Spring 5-17-2014

Shifting Paradigm: A Detailed Exploration of 3D Technology in Museums

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A Detailed Exploration of 3D Technology in Museums

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May 2014

Submitted in partial fulfillment
of the requirements for the degree of
Master of Arts in Museum Professions

Seton Hall University
May 2014

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SETON HALL UNIVERSITY
College of Arts & Sciences
Office of Graduate Studies

APPROVAL FOR SUCCESSFUL DEFENSE

Master of the Arts Candidate, Alycia Piazza, has successfully defended and made the required modifications to the text of the master's thesis for the **MA** during this **Spring Semester 2014**.

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Mentor: Jüergen Heinrichs, Ph.D., Jürgen Heinrichs 7/9/'14

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Abstract

This thesis explores the impact of 3D technology on the overall museum experience. Detailed analysis of the current utilization of 3D scanning and printing in the areas of exhibition, conservation, research, accessibility, education, and programming, has yielded informed findings on the potential advantages and distractions this technology creates. The information discussed raises important questions and opens the doors to critical discourse; it provides museum professionals with valuable insight and theoretical suggestions on how to best incorporate this technology within the museum setting, with careful consideration to its capabilities for both the present and future.

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Introduction

Why Settle for 'Almost as Good'?

Judith H. Dobrzynski of the *New York Times* and *Arts Journal* wrote about a project that photographed a set of sculptures three-dimensionally. The project was done for a traveling exhibition known as "The Mourners" lasting from 2010-2012, which displayed fourteenth and fifteenth century tombs of the Dukes of Burgundy. The tombs on view included alabaster figures of monks and clerics circulating around the lower register of the tomb, as if it were a cloister; these carefully carved figures are known as "The Mourners."[1] With the help of FRAME, the French Regional American Museum Exchange, this exhibition traveled to seven U.S cities before it returned to Europe. During the exhibition's stay at the Dallas Art Museum, an ad hoc photo studio was created to capture 3D images of the tombs, paying close attention to "The Mourners" that surrounded them. The purpose of taking these photos was for a website to support the traveling exhibition, and best illustrate what these gothic style sculptures looked like to the greater public.

Reflecting upon the exhibition, Dobrzynski states, "right now, you can go there to get close-ups, with zoom-in capability of each of the Mourners—and you can rotate them, 360 degrees. It's not quite, but almost, as good as being there."[2] While capturing 3D photographs of these sculptures was a once-in-a-lifetime opportunity, and being able to share them with a larger audience is greatly beneficial, the fact that these images are "almost as good as being there" is alarming for the future of the museum experience.

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[1] "About the Mourners," FRAME 2010, http://www.themourners.org/about.html.

[2] Judith H. Dobrzynski, "The Exquisite Mourners, with a Website to (Almost) Match," *Arts Journal Blog*, March 22, 2010, http://www.artsjournal.com/realcleararts/2010/03/the_mourners.html

With museum applications available in 3D, and similarly, augmented and virtual reality, the way we look at objects in museums has drastically changed form the traditional approach of viewing objects inside glass cases. As technology continues to evolve rapidly, I have concerns regarding how powerful technology's presence can be in museums. By implementing 3D technology into a museum setting, those glass cases are then lifted, providing the visitors a different way to view and interact with the object. This technology raises many important questions, and the upcoming chapters will assess 3D from multiple perspectives to provide a comprehensive understanding of its function and purpose.

I. The Origins of 3D Technology: Past and Present

3D printing is projected to be as big as the steam engine, computer or even the internet [3] and according to the *Harvard Business Review*, it will "change how the world leans."[4] While the hype around 3D technology is currently at an all-time high, the technology is nothing new to the general public as it has been seen most commonly in movies, television, games, medicine, and animation. Previously, 3D printers were used to produce prototypes for various medical, automotive, and aerospace industries.[5] Within the last decade, this technology has taken on various areas of industrial design, healthcare, education, art, architecture, manufacturing, fashion, culinary arts, and the list goes on.

The ways in which 3D technology can be used in medicine are being discovered daily, currently the advancements made from 3D technology in healthcare can be seen in orthopedics, dentistry, implants, prosthetic limbs, and cellular printing. These new developments have inspired companies such as Organovo to focus on bioprinting, which creates living, functional human tissue.[6] Additionally, the new developments impact how pharmaceutical companies and

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[3] Rolfe Winkler, " Reading the Fine Print on 3D Systems" *Wall Street Journal*, September 5, 2013 accessed September 29, 2013, http://online.wsj.com/article/SB10001424127887323893004579057284020672944.html

[4] Richard A. D'Aveni, "3D Printing Will Change the World," *Harvard Business Review*, March 2013, accessed August 2, 2013, http://hbr.org/2013/03/3-d-printing-will-change-the-world/

[5] "Print Me a Stradivarius," *The Economist*, February 10, 2011, accessed July 29, 2013 www.economist.com/node/18114327

[6] "3D Human Tissues," 2013-2014 Organovo Holdings Inc. accessed on November 15, 2013, http://www.organovo.com/company/about-organovo

medical professionals conduct research; by providing researchers with more accurate results, giving them the skills to better inform drug companies and the public about failed drugs.[7]

Furthermore, Science, Technology, Engineering, and Mathematics, otherwise known as STEM, classes have been included into curricula around the United States. STEM allows students to work and experiment with 3D technology to develop original projects in Computer Aided Design (CAD) software and print their designs using the 3D printer. As I mentioned earlier, 3D printing affects ways in which research is conducted, it does the same for how we learn—and establishes new problem-solving skills. According to Lizabeth Arum, Education Coordinator at Makerbot Industries, "the process of modeling and printing is not just about creating a solid, watertight form—one has to think about how that model can be printed. Students are creating out of constraints, and these limitations are forcing them to think creatively. Because the printer allows students to make their ideas tangible, they are inspired by their results to work at a design until it meets their expectations. This process engages their attention and encourages perseverance."[8] Instituting this type of informal learning allows the students to see the process of developing an object from the initial design phases through the production, to completion, and welcomes creative inquiry along the way.

3D technology provides manufacturers, inventors, designers, and artists a new medium to work with. Manufacturers such as Boeing are able to print devices used to build and maintain

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[7] Cady Thompson, "How 3D Printers Are Reshaping Medicine," *CNBC*, October 10, 2012, accessed May 19, 2013, http://www.cnbc.com/id/49348354

[8] Barry Joseph, "How 3D Printers Advance Museum-based Learning: Interview with MakerBot's Founder, Bre Pettis, and education lead, Lizabeth Arum," *Moosha Moosha Mooshme Blog*, May 13, 2013, accessed June 1, 2013, http://www.mooshme.org/2013/05/how-3d-printers-advance-museum-based-learning-interview-with-makerbots-founder-bre-pettis-and-education-lead-lizabeth-arum/

aircrafts, print on demand, and customize specific items without raising the cost.[9] Fashion designers and architects can manipulate the structure and design of everyday objects. The material they use can differ from nylon to concrete. In the culinary world, this material used in the printer can include various food pastes, to print anything from pasta to meatloaf.[10]

While this technology continues to flourish, I want to look at how it is affecting the world around us, what it is capable of, its advantages and disadvantages, and most importantly do so within the context of a museum setting. Is 3D printing a gimmick? Or is it the way of the future? Technology has become a common staple in our everyday lives and routines. An iPhone audio-guide or museum map from Google Maps, is convenient and accommodates the needs of the museum's visitors. However, I wonder if the inclusion of 3D technology in museums is just a marketing wow-factor; used to draw audiences in through the door, but will fade with time after this technology has been exhausted.

Liz Neely and Miriam Langer, authors of the conference paper "Please Feel the Museum: The Emergence of 3D Printing and Scanning" from the 17th Annual Museum and the Web Conference, remind us "the emergence of a 3D production ecosystem that is broadly accessible both in cost and ease of use makes this technology of particular and immediate interest to museums."[11] Each day the possibilities of 3D technology continue to develop. In this essay I will

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[9] Thomas Campbell, Christopher Williams, Olga Ivanova, Banning Garrett, "Could 3D Printing Change the World?" The Atlantic Council: Strategic Foresight Report, October 2011, accessed August 10, 2013, http://www.atlanticcouncil.org/images/files/publication_pdfs/403/101711_ACUS_3DPrinting.PDF

[10] A.J.Jacobs, "Dinner is Printed," *New York Times*, September 21, 2013, accessed on September 25, 2013, http://www.nytimes.com/2013/09/22/opinion/sunday/dinner-is-printed.html?src=recg&_r=0

[11] Liz Neely and Miriam Langer, "Please Feel the Museum: The Emergence of Printing and Scanning," (Paper presented at the annual conference of Museums and the Web, Portland, Oregon, April 17-20, 2013) http://mw2013.museumsandtheweb.com/paper/please-feel-the-museum-the-emergence-of-3d-printing-and-scanning/.

explore how this technology affects, changes, and modifies the museum experience. While this is a rapidly emerging and constantly evolving technology, this research will have to be continued. I realize that upon completion—this could be outdated, but I believe the issues explored provide a solid foundation for future research efforts and provide museum staff a better understanding for this technology; the uses, applications, benefits, and issues that arise.

3D technology can be used in a number of ways, scanning and printing are the core functions being applied in museums. Before getting into detail about the ways in which 3D technology is being introduced and used in museums, let us first define the term "3D." According to Leonard Steinbach, author of "3D or Not 3D? Is that a Question?" 3D is "defined by the three axes of height, width and depth."[12] Adam Metallo and Vince Rossi, 3D digitization coordinators currently working on a 3D digitization project at the Smithsonian, define 3D as being very broad with a meaning that can change depending on the context, but note that it is "digitally capturing the geometry of an object most often in the form of high-density 'point clouds.' These point clouds may then be processed further." Metallo and Rossi go on to say "once an object is captured in 3D, you have the ingredients for anything from a Hollywood-style-pop-out-of-the-screen experience, to a scientifically reliable dataset used for research and education."[13] This definition is valuable because it provides a comprehensive understanding of what 3D technology is capable of. To scan and print an object, capturing the geometry of an object, its height, width, and depth is the first step in doing so.

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[12] Leonard Steinbach, "3D or Not 3D? Is that a Question?" *Curator: The Museum Journal* 54, no. 1 (January 2011): 42.

[13] Adam Metallo and Vince Rossi,"The Future of Three-Dimensional Imaging and Museum Applications," Curator: *The Museum Journal* 54, no. 1 (January 2011): 63.

3D printing is an example of additive manufacturing, which builds an object layer by layer using a 3D printer. According to the American Alliance of Museum's TrendsWatch 2013,"instead of removing excess stuff," with 3D printing you can "build an object bit by bit, either by extruding materials from a nozzle or solidifying particles of organic or inorganic raw materials. Whatever the specific printing technology, digital information is translated into a series of physical cross-sections, which the printer lays down in successive layers of liquid or powder and fuses to form a solid object."[14] This process is different from subtractive manufacturing, a more traditional technique, which begins with a raw material and cuts away at it, to create the desired object. Constructing an object through additive manufacturing uses a CAD sketch, or computer-aided design. This sketch, is a digital drawing or blueprint that the printer reads to create the object.[15] The CAD holds all information about the object and the model can be used if the object was scanned or not; as these designs replace the need to physically design prototypes, because it can be done through the software.[16]

MakerBot's Thingiverse, is an online community that fosters creating 3D printed objects. One of the ways MakerBot gets users involved is by creating a forum to share the files produced from the computer-aided design program, so anyone can print an object from anywhere. Under

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[14] Elizabeth E. Merritt and Philip M. Katz, "TrendWatch 2013: Back to the Future," *American Alliance of Museums* (2013): 14.

[15] Satwant Kaur, "How is 'Internet of the 3D Printed Products' Going to Change our Lives?" *IETE Technical Review* 29, no. 5 (Sept-Oct 2012): 360.

[16] Michael Weinberg "It Will Be Awesome If They Don't Screw It Up: 3D Printing, Intellectual Property, and the Fight Over the Next Great Disruptive Technology" *Public Knowledge*, November 2010, accessed on July 25, 2013, http://www.publicknowledge.org/news-blog/blogs/it-will-be-awesome-if-they-dont-screw-it-up-3d-printing

the Creative Commons license, users are able to not only print the design but alter or change it.[17] This site gets independent 3D printer users involved within a greater community and encourages experimentation. Museums have started to post objects from its collection, in a 3D format, onto Thingiverse for users to print. On the site you can find the Art Institute of Chicago's 5th-6th century Horse, various ancient Roman and Greek Busts, fertility figures, and busts of Egyptian Pharaohs. As 3D printing welcomes invention and creativity, museums must find a way to make this resource meaningful. In the upcoming chapters I will delve deeper into the importance and benefits of museums sharing files, and how that ultimately affects the visitor and their experience.

As mentioned above, the process of 3D printing begins with the creation of a computer-aided design (CAD). A CAD can come from the scan of an existing object or an original design. This model or blueprint that is created dissects the information into cross sections, allowing the printer to print in layers; therefore producing an STL file captures the object's geometry. STL or Standard Tessellation Language, "renders surfaces in the CAD design as a mesh of triangles. The number and size of the triangles determine how accurately curved surfaces are printed."[18] This is beneficial for a museum's collection because it records the exact geometrical dimensions of an object. If the object were damaged, for example, this file would help reconstruct its complete dimensions. Now that the STL file is completed, it can be sent to the printer and the printing process can begin.

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[17] "About Thingiverse" MakerBot Thingiverse, 2014 http://www.thingiverse.com/about

[18] "CAD to STL," Stratasays, Ltd 2013 http://www.stratasys.com/customer-support/cad-to-stl

Furthermore, additive manufacturing is beneficial for creating more detailed items and has not yet gone mainstream due to high cost, slow production, and failure to reach high quality standards. Currently, 3D printing lends itself more to the inventor, artist, or small business owner in their efforts to build custom designed products. With that being said, museums have adapted this technology because it is customizable, meeting each institution's specific needs; whether that be in exhibitions, research, accessibility, conservation, programming, or education.

One of the ways in which 3D technology is currently being used in museums is for scanning, digitizing, and printing objects. This is the case at the Smithsonian, which is undergoing a project to three-dimensionally digitize 10% of the collection, this percentage consists of 137 million objects.[19] Adam Metallo and Vince Rossi are the two people working to complete this daunting task, and first came to the Smithsonian as model makers. They are now heading the 3D digitization project and aim to "digitize these huge collections in 3D—everything from insects to aircraft. Our day-to-day job is essentially trying to figure out how to actually accomplish that. How do we take 3D digitization and take it to the Smithsonian scale? We're at the ground floor of trying to understand that."[20] The tech savvy duo began by brainstorming how this technology could be used to assist in their daily duties at the museum, originally asking the question "how can we use it to make better exhibits?"[21] They soon realized the full potential and the benefits that 3D technology brings to the various departments of a museum. Rossi and Metallo started "to apply

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[19] Gunter Waibel, "About Smithsonian X 3D" Smithsonian Institute: Digitization Program Office, accessed on November 1, 2013, http://3d.si.edu/about

[20] Sam Pfeifle, "Scanning at the Smithsonian," Sp*ar Point Group*, February 1, 2012, accessed on June 6, 2013, http://www.sparpointgroup.com/News/Vol10No5-Scanning-at-the-Smithsonian/

[21] "Interview with Smithsonian X 3D Team about 3D Printing Initiative" *On 3D Printing Blog*, November 20, 2013, accessed on December 10, 2013 http://on3dprinting.com/2013/11/20/interview-smithsonian-x-3d-team-3d-printing-initiative/

the tech towards research, conservation and collections applications. Our motivation is many-fold, but ultimately we want to use this technology to help tell stories about our collection and share our knowledge beyond our physical museum walls."[22] Since the Smithsonian's collection is so extensive, only 1% is shown in the galleries and exhibitions to the public. With creating a digital archive and replicas, this collection, which has previously not been utilized to the fullest, can be shared with a global audience.

In 2012 the 3D System's Corporation partnered up with the Smithsonian in a multi-year agreement to provide the technology and printing services for the project. According to 3D Systems, the agreement "supports a Smithsonian-wide effort to strengthen collections stewardship and ensure the accessibility of its vast and diverse collections through exploring the possibilities of 3D representations."[23] Abe Reichental, President and CEO of 3D Systems continued to say, "we are honored and excited to be part of this visionary Smithsonian initiative, to increase the visibility and accessibility of our national treasures for all. The Smithsonian has shown both foresight and technological leadership in embracing the potential of 3D printing to preserve and showcase today's and tomorrow's collections, making them readily available to a global audience while demonstrating the power of 3D content-to-print in a compelling and meaningful way."[24]

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[22] Ibid.

[23] 3D Systems Corporation 2013, "3D Systems Partners with the Smithsonian on Landmark 3D Digitization Project,"3D Systems Press Release, September 24, 2012, accessed on November 15, 2013, http://www.3dsystems.com/press-releases/3d-systems-partners-smithsonian-landmark-3d-digitization-project

[24] Ibid.

While the initial intent of the scanning project was to make better models, now that Metallo and Rossi have started building the digital archive of 3D images, they have the ability to repurpose this information for avenues beyond just printed models. This information can be translated and made available online to researchers, students, and the public;[25] which is a remarkable advancement in sharing a museum's collection, especially considering only 1% of the Smithsonian's collection is normally seen by visitors. This also gives online users more than just a static image—they can interact with the 3D asset by turning it, zooming, and carefully examining it from any angle. Additionally, implementing this technology is not only a great way to share the Smithsonian's extensive collection, but it also serves as an excellent method of preservation. Objects that are too fragile to be put on display can be preserved in a 3D image and shared with the public.

The History of 3D Technology

The concept of stereography was introduced to photography during the early 1800s, giving viewers a sense of scale and likeness on a two dimensional plane. The stereograph, or stereogram, is defined as a "double photograph or printed image paired in such a matter that, when viewed with a stereoscope, it appears as a three-dimensional or solid image."[26] This concept was further examined in 1838 by Charles Wheatstone, when he published a paper that provided the scientific support for stereography; "showing that the brain unifies the slightly different two-di-

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[25] "Smithsonian Turns to 3D to bring Collection to the World," *CNET*, February 24, 2012, accessed on October 20, 2012, http://news.cnet.com/8301-13772_3-57384166-52/smithsonian-turns-to-3d-to-bring-collection-to-the-world/

[26] William C. Darrah, *The World of Stereographs*, (Gettysburg, PA 1977), 1.

mensional images from each eye into a single object of three dimensions."[27] Wheatstone first experimented by drawing two images and placing them side by side, this practice then became replaced by displaying a double photograph. To view the stereograph, Wheatstone made a stereoscope to view the two images, which were each at a slightly different angle, placed on either side of a wooden bar.[28] This obstruction between the images aided in creating an illusion solidity and depth.

In the mid 1800s William Brewster invented the lenticular stereoscope, and as a result the popularity of the stereograph grew. The fact that this device was lens-based differed from Wheatstone's plans. The lenticular stereoscope is a "closed box with one or two openings for light; two lenses are located on the top and enable the viewer to see a 3D image on the floor of the box."[29] It was a lenticular stereoscope, on display at the Great Exhibition of 1851, that caught the attention of the Queen. At this time, the demand for stereographs increased and by the late 1800s stereoscopes were manufactured for public sale. Brewster's stereoscope was the main design for about 25 years, until the hand held stereoscope was designed.[30] This invention improved previous design functions, while also offering the user convenience and mobility. Nevertheless, what was it about this technology that intrigued and enthralled users?

The answer lies in the stereograph's involvement in, and promotion of, the exploration of geographies—entertaining, educating, and engaging viewers about travel. Pauline Stakelon wrote

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[27] Lisa Spiro, "A Brief History of Stereographs and Stereoscopes,"*OpenStax-CNX*, October 30, 2006, accessed November 2, 2013, <http://cnx.org/content/m13784/1.5/>

[28] Sarah Atkinson, "Stereoscopic- 3D Storytelling- Rethinking the Conventions, Grammar and Aesthetics of a new Medium,"*Journal of Media Practice* 12, no. 2 (September 5, 2011): 139, 140.

[29] Spiro, "A Brief History of Stereographs and Stereoscopes," http://cnx.org/content/m13784/1.5/.

[30] Darrah, *The World of Stereographs*, 2-3.

about the purpose of the stereograph, how it "sought to offer an enhanced visual experience of reality through creating the illusion of three-dimensionality in photographs and drawings."[31] Stereographs provided the public with different ways to see and then learn about different regions and cultures. Largely used for educational purposes, stereographs were utilized for tourism, as people visiting different places would take a stereograph home as a souvenir. By keeping this item, it became an important part of revisiting memories thus making them more meaningful. John Falk includes anthropologist Clifford Geertz's definition of meaning, recalling it is "our mind's way of making sense of the world; the translation of existence into conceptual form."[32] These stereographs, created a strong connection to the viewer and their memories. Something that continued to build meaning long after they had left the destination photographed, for example.

The increased interest of travel and exploration was made possible through the investigation of these areas of interest—often captured by various photographers: architecture, still life, sculpture, natural scenery, and the group.[33] Architecture from cities around the world were depicted in stereoviews, along with the ruins from Rome, Naples, Athens, Egypt, and the Holy Land. The views taken were from both the exterior as well as the interior of buildings and cathedrals, to reveal the stained glass, vaulted ceilings, and stylistic differences between the Renaissance, Baroque, Gothic, and so on. Still life stereoviews captured "ingenious arrangements to

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[31] Pauline Stakelon, "Travel Through the Stereoscope: Movement and Narrative in Topographic Stereoview Collections of Europe" *Media History*, 16, no. 4 (2010): 408.

[32] John Falk, *Identity and the Museum Visitor Experience*, (Left Coast Press, 2009), 137.

[33] Darrah, *The World of Stereographs*, 16.

exploit detail, create graceful spacial parameters, and achieve artistic appeal."[34] Photographers developed enthralling compositions full of unusual objects to draw the viewer in for further study and examination. Reproducing sculptures gave photographers the opportunity to scour through prominent museum collections such as the Louvre, Vatican, and British Museum for material. This not only was used for educational purposes but it also allowed the museum to reach a wider audience and gain exposure.

Scenic stereoviews captured both natural and romantic shots of landscapes from around the world; this varied from rural scenery, seascapes, to images of the Swiss Alps. Photographers experimented with the angles to produce a sharper image, often referred to as an "instantaneous" shot. This technique called for a quick shutter time, yielding a shorter exposure. Depending on the landscape of the stereoscope the image would show qualities of movement, therefore creating an illusion of travel. Lastly, group views included two or more people in the frame. The objective of the group shot, was "to be pictorial, the effect being achieved by staging and enhancing by a wide variety of printed backgrounds and stage properties."[35] Furthermore, it was the photographer who also added nuances to enhance the image to fit either a nostalgic, sentimental, moralistic, allegorical, humorous, risqué or erotic theme.[36] The stereograph was a breakthrough invention which allowed viewers to interact and connect with an image. It altered the qualities of the photograph to reproduce the experience in a more immersive way, with the inclusion of another di-

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[34] Ibid, 17.

[35] Ibid, 19.

[36] Ibid, 18.

mension and movement. This basic idea of recreating human vision has grown and morphed since the eighteenth century and remains the foundation of 3D technology today.

The history could not be complete without mentioning the use and importance of casts. People have been creating casts of objects and full plaster casts of monuments since the fifteenth century; as it was a popular way to share the knowledge of art. While the process of creating the mold may have evolved, the intentions have stayed the same. David Bearman recalls the importance of casts at the Victoria and Albert Museum. Formerly known as the Kensington Museum which opened in 1873, the museum displayed "replicas of famous sculptures from around the world, made by leading artisans of the day and certified by national agencies in the countries of origin, were exhibited for popular and scholarly study."[37] The technical process of plaster casting is best described by the Victoria and Albert Museum stating:

> The first stage in the production of a cast is the taking of plaster moulds from the original, using a separating agent to prevent the plaster sticking to the surface. Since all sculpture, other than that executed in very low relief, has projections and undercutting these moulds were invariably made in many pieces. The piece moulds would then be enclosed in an outer casing, the interior coated with a separating agent and the wet plaster poured in. The divisions between the piece moulds produces a network of casting lines on the completed plaster cast. As the number of these lines shows, the casting process demanded

[37] David Bearman, "3D Representations in Museums," *Curator: The Museum Journal* 54, no. 1 (January 2011), 57.

> specialist skills and the production of a cast such as the Portico de la Gloria executed by the London firm of Brucciani, represents a formidable technical achievement.[38]

The ways in which plaster casts were used throughout Antiquity up to the Renaissance yield similar results to the ways in which 3D copies and replicas are used today. Plaster casts, at the time, were the cheapest way to produce precise replications that could be distributed amongst the greater population. Museums and private collectors could fill in gaps of their collection, while educating the public as well as artists. Creating 3D replicas by scanning and printing objects affords similar outcomes. As 3D printing becomes more affordable than it has in the past, museums can continue to share their collections with museums around the world, and the public can print their own museum objects, to create a personal collection. The main difference with creating casts and 3D replicas is that the object or sculpture has to be physically moved or touched; creating a 3D replica uses laser scanning and the object barely has to be moved. The object can be printed using various materials such as metals, plastics, and glass. The desired material is layered one piece at a time until the object is formed in its entirety, using a computer-driven machine. This process keeps the object out of harm's way, the risk of damaging the original during the casting process is negated.

Edna Harris, author of "Plaster Casts" published in 1899, explains the importance of well made casts to educate the masses. Harris states:

> Of course, authentic casts, made with care, are more valuable than marbles or bronzes, not in material, but in what counts for more than that, in workmanship and understanding.

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[38] Baker, Malcolm."The History of the Cast Courts," *Masterpiece Series*, Victoria and Albert Museum, 1982, Revised in 2007. Accessed on October 20, 2012. http://www.vam.ac.uk/content/articles/t/the-cast-courts/

> Examine a good cast care fully; you see it has no seams (poor ones have none, either, for they have been merely papered off); but more than that, you see the tense muscle, the curve of the neck, the carelessly falling drapery, just as in the original work. Then this will be the end of this art (may we call it so?), to reproduce and preserve the works of great masters of all times for the enlightenment and education of the world.[39]

This passage reminds us of the importance plaster casts have to offer, and how crucial it is to effectively replicate the object. While creating plaster casts of objects is something of the past, 3D printing revitalizes this practice, purpose, and ultimately provides us with similar results. 3D technology, such as scanning and printing, allows us to go further than before—and offers more opportunity for learning about and studying objects.

By understanding the history of 3D technology, how it derived and flourished from concepts of stereography and casting techniques, we are able to see its impact and possible path. The same needs, wants, and ideas of which founded stereographs and casts can be seen in the ways 3D scanning and printing is used today. Now that the foundation has been set for describing what 3D technology is, where it originated, and how it developed into what we know today, the upcoming chapters will explain the technical aspects of 3D scanning and printing with current museum examples as to how it is being used, along with the advantages and disadvantages that arise.

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[39] Edna Harris, "Plaster Casts," *Brush And Pencil* 5, no. 2 (November 1899): 59.

II. Timeliness of 3D Printing:
Why at this Historical Moment?

In 2009, President Obama presented his campaign "Educate to Innovate" to the public. With a goal to strengthen American students skills and proficiency in math and science, the president hopes to move these students from average to above par over the next decade. During the launch, President Obama declared, "students will launch rockets, construct miniature windmills, and get their hands dirty. They'll have the chance to build and create—and maybe destroy just a little bit—to see the promise of being the makers of things, and not just the consumers of things."[40] 3D technology has been a crucial element for the public transition from consumers to makers. Before we further discuss the direct impact 3D technology has on museums with specific examples, it is important to understand why this technology trend has come to fruition.

In 2008 the American Association of Museums published "Museums & Society 2034: Trends and Potential Futures," forecasting an upcoming "creative renaissance." The essay pulls research from James Chung, Susie Wilkening, and Sally Johnstone's Reach Advisors national survey, compiling information from young adults on issues outside of museums. The survey indicates "the emergence of a cultural shift that may prove to be a full-blown creative renaissance. The result will be a generation of adults with more extensive creative pursuits than any other generation. This generation grew up with a broad palate of digital tools and creative resources; as a re-

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[40] Devin Dwyer, "Obama Calls for Annual Science Fair: Achievement Should be Recognized like NCAA Championship Win" *ABC News*, November 23, 2009, accessed on January 5, 2014, http://abcnews.go.com/blogs/politics/2009/11/obama-calls-for-annual-science-fair-achievement-should-be-recognized-like-ncaa-championship-win/

sult, they are demonstrating an extraordinarily high level of creative output and creative consumption."[41]

The increasing interest of 3D printing is no doubt a result of the digital age we are in and the current trend known as the "maker movement." A 2011 report in *The Economist* says:

> The maker movement is both a response to and an outgrowth of digital culture, made possible by the convergence of several trends. New tools and electronic components let people integrate the physical and digital worlds simply and cheaply. Online services and design software make it easy to develop and share digital blueprints. And many people who spend all day manipulating bits on computer screens are rediscovering the pleasure of making physical objects and interacting with other enthusiasts in person, rather than online.[42]

The maker movement is strongly connected to the DIY, do-it-yourself, community which with the inclusion of 3D printing has created an entire subculture devoted to making, inventing, fabricating, building, and meddling with objects. These "makers" are harnessing open-source methods, through sites such as Makerbot's Thingiverse and Instructables which provide public access to various designs and blueprints to create and alter objects. These methods coupled with the latest technology, such as 3D printing, escort "manufacturing out of its traditional factory context,

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[41] Elizabeth Merritt, "Museums & Society 2034: Trends and Potential Futures," *American Association of Museums* version 1.0, (December 2008): 16.

[42] "More than just Digital Quilting," *The Economist, Technology Quarterly*: Q4 2011, December 3, 2011, accessed on December 15, 2013, http://www.economist.com/node/21540392

[43] Sam Gustin, "How the 'Maker' Movement Plans to Transform the U.S. Economy" *Time Magazine*, October 1, 2012, accessed on January 5, 2014, http://business.time.com/2012/10/01/how-the-maker-movement-plans-to-transform-the-u-s-economy/

and into the realm of the personal desktop computer,"[43] which is widely and easily attainable in homes around the world.

Comparably, Chris Anderson, editor-in-chief of *WIRED Magazine* from 2001-2012, believes this technology has "democratized the means of production" and he further explains, "until recently, the ability to manufacture was reserved for those who owned factories. What's happened over the last five years is that we've brought the Web's democratizing power to manufacturing. Today, you can manufacture with the push of a button."[44] By democratizing the power manufacturing holds, Chris Anderson believes this technology can grow and develop to be, like the laptop computer, in everyone's homes and away from major companies. By removing the power from manufacturing companies, individuals will be able to control their product design and consumption. This is a strong statement to make; is this technology capable of such power? Does this technology contain the longevity to one day build and create everything we want?

To find reason and possible hypotheses to these questions, it is important to look at our target audience; as this has changed and will continue to. Understanding the audience of the museum is crucial for understanding the visitor's motivation and identity. This drives the museum to make alterations to fit the generation's interest. With the museum visitor changing almost as fast as the technology is, Graham Black author of *Transforming Museums in the Twenty-First Century*, repurposes Tom Fleming's idea that cultural institutions need to "change or die."[45] Black sug-

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[44] Ibid.

[45] Graham Black, *Transforming Museums in the Twenty-First Century*, (Routledge, New York, NY: 2012): 1.

gests rethinking the ways in which museums have functioned for the past twenty years. Therefore, the traditional approach of viewing objects, behind glass cases, and interacting in museums must change. While often museums are late adapters to technology or change in general, Black pushes for museums to become an engaging museum that "must work to place itself at the heart of the communities it serves."[46]

With that being said, let us look at the various generations of people who visit museums. The silent/mature generation born between 1927-1945; this generation came from families of the Great Depression and grew up during World War II.[47] While this generation is not tech-savvy, they are supporters of museums and are more frequently museum advocates than younger generations. The baby boomers which came after the silent generation, were born between 1946 and 1964. This group grew up after WWII and saw first hand the "explosion of mass media, as television in particular united the nation and gave it a common voice,"[48] and were shaped by their experiences during a time of radical social change. Generation X, the generation born between 1965 and 1978 do not necessarily have a strong group identifier. Nevertheless, they are hard working, educated, and carry a sense of independence as they are known for "growing up amidst a rapidly evolving family structure."[49] By understanding the values, needs, and aspirations as well as the economic environment, developmental experiences and life stages, we, as museum professionals, are able to understand how to best transform the museum.

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[46] Ibid, 11.

[47] Susie Wilkening and James Chung, *Life Stages of the Museum Visitor*, AAM Press, Washington D.C, 2009, p. 10.

[48] Ibid.

[49] Ibid, 9.

Similarly, the younger generations Y and Z play an important role in the maker movement and also in the future of museums. According to Susie Wilkening and James Chung, generation Y also known as the millennials, born between 1979 and 1999, are "the generation behind the implosion of conventional mass media and traditional sources of 'curating' culture."[50] Growing up with technology, this generation has been exposed since inception and have become masters of multi-tasking. This group is keen on social networking and is always "connected" to the internet, which is often used to customize or filter their world. This is not to say that other generations such as generation X and the baby boomers do not know much about technology, both groups are likely to use the internet for research, join activities or search government sites, make purchases, download music, and utilize online banking.[51] According to the PEW Research center, "millennials are on course to become the most educated generation in American history."[52] Generation Y experienced first hand the 2008 recession, how it affected their parents and themselves in terms of jobs. With that being said, this generation shows high signs of optimism as they are on the search to "follow their dreams" and find the perfect job.[53]

Furthermore, the newest generation, Z, is currently being born began in the late 1990s, early 2000s until today (2013). This is the second generation to grow up with the internet at their finger tips, as this generation's "connectivity" is innate. While the previous generation shares

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[50] Ibid, 8.

[51] Kathryn Zickuhr, "Generations 2010," *PEW Research Center*, December 16, 2010, accessed on January 20, 2014, http://pewinternet.org/Reports/2010/Generations-2010.aspx

[52] Paul Taylor and Scott Keeter, "Millennials: Confident, Connected, Open to Change," *PEW Research Center*, February 2010, accessed on January 20, 2014, http://www.pewinternet.org/2010/02/24/millennials-confident-connected-open-to-change/

[53] Cal Newport, "Solving Gen Y's Passion Problem," *Harvard Business Review*, September 18, 2012, accessed January 20, 2014, http://blogs.hbr.org/2012/09/solving-gen-ys-passion-problem/

signs of optimism, young generation Z shows a more realistic approach. As they have entered a world post 911 and have experienced the terror of school shootings. Still, their realist qualities and access to the internet make them self-sufficient, seeking facts and fast information. According to the Cassandra Report, which pulls from 400 interviews conducted with adolescents ages 7-13, "generation Z sees little distinction between their digital and physical worlds. They aim to seamlessly engage with both. Marketers should begin to think about ways to further integrate their digital and physical communications, creating products, content, and games that feature both tangible and virtual elements working together and well."[54] These two young groups of people, are fully immersed in various modes of technology and it is because of them that museums re-think ways to incorporate technology into their institution—to meet the growing needs of their audience. If using Facebook, iPad apps, cell phones, virtual reality, and 3D technology is something that the public is holding on to and learning from, it is expected for museums to adopt it as well.

The Practice of 3D in Museums

Let us revisit the Smithsonian's 3D project that began in 2012 with the initiative to use this "technology to help tell stories about our collection and share our knowledge beyond our physical museum walls."[55] The project's leaders, Adam Metallo and Vince Rossi quickly realized that this project to digitize the 10% of the museum's collection, impacts not only the exhibition aspect of the museum, but conservation, access, and education. Both Metallo and Rossi hope

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[54] Lisa Cohen, "Intelligence Group's Gen Z Cassandra Report Paints Portraits of Independent Rebel Kids with Purpose" *The Cassandra Report*, May 12, 2013, accessed on January 15, 2014, http://www.cassandra.co/wp-content/themes/trendcentral/pdfs/IG_Tween_PR.pdf

[55] "Interview with Smithsonian X 3D Team about 3D Printing Initiative," http://on3dprinting.com/2013/11/20/interview-smithsonian-x-3d-team-3d-printing-initiative/

"this initiative will eventually lead to scores of 3D printed exhibits, as well as countless 3D models that could theoretically be used in the museums, in schools, or just about anywhere people have an interest in the Smithsonian's vast physical holdings."[56]

The Smithsonian's 3D endeavor began with the help of RedEye On Demand to create a "digital surrogate" of Monticello's life-size Thomas Jefferson statue, which was included in the Smithsonian's National Museum of African American History and Culture 2012 exhibit *Slavery at Jefferson's Monticello: Paradox of Liberty*. Instead of using the traditional method to produce a replication, which would be to make a rubber mold to create a caste, the Smithsonian's Digitization Program office decided to utilize modern technologies. Scans were taken, using a laser scanner and digital cameras to capture the geometry of the object from various angles, then the scans were used to produced a CAD model of the object. This method is much more efficient than creating casts, because the object does not need to be moved or touched—reducing any harm to the object. The completion of this single project took nearly 400 hours.[57] Due to the life-size of the sculpture, the piece was printed in sections, made from thermoplastics, assembled, and painted a bronze color for further affect. According to Mick Schrempp, RedEye Account Manager, who worked with Vince Rossi and Adam Metallo of the Smithsonian on this project, the "outer wall of the statue is about .075 of an inch thick. The inside looks like a honeycomb."[58]

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[56] "Smithsonian Turns to 3D to bring Collection to the World," http://news.cnet.com/8301-13772_3-57384166-52/smithsonian-turns-to-3d-to-bring-collection-to-the-world/

[57] "Thomas Jefferson in the House," *RedEye On Demand*: Case Study, 2014, accessed on April 15, 2013, http://www.redeyeondemand.com/CS_TJefferson.aspx

[58] Ibid.

This design makes the sculpture more light weight, durable, easily transportable, and more cost effective.

While this details only the first of the Smithsonian's efforts to digitize and print their holdings, this example shows the possibilities available with this technology. These efforts further reflect the Smithsonian's mission to increase and diffuse knowledge with a vision of "shaping the future by preserving our heritage, discovering new knowledge, and sharing our resources with the world."[59] For museums and its collection, being able to share the collection is crucial, however once they leave the institution the objects are in jeopardy and prevention is important. In terms of conservation, it is best to minimize these risks. Being able to safely print an object, in its exact replication and in a cost effective manner, the places it can be seen are endless.

Still, with handling and the transport of objects being high risk, 3D technology makes this slightly safer. While cavity packing is an important process for shipping artwork, it is also time consuming and not always exact. According to the US National Park Service's Museum Handbook, cavity packing is the "process of placing small medium-sized objects in hollow cuts into layers of polyethylene foam."[60] To do so, one needs to trace and mark each object by hand with pencil on the foam board then manually cut the outline with a knife. Then, for further protection against the harsh material, "cover the cavity with soft, unbuffered acid-fee tissue, Tyvek, or another smooth inert material."[61] Gwynne Ryan, sculpture conservator at the Smithsonian, reminds

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[59] "Mission and Vision." Smithsonian Institute. Accessed on November 1, 2012. http://www.si.edu/About/Mission

[60] US National Park Service Museum Handbook, Chapter 6: "Handling, Packing and Shipping," 1999, p. 21. http://www.nps.gov/museum/publications/mhi/chap6.pdf

[61] Ibid.

us "when you're thinking about what a conservator—what the responsibility is—one is to repair damage that has occurred to an artwork and any sort of problems with its aging, natural aging. But the other component that conservators are really concerned with is preventing that damage from happening in the first place."[62] To aid in prevention, Ryan uses 3D technology to build these cavity packs for shipping and storage purposes. Being able to scan the surface of the object, allows for "even distribution of weight and support."[63] This is also helpful in areas of the exhibition of an object, especially a fragile one. The object's shape can often morph, depending on its age and material. Scanning the object before the exhibition and again after, will allow conservators to compare data to make any necessary changes to the exhibition mounts to prevent future disfiguration.

As the members of the Smithsonian's digitization department continue to scan the collection, another way they have been able to share and expand the accessibility is through the institution's website. The *San Jose Mercury News* reports the Smithsonian's Secretary Wayne Clough remembering a strategic plan in 1927 which "called for the Smithsonian to have an office in every state so it could reach more people." As this plan never saw completion, Clough continues to state "now with more digital outreach, the museums could actually realize that dream, with the potential to reach billions of people. By scanning the collection, the Digitization Team has made these "objects" available on its 3D viewer online."[64] This was made possible in late 2013, the

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[62] Youtube, "Smithsonian X 3D - Conservation" Smithsonian's Digitization Program Office, November 30, 2013, accessed on January 10, 2014, https://www.youtube.com/watch?v=6ij4WtocR2U

[63] Ibid.

[64] Brett Zongker, "Smithsonian Makes Push in 3D imaging of Artifacts" *San Jose Mercury News*, January 4, 2014, accessed on January 25, 2014, http://www.mercurynews.com/business/ci_24840224/smithsonian-makes-push-3d-imaging-artifacts

Smithsonian partnered with Autodesk to create a 3D viewing experience online, accessible from anywhere. In doing so, the participating viewer is able to zoom and turn the object 360 degrees.

Most importantly this supplies the online viewer a more intense and up-close look at the object, a view which may not have been possible through the display case in the museum. The director of the digitization department at the Smithsonian, Gunter Waibel, states "museums are working to redefine their relationship with audiences to become more interactive."[65] To make this online venture even more interactive, visitors to the Smithsonian 3DX website can print the object which they are examining—granted they have their own 3D printer. Schools can purchase a printer and print objects from the museums collection to coincide with their lesson plans, allowing students to hold the replica in their hands for further study, if the 3D online view does not suffice. To date, reviews for the Smithsonian's 3D initiative have been positive, as one blogger said, "it is the end of do not touch" reinstating the importance of the project to "open up the history."[66] Only time will tell how the incorporation of this technology within the museum space will evolve, if this is something here to stay or if it will slowly die down. Before we enter the next chapter to discuss the issues that arise with this technology, I would like to introduce how other museums, not only the Smithsonian, are using this technology to support their exhibitions, programs, accessibility, and educational efforts.

Back in 2012 the Metropolitan Museum of Art hosted its first 3D Scanning and Printing Hackathon, allowing programmers and digital artists the opportunity to scan their collection to

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[65]Ibid.

[66] tayloramarel, "Smithsonian Opens up its 3D Collection Everywhere," Modelyst Blog, November 14, 2013, accessed on December 15, 2013, http://modelyst.com/blog/smithsonian-opens-its-collection-to-3d-printers-everywhere/

create new works. The museum partnered up with MakerBot Industries for this invitation only event. As reported by Jackie Terassa, Managing Museum Educator for gallery and studio programs and Don Undeen, Senior Manager of Media Lab, the goal of this event was to:

> Assess the potential of these technologies to engage artists and visitors with the Museum's collections. Artists will explore different collection areas—specifically, the American Wing, Asian Art, Oceanic Art, and European Sculpture and Decorative Arts—and discuss the works of art with Museum curators and educators…Finally, through alteration, transformation, and combination, the artists will create new works, which will be printed on MakerBot's low-cost, open-source Replicator printer. As a group, we'll look at the results, discuss the creative process, and consider the opportunities these technologies hold for the Met and our audiences.[67]

This process was completed using digital cameras; to capture the entire object, participants needed to photograph all angles of the object which then were pieced together in a CAD/STL file and sent off to the printers. Additionally, the Terassa and Undeen state "this two-day workshop, by partnering with artists and programmers who are already using these accessible technologies as creative tools, we will advance a core component of the Museum's mission to encourage the study and development of the arts, enhancing the Met's role as a dynamic site for creativity, inspiration, and exploration by artists and visitors alike."[68] This initiative to get both artists and programmers to focus on their collection has inspired other 3D hobbyists and museum

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[67] Jackie Taressa and Don Undeen, "Met 3D: The Museum's First 3D Scanning and Printing Hackathon," The Metropolitan Museum of Art, May 31, 2012, accessed on December 12, 2013, http://www.metmuseum.org/about-the-museum/now-at-the-met/features/2012/hackathon

[68] Ibid.

advocates to look at the collection from a new perspective. The overall response from this project was positive. With social media easily available to provide quick responses to events such as these, the feedback on Twitter thanked the museum for this opportunity, to "unlock the collection"[69] and "get your favorite pieces of art out of the Met."[70]

The Brooklyn Museum has recently put into action sensory tours that are geared towards individuals who are blind or partially sighted. On this tour, visitors will be able to experience the artwork through detailed descriptions as well as holding a small 3D printed version of the object in their hands. This interactive element will aid in understanding the texture and shape of the piece. If the piece is a painting, that should not be a problem as the Vincent van Gogh Museum in Amsterdam is experimenting with producing high quality reproductions of paintings. The replicas are full color and depict the "thickness of the paint and the brushwork"[71] of the original; this again would be valuable for interacting with the piece for further examination, whether used for accessibility programs or van Gogh fans.

The American Museum of Natural History allows museum goers to "think like paleontologists" with its latest project with MakerBot to reconstruct dinosaur fossils from the museum's collection. The program "introduced students to comparative fossil anatomy through digital 3D capturing, modeling, and printing technologies. Asked to replicate a dinosaur but not told its species, students worked with a collection of Allosaurus fossils from the Museum's Paleontology

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[69] Ben O'Steen, June 2, 2012, Comment on Twitter in response to #met3d, https://twitter.com/search?q=%23Met3D

[70] Lizabeth Arum, June 2, 2012, Comment on Twitter in response to #met3d, https://twitter.com/search?q=%23Met3D

[71] Nina Siegal, "Technology Mimics the Brushstrokes of Masters," *New York Times*, October 23, 2013, accessed on February 2, 2013. http://www.nytimes.com/2013/10/24/arts/international/technology-mimics-the-brushstrokes-of-masters.html

collection to scan, digitally model, and print the bones using 3D printers. They were then challenged to identify the dinosaur and construct a skeletal model from the printed bones."[72] For further reinforcement the group was given a tour though the various conservation and fossil labs to see the behind-the-scenes technology, projects, and responsibilities of museum staff.

These are only a few of the many 3D initiatives taken on by museums, all showing the impact this technology has on the various museum departments. As the maker movement together with digital growth appears to be the driving force behind the popularity of this technology, how long will this last? Currently, this technology's integration in museums is garnering a positive response but is it creating meaningful memories? And what can we learn from the use of this technology? Some of these questions cannot be answered at this time, but I will provide further analysis through exploring the issues and speculations that also come with this technology in Chapter 3. In doing so, we will gain an all-encompassing understanding about the use of 3D in museums and its impact on the museum experience.

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[72] "Using 3D Printing to Reconstruct Dinosaurs, Students Learn to Think Like Paleontologists," American Museum of Natural History, August 2, 2013, accessed on December 10, 2013, http://www.amnh.org/explore/news-blogs/education-posts/students-use-3d-printing-to-reconstruct-dinosaurs

III. Too Good to be True?
Evaluating the Benefits and Detriments

In principle a work of art has always been reproducible. Manmade artifacts could always be imitated by men. Replicas were made by pupils in practice of their craft, by masters for diffusing their works, and, finally, by third parties in the pursuit of gain. Mechanical reproduction of a work of art, however, represents something new. [73]

As you have seen, 3D technology offers a great deal of help to various departments of the museum; whether it be for exhibitions, accessibility, programming, education, or conservation, there are many ways this technology can be used to benefit a museum collection. While there are numerous advantages of 3D scanning and printing, assessing the potential issues and detractions that accompany is a necessary precaution.

Currently, small-scale 3D scanners and printers are quite affordable for the hobbyist or even a developing tech team in a museum. Scanners can be downloaded on to an iPhone for as low as $0.99 from a company called Trimensional and the MakerBot edition costs $4.99 in the iTunes store. These phone scanners are a great way to engage the public but the cost of professional scanners ranges from 3D System's $400 scanner to $100,000 for a Minolta laser scanner like the one Smithsonian uses. A quick Google search provides a varied list of 3D printers, with prices starting at $199 continuing up to $846,0000.[74] With a majority of the major 3D printing brands such as MakerBot, 3D Systems, Leapfrog, and OpenCube offering printers from $1,000-$3,000, the cost continues to decrease, allowing museums to join the revolution. These printers, however, are not large scale like the ones the Smithsonian is using to print life-size replica of

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[73] Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction*,"* In *Illuminations*, edited by Hannah Arendt, translated by Harry Zohn. New York: Schocken Books, 1978. p. 218.

[74] "Price Compare-3D Printers," *3D Printer and 3D Printer News*, 2011-2014, http://www.3ders.org/pricecompare/3dprinters/

Monticello's Thomas Jefferson statue or a larger piece like the Wright Brothers' Flyer. Therefore, cost is a limiting factor for museums with smaller budgets in terms of the technology's capacity. As previously noted, the Smithsonian is using this technology in more than one facet of the museum. With the hefty price tag and need for additional staff to operate, smaller museums may realistically only use 3D scanning and printing in one department, as opposed to three or four. The cost of 3D printers was problematic five or ten years ago and for many museums that remains a reality today.[75] The cost is high not just for the printer but also to acquire a tech staff that has the skill set to preform various operations for the museum, and manage the upkeep of the equipment.

The high price of industrial-sized printers can be attributed to an existing patent on laser sintering that is expected to expire in approximately early 2014. According to CNN, "when those patents expire next year the price of these machines will drop, increasing access to laser sintering technology and lowering the overall cost of manufacturing by 3-D printer."[76] Selective laser sintering (SLS) is one way 3D printers can print in layers. Selective laser sintering "uses powder instead of liquid and the laser beam heats up the powder to the sintering temperature so that the powder in a cross-section scanned by the laser is bounded."[77] Developed by Carl R. Deckard in the late 1990s, the patent claims:

> An apparatus for producing a part from a powder, comprising: means for successively dispensing a plurality of layers of powder at a target surface; an energy source; a con-

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[75] Interview with David Krop, director of the USS Monitor Center at the Maritime Museum, May 8, 2014.

[76] Clay Dillow, "5 Reasons 3-D Printing isn't Quite Ready for Prime Time," *CNN Money and Fortune*, September 3, 2013, accessed on November 8, 2013, http://tech.fortune.cnn.com/2013/09/03/3d-printing/

[77] M. Szilvasi-Nagy and GY. Matyasi, "Analysis of STL Files," *Mathematical and Computer Modeling* 38 (2003) p. 946.

> troller for directing the energy source at locations of each dispensed layer of powder at the target surface corresponding to cross-sections of the part to be produced therein and fusing the powder thereat; and temperature control means for moderating the temperature difference between unfused powder in a topmost layer of powder at the target surface and fused powder in the one of the plurality of layers of powder immediately beneath the topmost layer.[78]

Reports claim that once the patent expires, this technology will be available for 3D printing companies to use and develop, ultimately lowering printer costs. This notion remains a theory; we will not know if this will occur until the time comes. CNN asked the director of technology at Deloitte Canada, Duncan Stewart, about the power of the patent. Stewart dismissed the impact of patents:

> The reason 3-D printing isn't bigger than it is today is largely not because of intellectual property issues or who owns what patents. It's the fact that for most of the things that we need in the world today, 3-D printers are too slow, too expensive, or that—because of the limitations in the kinds of materials they can use—they cannot easily make the things that you want to. The single biggest factor keeping 3D printing smaller than it might otherwise be up until now has been the utility of 3D printers, not the patents.[79]

It is difficult to accurately assess the impact of cost and patents at this point in time; due to a variety of conflicting perspectives and opinions. As developments are made, there will be more

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[78] Carl R. Deckard, "Method and Apparatus for Producing Parts by Selective Sintering" Board of Regents, The University of Texas System, Austin Texas. Patent 5,597,589. 28 Jan. 1997.

[79] Dillow, "5 Reasons 3-D Printing isn't Quite Ready for Prime Time," http://tech.fortune.cnn.com/2013/09/03/3d-printing/

clarity on the subject. For now, these remain important considerations worth monitoring, especially for museums that need to weigh budget versus the technology's value in accentuating visitor experience.

The Importance of Viewing "The Real Thing"

As 3D technology continues to surge and flood museums, one is left to question, what is its value? Is it an effective new medium or is it a distraction? The use of mobile phones and devices were frowned upon in museums as it was distracting for visitors; now it is encouraged and promoted for tours, virtual reality, educational programming and games. While 3D is different from using an iPhone or iPad, the same argument can apply. This technology has the potential to also dilute visitor experience and divert attention from the actual object. Yes, this technology is intended to enhance the viewing experience, provide more information to visitors, offer new perspectives and ways to interact with the object; however, it also thwarts direct, one-on-one interaction with the object because there is now something else present between the visitor and the art work or object. Are visitors getting lost in the inclusion of this technology and becoming uninterested in the object's authenticity?

Walter Benjamin's 1936 essay *The Work of Art in the Age of Mechanical Reproduction* provides insight into the paradigm shifts of art in the modern age by understanding the history and development of photography and film. In doing so, Benjamin discovers a loss of the work's aura as a result of reproducing art. Throughout history, people have reproduced art work for study or to perfect their craft, but mechanical reproduction, according to Benjamin, represents something new and much different than previous techniques and/or efforts.[80] Benjamin reminds

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[80] Benjamin, "The Work of Art in the Age of Mechanical Reproduction." 219.

us, "even the most perfect reproduction of a work of art is lacking in one element: its presence in time and space, its unique existence at the place where it happens to be."[81] Author Andrew Robinson echoes Benjamin's viewpoint on the erosion of aura, offering another example that compares a poster to an original piece of art. Robinson urges the reader to "think of the way a work of classic literature can be bought cheaply in paperback, or a painting bought as a poster. Think also of newer forms of art, such as TV shows and adverts. Then compare these to the experience of staring at an original work of art in a gallery, or visiting a unique historic building."[82] Robinson's analogy perfectly illustrates the pitfalls that come with the inclusion of 3D technology. It has the capability to completely alter what should be a uniquely original experience due to the removal of intrinsic value through reproduction.

Thomas P. Campbell, Director of the Metropolitan Museum of Art, speaks to the conflicted nature of technology in museums, stating:

> Technology is in fact one of the most exciting things that's happened to museums today—but one has to be careful about where one uses it. For instance, the internet provides an incredible opportunity. It is a way for us to reach audiences around the world and further our educational mission…Where you have to be careful is introducing technology in the

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[81] Ibid, 220.

[82] Andrew Robinson, "An A to Z Theory, Walter Benjamin: Art, Aura and Authenticity," *Ceasefire*, June 14, 2013, accessed February 25, 2014, http://ceasefiremagazine.co.uk/walter-benjamin-art-aura-authenticity/

> galleries because you want people looking at the objects, not the video screens. You want people to be in heads-up, not heads-down mode.[83]

Campbell's idea subscribes to the concept that technology is best suited to enhance education and expand audience. He cautions that we, as museum professionals, must be wary in where and how technology is incorporated, warning that its introduction into galleries must be carefully considered, so as not to detract from exhibitions and collections.

As 3D technology continues to saturate various channels and industries, Campbell's perspective is a practical one; it resonates and raises valid points. He continues to state, "we live in an age of 24x7 newsreels, instant information from around the world and museums are all the more important as places that can help explain the context of current affairs…And most importantly, they are a place of authenticity. We live in a world of reproductions—the objects in museums are real. It's a way to get away from the overload of digital technology."[84] Thomas Campbell's concerns regarding the influence technology has on the viewing experience coincides with Walter Benjamin's theory on aura and authenticity. Museums acquire and house these authentic objects as a means to explain culture through preservation and share knowledge through programming and exhibitions. With that said, authenticity is a prominent and motivating reason why people visit museums. Following Benjamin's theory, to reproduce an object removes the time and space from an object, eliminating its authenticity, provenance, and history. An object's aura is "the essence of all that is transmissible from its beginning, ranging from its substantive dura-

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[83] Madhavi Rajadhyaksha, "Museums are about authenticity in a world of reproductions: Thomas P Campbell," *The Times of India*, April 10, 2013, accessed February 5, 2014, http://timesofindia.indiatimes.com/home/opinion/interviews/Museums-are-about-authenticity-in-a-world-of-reproductions-Thomas-P-Campbell/articleshow/19463958.cms

[84] Ibid.

tion to its testimony to the history which it has experienced. Since the historical testimony rests on the authenticity, the former, too, is jeopardized by reproduction when substantive duration ceases to matter. And what is really jeopardized when the historical testimony is affected is the authority of the object."[85]

In further exploring the issue of authenticity, the following account illustrates its significance and impact. In 2013, the Naval Training Center at Liberty Station in Point Loma housed the controversial exhibit *The Complete Frida Kahlo: Her Paintings, Her Life, Her Story*. The controversy was rooted in the fact that the exhibition was advertised as containing 123 of Kahlo's paintings; however, there was one catch, the paintings were not painted by the artist herself. Instead, the paintings were commissioned for Chinese artists to paint exact replicas. This conclusion would be difficult for the average visitor to arrive at upon viewing, since they were all signed by Kahlo. Director of the Museum of Contemporary Art San Diego, David C. Copley, commented on the exhibition, stating "to have a show entirely of copies and to promote it as all Frida Kahlo's paintings together for the first time is completely dishonest."[86] The lack of transparency about the replicas created for the exhibition was unethical and caused confusion since visitors thought they were witnessing original works. This issue leads one to infer that there could be similar confusion determining the authenticity of an object in the future, when museums start to take on more exhibition projects that include 3D-printed works. Furthermore, will introducing duplicates to the public result in a lesser appreciation for the piece? And will the inherent

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[85] Benjamin, "The Work of Art in the Age of Mechanical Reproduction," 218.

[86] Angela Carone, "Frida Kahlo Paintings In San Diego: Do Audiences Know They're Copies?" KPBS News, November 25, 2013, accessed February 22, 2013, http://www.kpbs.org/news/2013/nov/25/frida-kahlo-exhibit-raises-questions-about-mislead/

value of the piece be lost through the process of replication? Will the need for museums diminish?

A project done in 2008 though the Research Council of Norway which included the British Museum, University of Bergen, and the University College London provides further insight into these questions that arise from the inclusion of 3D technology in museums. The project featured the Solomon Island's War Canoe, part of the British Museum's ethnographic collection. The goal was to three-dimensionally scan the canoe, and "produce a high resolution 3D image which can be taken back to the source community, for study use, so as to encourage technological and ancestral knowledge restitution to the inhabitants in the western Solomon Islands, where this type of canoe remains a core symbol of culture and history."[87] The war canoe was built in the early 1900s and measures about 37 feet long. This canoe, in particular, is important to the Solomon Islands and, more specifically, to the people of Vella Lavella (where the canoe was originally built) because a canoe of this size no longer exists. To see one of this size and detail is helpful for the people of the community to study from, to ultimately reestablish canoe building. As the team of museum staff curators, registrars, archeologists, and engineers worked towards their goal, to scan and repatriate an image of the canoe to the people of the Vella Lavella, the final outcome was not as well-received as anticipated.

Project leaders recall the people of Vella Lavella had difficulty identifying the war canoe as their own. The canoe scan was not in color and lacked decorations, such as "cowry shells, red twill and feathers." As a result, the museum staff said the community "did not recognize the digi-

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[87] Mona Hess, Stuart Robson, Francesca Simon Millar, and Graeme Were, "Niagara - the Western Solomon Islands War Canoe at the British Museum:3D Documentation, Virtual Reconstruction and Digital Repatriation," 2009 15th International Conference on Virtual Systems and Multimedia, accessed on January 21, 2014, http://discovery.ucl.ac.uk/1305320/1/1305320.pdf

tal canoe as a particular class of war canoe from Vella Lavella. They were unable to relate the 3D digital image of the canoe to what they imagined the canoe to be in the past. As a consequence, they claimed the digital image was dead, lifeless and even broken."[88] Although more attempts were made to please the local community, and another image in color was produced, the reaction of disdain and unfamiliarity exuded by the public is important to note. The words "dead, lifeless, broken" that were used to describe the 3D image demonstrate and validate Benjamin's theory. That response was born out of the piece's compromised integrity and lack of inherent value; the history attached to the canoe was not present. While this project was aimed to create access for the community of the canoe's origin, without the originality, authenticity, and integrity of the object, all interpretation was lost in translation.

To summarize, this chapter presented the detractions and speculations of 3D technology. These concerns come through in the cost of the product, which can be misleading, as the high prices speak to the exclusivity of the technology—reconfirming that it is not accessible to the general public, just yet. Furthermore, 3D technology can be seen as a major distraction, resulting from the wow-factor it presents to the public. While this technology has great potential to create global visibility and accessibility for museums, there are valid concerns of inauthenticity that come with reproducing cultural objects. As these issues may not be at the forefront right now, they are important to realize and become aware of for the future when this technology continues to grow and flourish. In the upcoming chapter I will further analyze this technology and

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[88] Stuart Robson, Sally MacDonald, Graeme Were and Mona Hess, "Chapter 5: 3D recording and museums" *UNCL Center For Digital Humanities*: Case Study, accessed on February 15, 2014. http://blogs.ucl.ac.uk/dh-in-practice/chapter-5/

begin to look towards the future, making predictions and raising questions for future investigation.

IV. Concluding Thoughts:
Reflecting on the Present, Looking Towards the Future

In the three previous chapters, we have explored, dissected, and analyzed 3D technology. Through this investigation, we have created a timeline illustrating where 3D technology originated and the different avenues it is traveling down. With no direct end in sight, we have seen 3D begin to permeate a myriad of industries and, more importantly, we have studied the ways in which this technology has been adopted into museums. Throughout this thesis, I raise provoking questions about the current and potential impact this technology holds in museums; specifically, the effect 3D technology has on the museum experience: is it gimmick or the way of the future? Does it liberate the object or obscure it? Does it have longevity and sustainable value, or is it a distraction?

We have been exposed to the innovative influence this technology has in various fields, from medicine to movies and beyond. Since the full potential of 3D technology has yet to be revealed, we are not able to study the long-term effects its implementation has on the museum experience as a whole; however, through our exploration of how 3D technology is being expressed inside and outside of museums and understanding of how other types of technology have been used in museums, we can learn how to effectively harness 3D scanning and printing for use in the museum setting to enhance visitor experience.

Museums are generally hailed as late adopters of technology. Kate Haley Goldman recounts Everett Rogers' studies on the adoption of new ideas and technologies in his book *The*

Diffusion of Innovation. Rodgers segmented the public into a variety of groups—the Innovators, Early Adopters, Early Majority, Late Majority and Laggards—based on the public's utilization and acceptance of innovations. Goldman reminds us of an individual's reasons and motivations for adopting technology, stating that, for late adopters specifically, "their skepticism must be addressed. Peer influence and, at times, economic necessity are key factors for individuals in the late majority adopting new innovations."[89] These same characteristics for laggards, or late adopters, can also apply to the technology profile of museums. While museums do experiment with various forms of technology such as kiosks, iPads, audio headphones, and virtual reality to name a few, incorporating new technology (despite being taken seriously) is not rushed to fruition. Museums adhere to a careful budget and value predictability when it comes to technological innovations. According to Rogers' theory, "innovation is believed to spread throughout society on an S-shaped curve, with one plateau early on as innovation is changing, followed by a rapid escalation in users, followed by another plateau as the laggards eventually adopt the innovation."[90] It seems, when examining 3D technology, museums are defying the typical characteristics that come with being a late adopter. Why is that? Could it be a combination of the evolving visitor and the fact that technology has become an indispensable component of our everyday lives?

In each chapter, I have gone through the development of 3D technology and its capabilities, beginning in Chapter 1 with the origins of 3D in stereography and cast making. The illusion of 3D (as seen in photography) and the replication of objects, originally piqued public interest

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[89] Kate Haley Goldman,"Cell phones and Exhibitions 2.0:Moving beyond the Pilot Stage," Paper presented at Museums and the Web 2007, Accessed on October 15, 2012. www.archimuse.com/mw2007/papers/haleyGoldman/haleyGoldman.html

[90] Ibid.

which perpetuated further exploration of the medium, greatly impacting and expanding education and entertainment. It is the emergence of the internet, however, which has transformed this technology we are familiar with today. The core functions and elements of 3D remain intact but the intent and motives have matured with time. The forecasted "creative renaissance" expresses the notion of a revival but also supports a reinterpretation in tune with the evolution of the technology.

The ways in which 3D has evolved coincides with the growing "maker movement," which supports personal innovation and creativity. This movement, which spawned from the ability to 'make' through scanning and printing, represents another facet of why people are vested in 3D technology. This technology is growing at a rapid pace and we, as museum professionals, need to take a step back to evaluate the origins of its development and the prior uses to best understand the capabilities and power of 3D scanning and printing.

Chapter 2 discusses the current ways in which 3D scanning and printing are being used throughout various museum departments. In the interest of conveying a comprehensive synopsis, Chapter 3 was essential to ground readers with the realities of the technology. I hope to have given readers a thorough, objective understanding of how and why 3D is being used, highlighting both the positive and negative aspects, as it is imperative readers aren't blinded by recent reports of the ground-breaking power of 3D.

While high cost can be perceived as a significant barrier to 3D scanning and printing, it is becoming more affordable to the everyday consumer. Depending on the objective of the museum, the project, and budget, this technology can be customized to fit various needs. The Smithsonian project introduced an assortment of ways 3D technology can be used in the museum

space and although the Smithsonian's larger budget may allow for more experimentation than most, smaller museums can adapt the approach of the Smithsonian to fit their own mission, vision, and budget. I was fortunate to get in touch with museum director, David Krop, of the USS Monitor Center at The Mariners' Museum in Newport News, Virginia to discuss the effects of 3D technology on museum experience. Although Krop had very positive aspects to discuss, he did agree that price is a restricting factor in terms of the types of projects the Maritime Museum is interested in accomplishing. The salary, skills, and maintenance an employee or tech staff require, combined with the processing time to replicate one single object, is difficult to balance on a museum budget.

Similarly, while discussing the pros and cons of 3D technology with Don Undeen, Senior Manager of Media Lab in the Digital Media Department, one disadvantage he encountered echoes the concern Krop will soon face at the Mariners' Museum—the need to settle expectations. The expectations visitors have when entering a museum that utilizes 3D technology are extremely high. When people think of 3D, they think: fast, easy, and accessible. While these characteristics of 3D are definitely in progress, the kinks are still being worked out. Prints cannot be made in a matter of minutes and not every print comes out perfect the first time—it may take a few attempts. Depending on the size of the piece, the printing process may take hours or days. As mentioned earlier, the Smithsonian's print of the Thomas Jefferson statue took nearly 400 hours to complete.[91]

Chapter 3 continues to raise important questions about the issue of authenticity when comparing an original object to a printed one. Authenticity is a crucial element of the museum

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[91] "Thomas Jefferson in the House," *RedEye On Demand*: Case Study, 2014, accessed on April 15, 2013, http://www.redeyeondemand.com/CS_TJefferson.aspx

experience and is something that must be carefully considered for exhibition and educational purposes. A Reach Advisors survey from 2012 revealed that it is "the artifacts, artworks, and objects we preserve and share with visitors that are most likely to hit their emotional core and create meaning and response in them." The study continues to disclose, "respondents were two times more likely to mention an original object than [the] information [they] learned, and it also appeared over four times more than hands-on experiences."[92] 3D technology recreates and replicates the objects and, in theory, removes the authenticity of the piece in the process. Therefore, in order to achieve an exceptional and meaningful experience that promotes learning, this technology needs to work in unison with the original object to provide a new layer which visitors can examine on their own accord.

I am not in favor of all reproduction scenarios. I believe there is something sacred about viewing an original, something that could be diluted by duplication, but it's important to note that we have not fully realized all of the potential uses for this technology—we are only scratching the surface. With that said, the future of this technology may hold significant and groundbreaking benefits that have not possible to this point. Even currently, this technology runs the gamut. It is capable of creating the ultimate "wow factor" or it can simply be used to print knick-knacks and small figurines, but the impression it makes upon visitors varies and will continue to do so. Nevertheless, it seems there are more ways 3D technology can be manipulated to provide visitors with deep layers of information. As detailed in this exposition of 3D scanning and printing, stories can be uncovered about an object that have never been previously known to the pub-

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[92] Reach Advisors "Museum Audience Insight"Audience Research, Trends, Observations from Reach Advisors and Friends," September 25, 2012 http://reachadvisors.typepad.com/museum_audience_insight/2012/09/meaningful-museum-experiences-its-the-cool-stuff.html

lic. To this point, David Krop mentions, “3D scans provide information you cannot see with the naked eye.” Instead of replacing the original object, the duplicate should be used in conjunction with it to enhance the experience. Being able to tell the story of an object in such a detailed, unique way provides various opportunities for each visitor to connect with the object and build memories.

We live in an age where customization and personalized experiences are pervasive throughout society. Whether you are at a restaurant creating your own artisan sandwich, designing your own pair of sneakers online, curating your boards on Pinterest, or filtering your news feed, we want our experiences custom-built to serve our individual needs and interests. Is that what makes 3D technology so appealing? Are museums intent on customizing the museum experience to fit the various desires of each visitor?

I am very interested in monitoring this revival of 3D and am eager to see where it will go. During my conversations with various members of the museum community, I inquired about the longevity of 3D technology and what path they foresee it traveling down. This inquiry resulted in a similar consensus: 3D technology is definitely not a fad and is certainly here to stay. It makes the object more available to the public, providing a greater hands-on learning experience by presenting the visitor with tools to experiment with the collection. In the upcoming years, we can expect to see the price points of scanners and printers decrease greatly, making it more affordable to print on a variety of scales. It is the moral responsibility of museum professionals to uphold the best intentions for the visitor and the collection. Maintaining that commitment is paramount when using 3D technology; asking if the incorporation of 3D technology will truly accentuate the knowledge and understanding of the collection can help to ensure it doesn’t become a distraction.

This technology has the ability to deliver a very powerful and engaging museum experience, which will affect each department in various ways depending on the institution; however, the power must be tempered with purpose and proper execution.

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