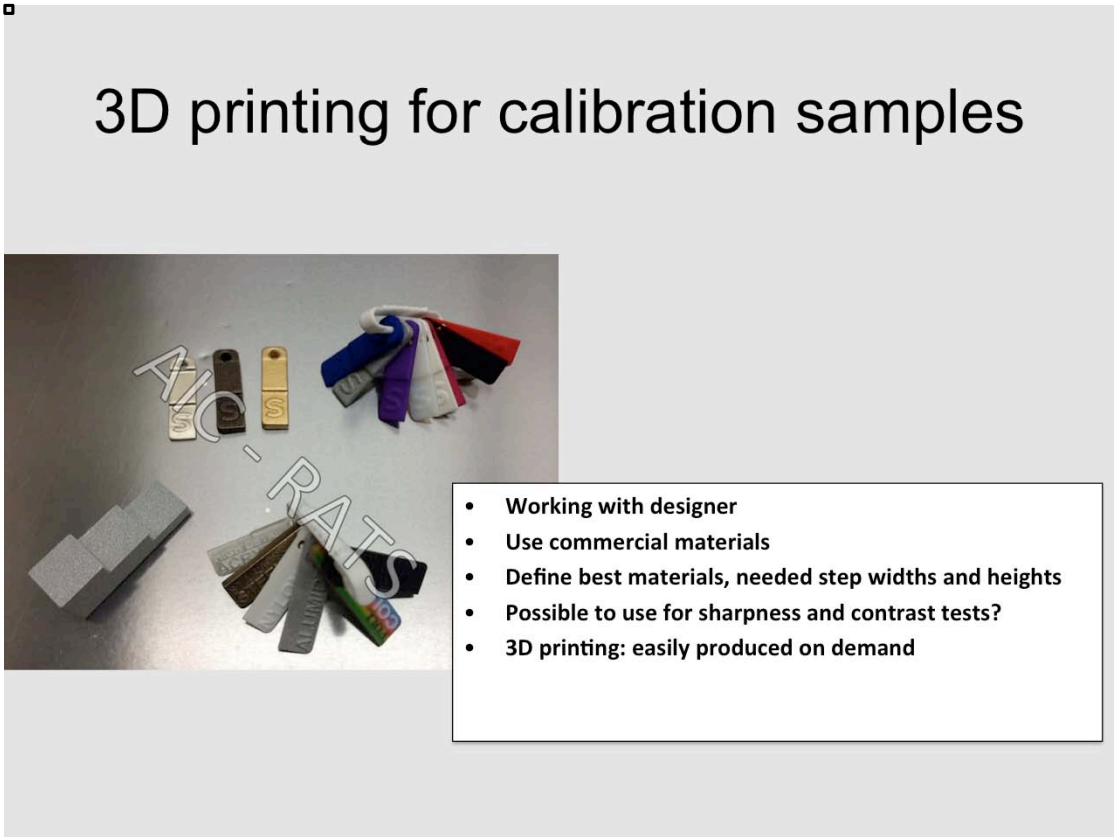
Step wedges can be used to test the consistency of a radiography set-up. They can be used to determine the linearity or non-linearity of exposure response to changes in time and current as well as the exposure response to changes in thickness of the object being radiographed.

If using multiple imaging plates (IP plates), step wedges can provide an easy check for differences between the plates, and a method to track changes in the plates over time.

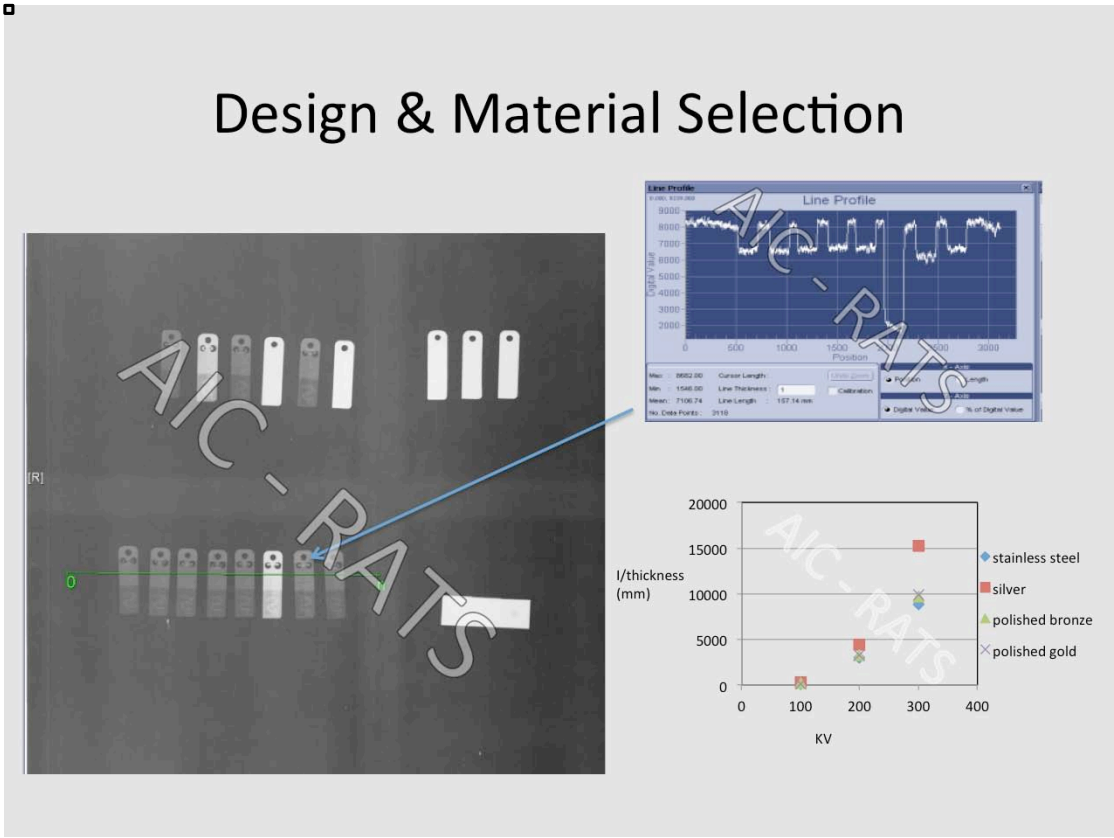
Calibration samples can make comparison between laboratories more straightforward. They can be used for comparison studies that incorporate objects from multiple museums/collections or adoption of techniques from other museums or other x-ray setups.

They can also be used to compare results from different detectors. If the power of two x-ray sources differs, you may need to adjust to get comparable exposures. The step wedge gives you a measurement to do so.

They are commonly used in film-based systems to guide selection of exposure conditions. This is generally not such a concern with digital systems due to their greater dynamic range.



Blythe McCarthy is working with a designer to develop calibration samples that could be printed on demand using 3D printing processes.

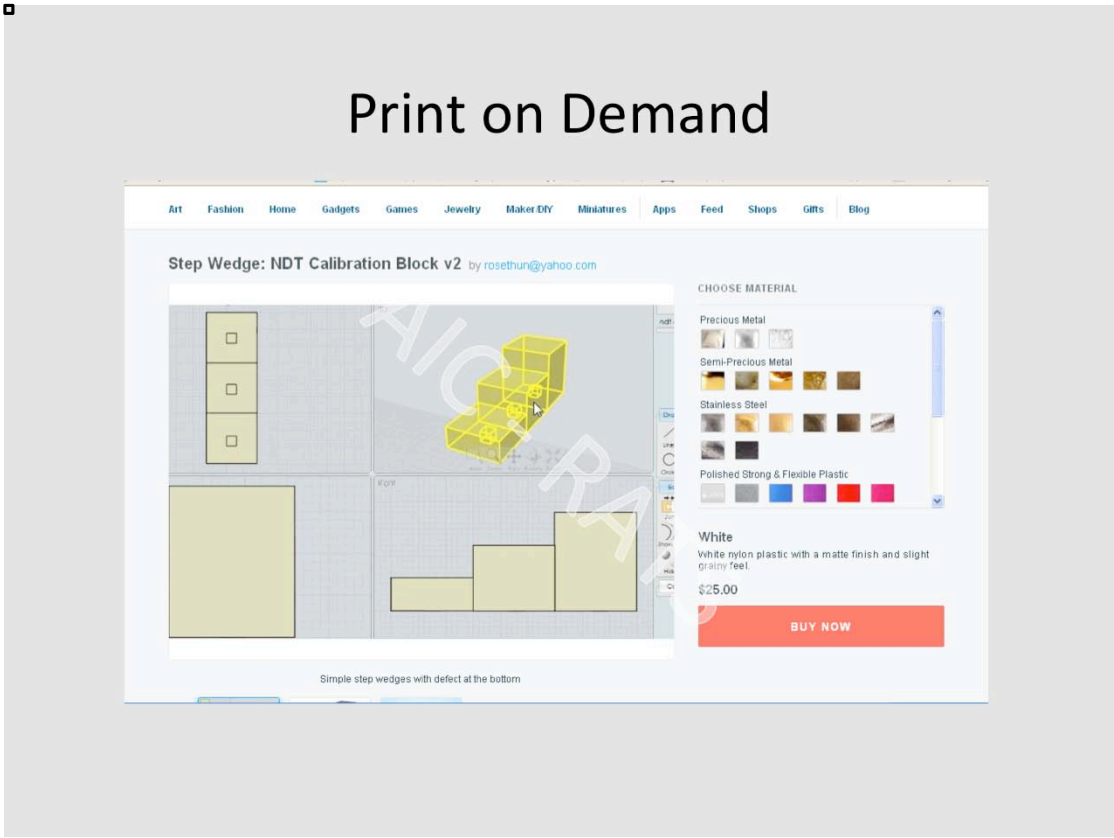


She carried out x-radiography of commercially available sample materials at a series of exposure conditions to see if colorants in the plastics would result in variable radiodensity. Colorants in the plastic (negative XRF results for inorganic pigments other than titanium suggest the use of organic dyes) did not result in variable radiodensity.

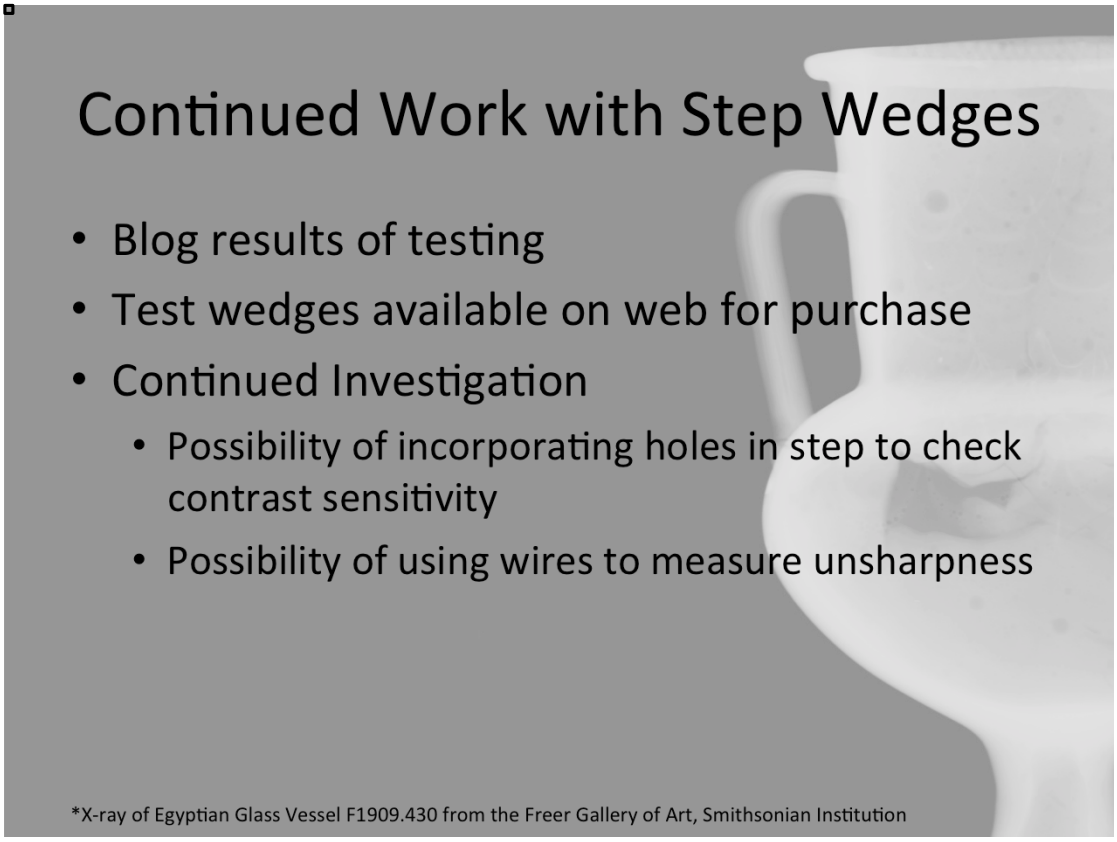
From these experiments, we have reduced our selection for further testing to two commercial plastics ("alumide" and "detail acrylic") and two metals (stainless steel and silver). Note that with the exception of silver, most of the metals tested so far, regardless of their name, are plated stainless steel, hence the similarity in results.

The graph at lower right shows the variation in image intensity versus kV. Intensity was divided by test sample thickness to correct for differences in thickness.

We are currently working out options for step wedge thickness that would cover a broad range of exposure conditions, object thickness, and that would use design and materials to minimize cost.



While these will not have the accuracy of test pieces designed for the NDT community, they should be much more affordable. The hope is to end up with test objects (step wedges) that can be used by many labs and that will make sharing between labs easier.


Continued Work with Step Wedges
• Blog results of testing
• Test wedges available on web for purchase
• Continued Investigation
• Possibility of incorporating holes in step to check contrast sensitivity
• Possibility of using wires to measure unsharpness
*X-ray of Egyptian Glass Vessel F1909.430 from the Freer Gallery of Art, Smithsonian Institution

Where do we go from here?

- Participation: please get involved with the website by contributing to the profile, blogging, resources areas.
- Communication: reach out to people working with similar materials or using the same equipment.
- Possible future digital/remote gatherings: in the couple of months preceding the 2014 conference, we had a panel discussion on Reflectance Transformation Imaging (RTI) using Google Hangout and YouTube.


Acknowledgements
Brooklyn Museum of Art
Lisa Bruno
Buffalo SUNY
Dan Kushel & JJ Chen
Design Rosetta, LLC
Rose Thun
Freer|Sackler
Jennifer Giaccai & Alison Schorr
LACMA
Yosi Pozeilov
National Museum of African Art
Dana Moffett
National Museum of Natural History
Chris Dudar & Sandra Raredon
Smithsonian Office of the Assistant Secretary of Education & Access
Peter Haydock & John Stafford
Walters Art Museum
Terry Weisser & Greg Bailey
Winterthur Museum
Lauren Fair & Mary McGinn
*X-ray of a ceramic mug belonging to E. Keats Webb

Mel Wachowiak, senior furniture conservator at MCI passed away on May 28 after a long struggle with cancer. Mel was the soul of MCI and a great asset for the Smithsonian. In his nearly 25 years there he brought in many imaging and microscopic techniques to the Smithsonian Institution, including 3D scanning, and he trained furniture conservators who are now in many of our nation's museums. He was very generous in sharing his knowledge with everyone and will be deeply missed.

Thank You!

E. Keats Webb, WebbEKeats@si.edu
Blythe McCarthy, McCarBl@si.edu

http://my.si.edu/DigitalX-ray

*Inverted X-ray of Friar Automaton 1977.1191 from the National Museum of American History, Smithsonian Institution