DIGITAL ARCHAEOLOGY AND THE CURATION CRISIS: 3D MODELING AS AN ANSWER TO THE PROBLEMS OF COLLECTIONS ACCESS AND USE

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Mallory Claire Marcone

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DIGITAL ARCHAEOLOGY AND THE CURATION CRISIS:

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Thesis Supervisor:

_____

Stephen L. Black, Ph.D.
Department of Anthropology

Second Reader:

_____

Mark Willis, B.A.
Blanton & Associates, Inc.

Approved:

_____

Heather C. Galloway, Ph.D.
Dean, Honors College

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ABSTRACT

The archaeological curation crisis has plagued repositories and archaeologists alike with a multitude of problems for several decades, most notably inaccessibility to collections. Archaeological artifacts continue to be curated in repositories with little prospect of ever being used by researchers to uncover new information about the past, rendering them essentially useless and removing much of the moral justification of archaeology itself. However, in creating digital 3D models of artifacts and site excavations, archaeologists and repositories can make archaeological data and research widely available to people around the world through the Internet while protecting artifacts from transfer, travel, and potential harm through handling. Alongside 3D models, digital repositories like tDAR are helping to alleviate the problem by providing a digital environment for curation and instant access. An analysis of 3D model creation and digital repository curation, along with a discussion of how to alleviate copyright and access control concerns that arise from sharing digital information, show that while there are still some problems that exist, the benefits of digitizing archaeological collections for research far outweigh the costs.

Introduction

"Sites and the collections resulting from archaeological excavations are both nonrenewable and unique."

Bethany Hauer Campbell

In 1990 the federal government of the United States passed the 79th section of the Code of Federal Regulations, titled Curation of Federally Owned and Administered Archaeological Collections, more commonly called 36 CFR 79 (National Park Service 2014). This law means that all federally-owned collections of archaeological artifacts and documents have to be curated long-term in a repository that meets minimum standards set forth by the law. Most importantly for the purposes of this thesis, 36 CFR 79 also dictates how these collections can be accessed and used through loans by researchers and the public. Despite this attempt at standardizing the regulations, however, there are still some major problems with archaeological curation; for example, the law states that all federal collections must be curated but it does not provide funding for repositories to do so (Campbell 2011:27). Many repositories also house collections that are not federally owned, meaning they must acquire permission from the owner in order to make the collections available for study by researchers. However, the owner is often unknown because the collection comes from excavations done decades before. Furthermore, many of the documents have become lost or ruined due to poor storage conditions. Repositories also face huge issues with backlogging. They often have many collections waiting to be catalogued, labeled, and stored (which can be a lengthy process), and these collections

are unavailable for use until they have been completely accessioned. All of these factors contribute to what has been dubbed the "curation crisis," a phenomenon in which repositories are understaffed and underfunded and access to the collections for research is difficult if not impossible (Childs 1995). There are many facets of the curation crisis, such as lack of accreditation for repositories, lack of funding, lack of staff, lack of standard accessioning procedures, and so on. While these are all serious problems that put archaeological collections in danger of being lost or destroyed, the major long-term consequence of the curation crisis is the lack of access to collections for use by researchers and students. Herein lies the major moral problem: if people wishing to research archaeological artifacts from previous excavations cannot gain access to those collections, then in many ways archaeology is no longer justified. The past does not belong to a single person or entity, and if citizens are to fund archaeological projects through tax or donation money, they have a right to use the results to learn new information.

Fortunately, advances in technology affect archaeological practice as much as other aspects of life and learning, and offer a means to remedy the problems of collections access and use. Three-dimensional modeling and scanning technology now exists that allows archaeologists to create digital models and hypothetical reconstructions of sites and artifacts that can be instantaneously shared with researchers around the globe. Currently this technology is used mostly by archaeologists to further public outreach goals after excavations are complete (Dawson et al. 2011; Ask 2012:9, 13-19). However, as Ask (2012) argues, 3D modeling can be used during the research process to raise new questions and directions of focus, much in the way of experimental archaeology. If

archaeologists do use 3D scanning and modeling throughout their excavations, the digital records produced can also be given to repositories to be curated and can be “loaned” out to researchers to study different stages of the project. Likewise, digital models of individual artifacts can also be “loaned” to researchers to prevent having to send the actual artifacts, which may be costly or put the artifacts at risk of destruction. The first section of this thesis will discuss how 3D models and scans are created in the archaeological setting, followed by a discussion of the applications of these models to the curation crisis. The final two chapters of this thesis discuss methods for controlling access and use online and potential problems with the use of digital 3D models for research. Overall this thesis shows the feasabiliy for repositories of using 3D models in lieu of actual artifacts and documents to greatly improve access to archaeological collections for students and researchers.

Chapter 1

Creating 3D Models

"Rasmussen considers the visualization as a fundamental starting point for interpretation of archaeological material."

Carolina Ask

As the years progress, archaeologists are becoming more and more familiar with new innovations in technology and are integrating them into ordinary field practice. Total data stations (TDS), ground-penetrating radar, and geographic information systems (GIS) are all examples of technological tools used by archaeologists on a regular basis. Archaeologists around the globe have begun adopting 3D modeling and scanning software to create digital models of sites and artifacts. Many have also explored the capabilities of 3D digital modeling to create hypothetical visualizations of archaeological sites the way they might have looked in the past; one example is the virtual Thule and Inuit dwellings project that Dawson, Levy, and Lyons of the University of Calgary created to allow users to explore the houses through a CAVE (Computer Assisted Virtual Environment) projection system and virtually interact with the artifacts (Dawson et al. 2011).

While these hypothetical digital "reconstructions" are an effective way to increase public interest in archaeological work, they are not the limit of 3D modeling technology's usefulness in archaeological practice. Incorporating the creation of 3D models or scans of each layer of an excavation into the routine field work is an effective way to document

the excavation process and review the layer for anomalies or areas of further inquiry (Ask 2012; Dell'Unto et al. 2013; Dellepiane et al. 2012). Dellepiane et al. (2012:209) even argue that 3D models of excavations may later be used to teach archaeological field techniques to students. This chapter outlines the basic steps in producing 3D models—from the data capture performed by archaeologists in the field to assembling the models on computer software—in order to show the accuracy and therefore usefulness of 3D models as documentation of sites that can be kept in repositories for use by researchers.

Data Capture

Capturing the data needed for 3D scans or models in the field can either be the simplest or the most complicated step, depending on the nature of the site or area being documented. Some sites have naturally undesirable lighting conditions, dense vegetation cover, or complicated structures that are difficult to record, while others lie in open, flat areas that can be photographed very easily. There is also a difference in the data capture procedure for 3D scanning and 3D modeling. This thesis focuses on 3D modeling because it can be accomplished with a simple digital camera and web-service software, whereas 3D scanning requires an often expensive laser scanner (though when airplane-mounted it comes with the added benefit of being able to record large areas very quickly).

3D modeling software is based on structure-from-motion (SfM), which is based on digital photogrammetry. This is a process in which the location and orientation of the camera is calculated from a series of overlapping images (Ask 2012:27). Therefore, to begin the process of creating a 3D model, the archaeologist must take a series of overlapping digital photographs of the area to be modeled. This is usually done by taking

a photograph every few steps as the archaeologist walks around the edge of the excavation unit or area. Aerial photographs must also be taken every few feet, as well as photographs of wall faces in order for the model to be fully three-dimensional. If an object or artifact is being modeled, then photographs must be taken of all surfaces. As mentioned previously, this step can be exceedingly simple and quick if the area is easily photographed and light conditions are good; however poor light and small spaces can make this step very difficult. Dell'Unto et al. (2010) offer a diagram of different patterns they took when photographing different types of sites (Figure 1). Data capture for archaeologists also includes acquiring the coordinates of the area being modeled using a Total Data Station (TDS). In addition to regular datums, ground control points (GCPs) must be chosen and measured with the TDS, then applied to the 3D model to "bring the 3D model produced via photogrammetry into real-world coordinates" (Shumla 2013:12). The best GCPs are places that are easily distinguished in the photographs, such as corners or unusual features.

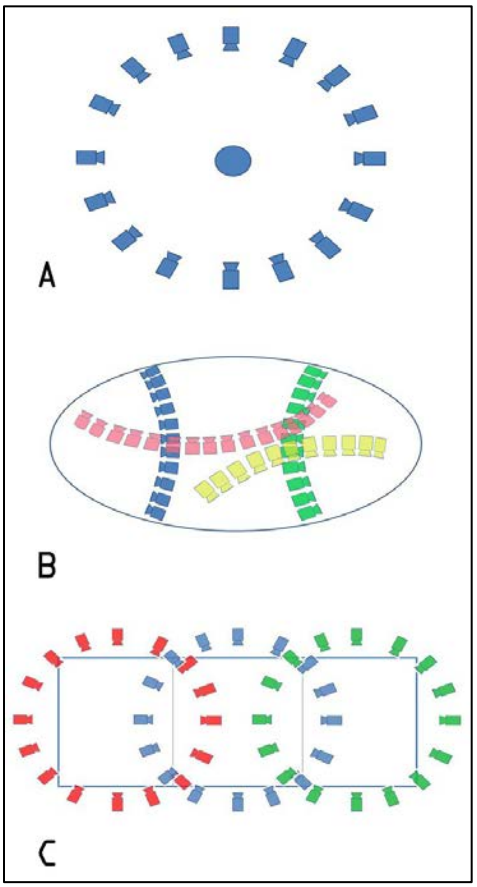

Figure 1. Three different views of the camera positions used in the Dell'Unto et al. (2010) case study of three different sites in Sweden.

Image Processing

Once all of the necessary photographs have been taken, they must then be uploaded to the digital modeling program. There are a

variety of different programs archaeologists may use, ranging from free in cost to several thousand dollars. Some programs, usually those that are free or low-cost, are web-based, meaning that the user uploads their images to the server and the server computes a 3D point cloud of the area or object that was photographed using SfM (Torres et al. 2012). This 3D model is then sent back to the user, but the user usually has to import this point cloud into another program in order to refine the image, add texture, etc. Examples of web-based SfM programs include Microsoft Photosynth; open source (non-web-based) programs also exist such as Bundler and Bundler with PMVS2, which operate in the same way but with the digital reconstruction process occurring on the user's own server. The outputs of all of these programs are usually paired with MeshLab (discussed more in Chapter 2) to view complete 3D models (Torres et al. 2012).

The major commercial program used by archaeologists is Agisoft PhotoScan. The professional edition of this software costs over three thousand dollars, but it is much more user-friendly and has all of the capabilities of the other programs mentioned above. Through PhotoScan, users can export to other programs, convert the models to PDF files, and perform other functions on the model such as measure, splice, and scale.

These 3D software programs allow archaeologists to create fully three-dimensional models from the photographs they have taken, but the process can take many hours depending on the number and quality of the photographs taken. Often the user has to "mask" certain portions of a photograph that are blurry or contain undesirable shadows, meaning that the user has to manually go through the photographs and outline those portions to be excluded from the 3D model (Shumla 2013:13). Depending on the number of photographs taken for the model, this can be time-consuming—one of the

major setbacks for many archaeologists that prevents them from making 3D models every day in the field.

Georeferencing

Once the archaeologist has built the mesh in a 3D modeling software program, the model must be georeferenced to real-world coordinates using the ground control points (GCPs) collected in the field. These coordinates transform the model from representing an arbitrary space to an actual location that can be scaled and measured, and is necessary if the archaeologist wishes to export the model to a GIS or other spatial software (Shumla 2013:15). This is simply done by clicking on a GCP on the model and entering the X, Y, and Z coordinates for the point (Shumla 2013:16).

Once a 3D model has been georeferenced to real-world coordinates, other models can be aligned to the same coordinates in the modeling software program (Shumla 2013:16), saving a lot of time if multiple models have been made of the same area (e.g., in the case of creating models for every excavation layer of a unit). Georeferenced models can then be imported to other programs like ArcGIS, a tool that has become well-established in the discipline of archaeology. This flexibility of 3D models to be used in various programs and formats is one of the major reasons why they should be relied on more heavily for conservation and collections access and use. Researchers can use a single 3D model file and import it into a GIS or other program necessary for their work, rather than needing multiple shapefiles for a site or excavation area. This is also a benefit for repositories, which would only need to store single 3D model files rather than numerous shapefiles or other digital files of a site in various formats.

This chapter has outlined briefly how 3D models are made by archaeologists. The process can be quite cheap, using only a digital camera and free 3D modeling software, making it very attractive for archaeologists on a modest budget. The more these software programs are developed over time, the simpler and faster the process will become, even for those who have no extensive experience with computer programs. But 3D models will not only become more useful and flexible for archaeologists in the field; they will also serve a wide variety of functions for researchers wishing to study previous excavations and artifact collections. Viewing and manipulating the 3D models tend to be much simpler than creating them, meaning that even archaeologists who have never made 3D models before can use them with reasonable comfort for research. Because creating 3D models is a relatively fast and simple process, archaeologists should create 3D models of their entire excavation process and of diagnostic or sensitive artifacts in order to make them widely available for research. The specific benefits of using 3D models for research is explored more in the following chapters.

Chapter 2

Digital Models and Collections Access and Use

"There is a second curation crisis that receives much less attention but whose importance is growing daily: a digital curation crisis."

Keith Kintigh and Jeffrey Altschul

As mentioned in the introduction of this thesis, the archaeological curation crisis is demonstrating widespread devastating effects for the long-term care and preservation of artifacts and cultural heritage items (Childs 1995). Because of the time-consuming difficulty required to gain permission to access or borrow collections, archaeology students are often actively discouraged or even prevented from using existing collections for research rather than conducting new excavations (Campbell 2011:14). This is compounded by the perception that "excavation is seen as a more worthy aspect of the profession than what must inevitably come afterwards" (Childs 1995). However, if students or scholars are prevented from researching existing archaeological collections, then the money and labor spent on preserving them becomes pointless. The solution to this problem is to make existing collections as easy to research as new collections. This means that students or researchers of any kind need relatively easy access to the collection and need to be able to conduct their research without damaging the artifacts. They also need access to all of the notes and metadata that come along with the collection

so that they can take its provenience into account. The current status of archaeological collections makes these criteria difficult to meet for many repositories.

Current Access and Loan Policies for Analogue Collections

Currently, if students or researchers wish to gain access to or borrow analogue (non-digital, physical) collections, they must go through a lengthy process that can be unique for every repository, despite the "regulation" of 36 CFR 79. This section reviews the current procedures a researcher must follow to gain access to archaeological collections at two local repositories, Texas State's Center for Archaeological Studies (CAS) and the University of Texas at Austin's Texas Archeological Research Laboratory (TARL). The requirements and procedures for both loans and in-house access are given, as well as a discussion of the ease of simply finding these policies for a student or interested researcher.

CAS, Texas State University-San Marcos

CAS's webpage (www.txstate.edu/anthropology/cas/) can be found through the Texas State University webpage through a simple search. A row of tabs at the top of the page directs the researcher to various kinds of information, and the "Curation at CAS" tab stands out as an obvious place to find the repository's policies on access and use. A drop-down menu from this tab lists "Collection Management Policy" as the first item. Clicking this link directs the user to a webpage that has CAS's collection management policy written out, as well as a link to the PDF file of the document at the top. The repository's policies on loans are listed as article VII, while the access policies are found

in article XI (CAS n.d.). The loans section has fifteen listed policies, the most notable of which are the first eight:

> 1. Only the director of CAS has the authority to accept or grant a loan.
>
> 2. Loans may be granted for the purpose of research, education, exhibition, conservation and/or inspection.
>
> 3. *Outgoing loan requests will be granted only to institutions affiliated with a research or public education*, while incoming loans may be accepted from institution or individuals.
>
> 4. Loans are not to be used for commercial purposes.
>
> 5. *Collections that are not accessioned/cataloged are not loaned.*
>
> 6. *The director will make the final decision regarding the loan period*. Loans will be granted temporarily for a negotiated specific amount of time. Loan renewals are granted at the discretion of the director. Materials on extended loan may be recalled by the director.
>
> 7. *Costs associated with the transfer of the loaned material are to be paid by the borrowing institution*.
>
> 8. Loaned materials must be covered under the borrowing institutions insurance.
>
> [CAS n.d.:3, emphasis added]

These policies show how gaining permission to have collections or portions of collections loaned to a student or researcher who is too far away from CAS for in-house visits to collections can be difficult. Further discussion of the specific drawbacks will come after the list of both institutions' policies.

The section on the access to collections is very short and contains only four policies:

> A. Physical access to all CAS collections is restricted to the CAS collections manager/curator and the director.
>
> B. Physical access to the collections by other individuals must be granted by the director and *supervised by the director or collections manager/curator*.
>
> C. Research access by CAS staff and non-CAS individuals (i.e. visiting scholars/researchers) is dependent upon the research design and is granted by the director.
>
> D. Physical access to the CAS facility is restricted through use of key-controlled entry. *Access to CAS collections is monitored by the director and CAS staff.* [CAS n.d.:4, emphasis added]

These policies are not very detailed in scope and require the researcher to contact the CAS director or staff for more information about required proposals, forms, or references. It does however appear to be simpler to access the collections in-house rather than requesting a loan of the collections, making it much easier for Texas State students or other researchers in the immediate area to use the collections.

TARL, University of Texas at Austin

Upon opening TARL's webpage (www.utexas.edu/research/tarl/), there is no immediate link or tab directing prospective researchers to the loan or access policy. There is a "Contact Us" tab that a researcher may jump to rather than searching through the website for the access policies. The researcher has to click on the "About Us" tab and

then on the “Collections and Acquisition Management Policies” link to open the PDF file containing all of TARL’s polices on collections, including how to conduct loans and request permission for access. Finding this document and then scrolling through it to find the sections on loans and access took a while, as opposed to the easily accessible “Curation Packet” tab on the homepage; this indicates that TARL favors accepting new collections rather than loaning or providing access to ones that they already have. This is not to say that TARL is purposefully trying to prevent students or researchers from accessing the collections; rather it is most likely a result of the small number of access requests they receive, which in turn is a representation of the attitude among archaeologists that collections-based research is less desirable or prestigious (Childs 1995; Campbell 2011).

Once the “Collections and Acquisition Management Policies” document is found, the researcher must scroll through it to find information on loans in chapter six and requesting access in chapter ten, since there is no table of contents to direct the researcher to the chapter they are seeking (TARL 2006). If the researcher is attempting to request a loan to have a collection or specific artifacts transferred to another location for his or her research, TARL lists the requirements for loan requests as follows:

> TARL will consider only formal written requests submitted on letterhead. A written research proposal must be submitted and must include research goals and objectives, qualifications of researcher, and the specific samples or objects of interest (including any that may be destroyed during analysis). The decision to approve the loan is based on qualifications of researcher, uniqueness of the project, value of knowledge to be gained, size, condition, and importance of

collection. *It should be noted that in general, loans of entire collections will not be approved*. Any and all questions concerning the qualifications of the borrower must be clarified before the loan process begins. [TARL 2006:10, emphasis added]

In addition to these requirements, the document lists several other requirements for the actual transfer of the collection:

1. Loans shall be made to qualified institutions or corporations with which the exhibitor or researcher is affiliated, and that institution or corporation shall be responsible for the well-being of the objects. *Objects that cannot withstand the rigors of being packed, moved, and handled/exhibited will not be loaned. Collections that are not accessioned and/or catalogued will not be loaned.*
2. Conditions (environmental, fire protection, and security) at borrower's institution should mirror or be better than TARL's.
3. *No objects will be loaned if there is any question that its condition would be imperiled*.
4. Any conservation needed to stabilize an object prior to a loan is to be borne by the borrower.
5. A condition report and a complete inventory of all objects to be loaned will be completed at TARL prior to loan issuance.
6. Insurance is to be provided by the borrowing institution. All State-associated Held-in-Trust collections must be insured for the loan period. Loans are insured commensurate with the evaluation of the objects as determined by TARL staff.

7. An annual report of loan activities is made to the THC regarding State-associated Held-in-Trust collections. [TARL 2006:10-11, emphasis added]

These policies show the inherent difficulty of gaining permission to borrow archaeological collections from TARL. Gaining access to the collection at the TARL facility rather than requesting a loan is simpler, but also comes with its own set of requirements and procedures. Generally, the document states that researchers must contact the Heads of Records and Collections to arrange a visit and may be asked for appropriate references. Furthermore:

> Those wishing to conduct lengthy or detailed examinations of either records or objects will be asked to provide a proposal defining the scope and purpose of their research. All records users are asked to complete a Work/Activities Record form to document their visit, the materials accessed, and work done. All users of collections must complete a Request for Access to Collections form. [TARL 2006:17]

The requirements get more specific depending on the type of methods the researcher intends to perform, such as photography. The document also provides a long list of rules and procedures the researcher must follow when visiting the repository, such as leaving all personal items and large bags outside the facility (TARL 2006:17-18).

Comparison and Analysis

The policies of these two university-based repositories are similar to the policies of larger institutions such as the National Parks Service's Museum Management Program (NPS 1998), so even though these two particular repositories are small and focused on servicing central Texas, the procedures—and problems—are the same for national

repositories. The main issues with the loan policies are that they are time-consuming and difficult, especially for students. It is important to note that the italicized sections above are not a criticism of these repositories' policies, but rather a maker for the specific issues that 3D digital modeling is related to and can alleviate or solve. Archaeological collections *should* be difficult to borrow and access for many reasons, namely to prevent unqualified people from being responsible for them and to prevent unnecessary handling for non-justified purposes that could damage or destroy sensitive artifacts. However, the difficulty of accessing these collections even for qualified people severely discourages and disables collections-based research. This is perhaps the most significant way that digital collections, consisting of 3D digital models of artifacts and excavations, can help solve the curation crisis and open up much broader opportunities for research around the globe; if researchers can request a 3D model of a collection rather than transfer of the actual collection itself, the process becomes much simpler and less time-consuming.

The emphasized portions of the CAS and TARL loan policies given above highlight specific issues with loans; namely covering the costs of transportation and restricting the availability of collections for loaning. If digital copies (in this case, 3D models) of all collections are available, there is no longer a question of cost for "transporting" those copies, since they can be sent to the researcher instantaneously via the Internet. The question of insurance for the care and housing of the collection is also rendered meaningless with digital copies. Secondly, these digital copies also prevent damage to sensitive collections, since the digital 3D representations of the artifacts cannot be damaged by transport or analysis. Therefore access to all collections for loaning becomes available. There is also the issue of defining a distinctive loan period for

collections, which means that researchers wishing to use the collection have only a limited time to do so and must define that time—something that is not always easy, since research questions change and new problems arise that cause the researcher to need more time than previously expected. With digital models of collections, requesting a longer loan period of the files would be much simpler and could be conducted entirely through the Internet.

The only aspect of research-oriented loans (as opposed to loans for exhibitions or public outreach, which in many cases do still require transfer of the original analogue artifacts) that digital models cannot ameliorate is the policy against loaning collections that have not been formally accessioned or catalogued. Repositories would still have to have collections completely accessioned and documented before 3D models could be made, unless the excavator of the collection made his or her own 3D models as a part of the collection. In this case the repository may possibly be able to loan those models with explicit permission from the owner or creator, but in most cases repositories still will not loan digital data from a collection that has not been formally accessioned because it violates the repository's own loaning policies.

In-house access of collections is a simpler process than loaning for both CAS and TARL. Overall it seems fairly straightforward to access the collections at the repository for students or researchers in the immediate area of the repository, but the policies require the researcher to limit their research to specific pre-arranged meetings and hours of operation for the repository, rather than being able to access the collections at any time or for any length of time. They also require constant supervision of the researcher using the collection, meaning that repository staff must put off their own work and normal

operations to supervise a researcher during the visit. This could logically lead to a reluctance by both CAS and TARL to allow frequent visits for research by multiple researchers that would force the staff to take too much time away from other matters.

Once again, digital collections have the ability to solve the majority of the issues surrounding access to collections. If students or researchers had access to 3D models of collections through the Internet or downloaded files, they would be able to conduct their research at their own leisure and in any location where they could access a computer. They would no longer have to restrict their research to the hours of operation of a repository or need pre-arranged appointments. Likewise, the repository would no longer have to lose valuable staff hours to supervision or risk damage to collections by allowing non-staff to use them. Digital models also allow multiple researchers to use the same collections for different research projects at the same time, since digital files can be copied an infinite amount of times. Unfortunately digital models cannot account for all possible uses of an artifact for research, so some researchers will still need to visit a physical collection in a repository. However, availability of digital versions of artifacts should reduce the amount of in-house visits needed while increasing the amount of people who have access to a collection.

Digital Repositories

The above section detailed how physical repositories can make access to their collections easier by creating digital versions (i.e. 3D models) of their collections, but there is also the possibility of creating *entirely* digital repositories. This concept becomes more and more viable as more and more technology is integrated into the actual

excavation process. As Kintigh and Altschul (2010) point out, “Increasingly, our records lack the traditional paper forms; photographs, databases, maps, survey and excavation forms, reports, etc. are “born” digital, with no paper copy.” Kintigh and Altschul go on to point out that these digital records are frequently curated on CDs or DVDs, which become outdated quickly by new developments in technology. They describe instead the need for “trusted repositories,” a term developed by the library sciences to describe “an institutional structure that provides for the proper preservation, discovery, and access to digital material,” which they declare does not exist currently in archaeology (Kintigh and Altschul 2010:264). However, the authors do supply a solution: the Digital Archaeological Record (tDAR), an “on-line digital repository of archaeological data and documents” created by Digital Antiquity, an organization hosted by Arizona State University (Kintigh and Altschul 2010:265).

The Digital Archaeological Record

tDAR operates under the “contributor pays” model followed by most physical repositories. In this system, the “institution, agency, or individual that is responsible for the digital data” pays a fee at the time of submission of the digital files to the repository (Kintigh and Altschul 2010:266), which the tDAR website (www.tdar.org) lists as based on the size/amount of data submitted in megabytes. Viewing these files requires registering for a tDAR account, but creating such an account is free of charge; once the user signs up, the user is free to simply search the website using the search bar tool for data related to his or her area of interest, meaning that any researcher around the globe

can use tDAR instantaneously and without submitting formal requests for permissions. Submitting data to tDAR for curation requires an account as well.

Some concerns undoubtedly arise of whether or not the data on tDAR can be trusted. While the curation fee discourages any random members of the public from uploading un-academic or irrelevant data to the repository, some users may be concerned with the accuracy or completeness of the data they find on tDAR. While tDAR's main drawback as a repository is that it "has the liability of placing curatorial responsibilities for which they are not trained in the hands of archaeologists" (Kintigh and Altschul 2010:268), it does provide guidance to submitters on what kind of information they should supply about their data. For example, the tDAR submission process begins with a webpage that lists the different kinds of digital data tDAR accepts, guidelines on how to decide the confidentiality of the data, and tips on practical issues like file naming conventions and back-ups (tDAR 2013 "Upload"). Also, during the registration process, users are prompted to detail what organizations they work for or are affiliated with as well as their RPA (Register of Professional Archaeologists) number, meaning that other users can check the authority of individuals who submit data to the repository (tDAR 2013 "Terms").

The benefits of access to 3D models in such a repository have already been touched upon: unprecedented, world-wide access; immediate transfer of data with no transportation fees or risks; availability of data on the user's own time and schedule; no risk to artifacts by handling, exposure, or misplacement; and ease of access to collections without lengthy application or approval processes. All of these factors combined reduce costs for allowing access to collections, but costs for curation of the original collections

and storage of the digital data still remain. Therefore, under the "contributor pays" model, costs still remain for the archaeologists or researchers wishing to submit digital data to tDAR, on top of the costs that they are already paying to submit the physical collection to a physical repository. This is one of the major issues still troubling digital repositories, but as Klintigh and Altschul (2010) pointed out, many archaeological data are now "born" digital, so archaeologists can expect there to be less and less physical documents in the future that they have to pay to curate in a physical repository. Eventually, therefore, archaeologists will not have to pay to curate the same document twice (once in its physical form and a second time in its digital form), a reality that will encourage archaeologists to incorporate digitization into the excavation process instead of digitizing physical documents afterwards.

However, while this solution works for documents, it cannot apply to 3D models that are digital copies of physical artifacts. Artifacts cannot be "born" digital, and so will always necessitate curation of the physical artifact itself, unless the archaeologist intends to leave it in the ground. 3D models of excavation layers or units are "born" digital, however, with their only equivalent being hand-drawn maps. However, 3D models of excavation units and layers have the capability of replacing hand-drawn maps, since they can portray the same information with the added benefit of depth and actual color. Incorporation of 3D modeling of excavation units and layers into the excavation process, as proposed by many archaeologists already (Ask 2012; Dell'Unto et al. 2010; Henderson et al. 2013), could, therefore, eliminate the need for mapping by hand entirely. This would thereby eliminate another type of document that needs curation in both a physical

repository and a trusted digital one. Again, this prospect of lower costs should convince archaeologists of the benefits of digitizing the excavation process.

3D Viewing Software

Regardless of where a student or researcher gets a 3D model from, be it a digital repository like tDAR or a physical repository like TARL or CAS, that student or researcher still has to find his or her own means of viewing the 3D model on a computer. This is perhaps one of the most prominent problems with using 3D models in place of actual artifacts for study simply because many researchers are unfamiliar with the required software programs for viewing digital models. Some problems may also arise if the researcher's computer, whether a personal laptop or an institutional desktop, does not have the processing power to run such programs smoothly or quickly. Fortunately, however, viewing 3D models does not require nearly the same amount of processing power as creating them, so most average computers should be able to handle viewing completed 3D models, even if they could not create them. Also fortunately, many 3D viewing software programs can be downloaded for free from the Internet, adding no extra costs to the research project. Two such free 3D viewing programs, Blender and MeshLab, are evaluated below in terms of their usability for this purpose. An important note, however, is that Blender is slightly different than MeshLab in that it is predominantly used for creating 3D reconstructions of sites on top of the bare models or improving the texture mapping during the 3D model creation process. Therefore it has a more complicated setup and may not be the best choice for everyone. It can still be used for

viewing 3D models, however, and is one of the free options available, so it is included in the discussion below in order to show the variability of programs.

Blender

Blender can be downloaded in its latest version (2.69) for free from blender.org. Older versions for better compatibility with older operating systems can be downloaded from the website as well. Once downloaded, users open the program to find a screen that can be confusing and intimidating for users who have never had specialized training in using digital art or animation programs. To test Blender as a 3D viewing platform, I downloaded a 3D image file of a small Mississippian jar uploaded to tDAR by Angie Payne as a part of the Virtual Hampton Museum Project (Ark_HM_0002 2007). I had to conduct an Internet search to find out how to open 3D images in Blender, and found that I had to click File → Import → Wavefront (.obj) in order to open 3D files (the 3D model from tDAR is in .obj format). I then had to select the .obj file from my computer's folder and Figure 2 shows the result.

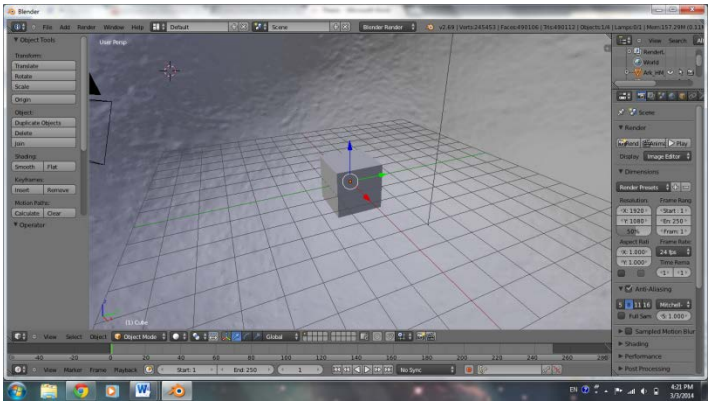

Figure 2. The Mississippian jar first opened in Blender.

As Figure 2 demonstrates, the image does not appear to be the 3D model of a Mississippian jar. That is because .obj files open extremely large in Blender, so what I actually see is the inside of the jar, zoomed in to the "origin" (the grey cube). In order to

see the jar entirely, I either have to zoom out my view (Figure 3) or scale down the 3D model itself (Figure 4).

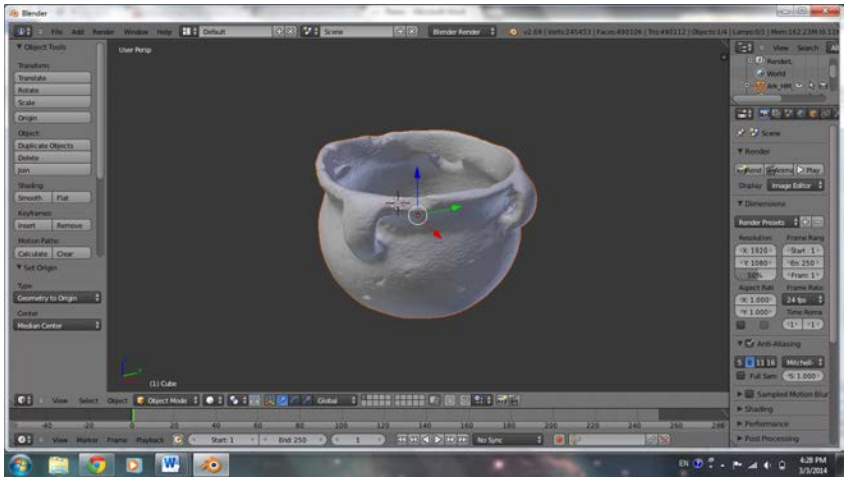

Figure 3. The view of the Mississippian jar when zoomed out. The "origin" is now just a dot in the middle of the white circle.

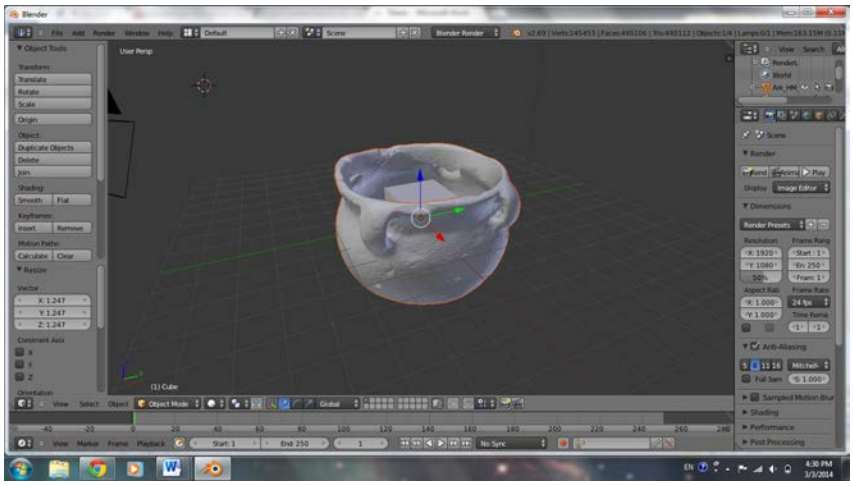

Figure 4. The Mississippian jar scaled to a smaller size. The grid is now visible again, as well as the "origin," which is inside the jar.

The large file size in Blender makes working with the 3D model difficult, and I find the grey box or "origin" very distracting to my view of the jar, especially when the jar is scaled down as in Figure 4. I also could not find an effective way to rotate the jar to view it from a different side, even though I spend some time adjusting the various colored

arrows and clicking on tabs on the sidebars. I feel certain that I could find the proper way to rotate the 3D model in Blender with another Internet search, but I think that the mere fact that I cannot figure out how to do it on my own speaks volumes about Blender's usability for those simply wishing to view 3D models. Most archaeologists likely have little experience with using programs like Blender, and so would not be encouraged to do so further if they could not navigate the program easily.

Figures 2, 3, and 4 also show that while the 3D model in Blender shows the texture of the jar, it does not represent the jar's actual color, rendering it useless for many ceramic analyses that require studying the coloration of the clay. I also could not easily find a tool for measuring parts of the jar, another important feature for many research analyses. Therefore I believe that if students or researchers who are not already familiar with Blender or other programs similar to it are required to use it in order to view and use 3D models of artifacts, they will not be able to conduct sufficient analyses to replace having to view or gain access to the physical jar itself (without conducting extensive research of and practice with the program first, which they may or may not be willing to do). As mentioned before, Blender has been used by many archaeologists successfully for creating hypothetical reconstructions or visualizations of sites, as shown notably by Ask (2012); however, for the simple purposes of viewing 3D models for those who are not attempting to create hypothetical visualizations, Blender is not highly effective. This is an example of how finding a 3D viewing program may be difficult, as researchers might have to download and try several different programs before finding one that is easy for them to use and suits their purposes. Fortunately, many of these programs are free.

MeshLab

MeshLab can be downloaded for free from meshlab.sourceforge.net, which has the latest version (V1.3.2) available. Upon downloading MeshLab and opening it on my computer, I was confronted with a much more simplified screen than I was with Blender. Following along the same guidelines as Blender, I selected File → Import Mesh and chose the .obj file for the same jar. Figure 5 shows the jar as it first appears in MeshLab, without any resizing or scaling necessary like with Blender.

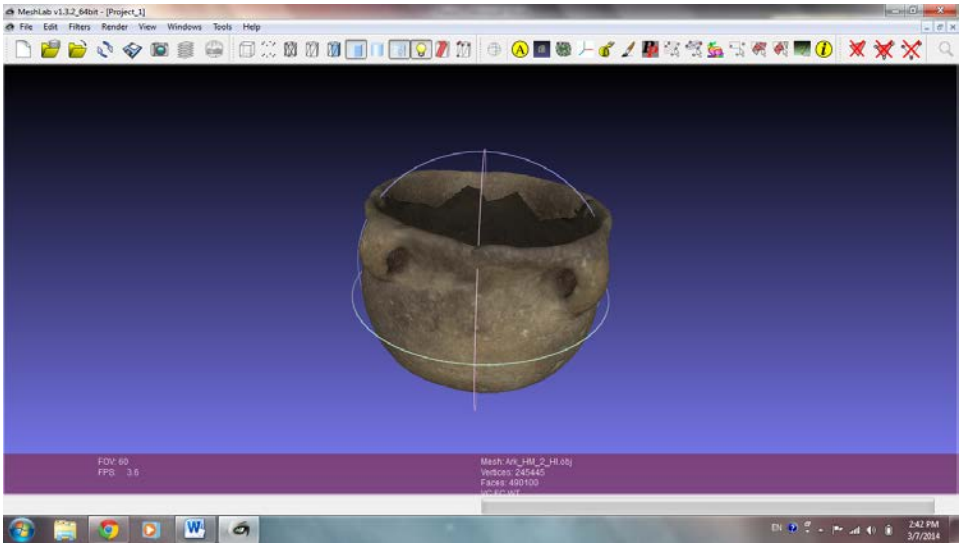

Figure 5. The Mississippian jar opened with MeshLab.

MeshLab has some other important benefits that Blender did not as well: namely the fact that the actual color of the jar is shown in MeshLab whereas only the texture translated to Blender. The uneven shadows seen on the inside of the jar in Figure 5 are an effect of the photographs taken to make the model, and so must simply be accepted. Also unlike Blender, the 3D model can be easily rotated in any direction by simply clicking and dragging the mouse (Figure 6). This allows for easy and immediate full 3D viewing.

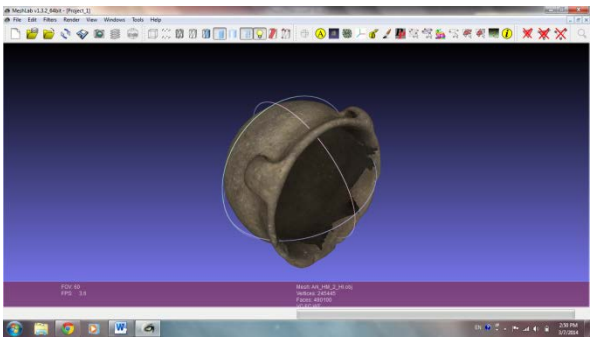

Figure 6. The Mississippian jar rotated in MeshLab to show how it can be viewed from any angle.

Measuring the jar is not so simple in MeshLab, however. There is a measurement tool on the top bar indicated by an icon of a yellow measuring tape, which the user can click on and measure between two points by clicking on the points with the mouse. However, the measurement given by MeshLab is arbitrary, and does not represent the actual measurement of the artifact in real units. In order to measure the artifacts in real units, the 3D model has to be scaled manually, which requires the user to know at least one real-world measurement of the original artifact (Mister P. 2013). This is a major problem since the researcher may not always have a measurement of the artifact and it requires the researcher to go through the extra steps of scaling the model manually. The process of scaling the model also introduces inaccuracy; it is difficult to measure the exact distance on the 3D model in MeshLab, which means that the scaling ratio used to scale the model is also slightly inaccurate. Researchers can of course use averages to help reduce the inaccuracy, but there is no doubt that researchers would have better results measuring the original artifact—a fact that makes using 3D models for analysis less appealing.

Despite this drawback, MeshLab is still excellent 3D viewing software that is much more user-friendly than Blender. Downloading it enables any researcher to view 3D models easily and quickly on their own computers, opening up the possibility of using 3D models curated in digital repositories like tDAR for research. The problem of scaling the models is one that desperately needs attention from those submitting 3D models to

repositories; if the submitters include some measurement information in the metadata or other catalogued information for the original artifact, it will be much easier for those wishing to use the 3D models to scale the models themselves. An even better solution would be for the submitters to calculate a scaling ratio themselves and include it with the information about the artifact that comes with the 3D model. In this scenario, the scaling ratio may still be slightly inaccurate, but at least every person that accesses or downloads the model for research is operating on the same scale instead of generating their own.

This chapter has shown some of the major problems with current collections access and use in physical repositories like TARL and CAS. Lengthy procedures, restricted hours, and limited availability of collections all make collections-based research difficult. Digital records and 3D models solve many of these problems by making collections easier to use and easier to find through world-wide digital repositories like tDAR. Some drawbacks still remain, like requiring researchers to have their own 3D viewing software and finding ways to perform a full range of analyses within those software, but these issues all have foreseeable solutions as technology continues to improve and users continue to become more and more familiar with operating in a digital environment.

Chapter 3

Controlling Access and Use Online

"Digitation of works makes them more difficult to control: users can easily redistribute, alter, or republish works leading to fears such as misrepresentation, defamation, copyright violation, and inappropriate commercialization by third parties."

Kristin R. Eschenfelder and Grace Agnew

The previous chapter discussed the major ways in which 3D digital reproductions of artifacts and sites can greatly improve issues of access and use around the globe. However, as the above quote points out, digital files are easily stolen, reproduced, or copied from the Internet, leaving many archaeologists and conservators concerned with issues of copyright and cultural sensitivity when it comes to making 3D models available for use on the Internet. Most archaeological artifacts are meant to be studied and enjoyed by the public, but there are certain types of archaeological information (such as site coordinates) that should not be available publically in order to protect the archaeological record. There are also some types of artifacts that are not meant to be available to the public, such as cultural or ethnic ritual/religious artifacts that may still be in use today. Therefore online digital reproductions of these artifacts also must be controlled in many cases, and site location information should only be available to qualified researchers to protect it from potential looters. Aside from copyright and cultural sensitivity issues,

there are also some economic concerns for museums and repositories, as highlighted by Bertacchini and Morando:

> …Low reproduction and transmission costs for digital content are likely to threaten museums' economic control over their intellectual property and to erode their authority as leading players in the authenticity, integrity, and contextualization of artworks and cultural objects. As a result, museums face a clear tension between favouring increased access and tightening control over their digital collections. [Bertacchini and Morando 2013:60]

This chapter will discuss the major ways that museums, repositories, and archives are currently maintaining control of digital collections to protect sensitive information and to preserve ownership rights, and will discuss which methods are best suited for archaeological 3D models. The difference between *access controls* and *use controls* should be noted in the following sections. According to Eschenfelder and Agnew (2010), access controls interact directly with the user to control the user's access to certain collections. Use controls involve "manipulating or mediating the source itself," meaning they act on the actual digital file to control how a user can use it instead of interacting with the user (Eschenfelder and Agnew 2010).

Access Controls

There are several different forms of access controls that museums and repositories can use to restrict who may actually view or use online digital files, such as 3D models, stored in their collections. They usually involve gathering some kind of information on the potential user or giving permission to specific users. Eschenfelder and Agnew (2010)

conducted a study to determine which kinds of access controls US museums, libraries, and archives are using most frequently, and the types of access controls they identified are discussed below.

Asking Permission

Requiring users to ask directly for permission to view collections is the standard method used by most archaeological repositories today (as shown in the previous chapter with CAS and TARL). This method makes the user contact the institution and usually provide details about his or her credentials and research aims. This method is effective for archaeological repositories to ensure that only qualified individuals are granted access to artifacts. However, in the case of digital 3D models, this method becomes more ineffective because most users will probably want to view digital files repeatedly on different occasions, and having to repeatedly ask for permission takes up both the user's and the institution staff's time. Online digital collections will probably also attract a larger number of potential users since they are available to anyone with an Internet connection, meaning that institutions may have to deal with large numbers of permission requests daily that may be difficult to keep track of.

Account Registration

This is one of the most common types of controls used by all three types of institutions (museums, libraries, and archives) from Eschenfelder and Agnew's 2010 study. This type of control involves forcing users to create an account (either free or paid) in the institution's system in order to gain access to the digital collections. A variation of

this same concept is network ID verification (such as a university library requiring a student ID in order to search the database) that require the user to be registered in a specific system. This method solves many of the issues for archaeological repositories with the permission request-based method. First of all, having users register for an account eliminates the "need for users to seek permission from the rights-holding [institution] every time" (Bertacchini and Morando 2013:66). Users with an account or ID can view the digital collections as many times as necessary without taking up valuable time requesting permission. User accounts also provide many benefits to the repository itself, such as helping it collect better data about its users by requiring them to enter information about their affiliated institutions, age, location, etc., and making it easier to contact users about misuse or violations of copyright (Eschenfelder and Agnew 2010). Repositories could also restrict access to certain 3D models or digital data by only allowing accounts that meet certain criteria (such as student or researcher status) to view and download them. Account registration also helps repositories share 3D models of copyrighted collections by being able to claim that all users with an account are using the collection for research purposes (Eschenfelder and Agnew 2010).

Approved Terminals and IP Range Authentication

In this method of access control, the institution's software only allows access to digital collections through specific computers or terminals or from specific IP addresses that have been approved. This method would allow the repository to restrict access to users coming from the affiliated university's (or other research institution's) IP address, or require that researchers interested in accessing the digital collection use the

repository's own computers where they can be monitored by the repository staff. The problem with this method, however, is that it prevents users from other states, countries, or institutions from accessing the 3D models. IP range authentication provides some leeway with this issue by perhaps providing distant users with a specific IP address to access the digital files from, but this would first require the user to ask permission, the problems with which have already been discussed.

Software Decoders or Viewers

This method requires users to have specific software to decode or view the digital files, thereby allowing the repository to strictly control who has access to digital collections. This method is very similar to asking permission in terms of its requirements, but it could potentially allow users to view collections multiple times without requesting new decoders each time. This method was among the least commonly used by museums, libraries, and archives in Eschenfelder and Agnew's 2010 study, perhaps because it requires more software and expertise, which in turn require more money. This method is not highly applicable to 3D models since they already require certain viewing programs like MeshLab which are not controlled by any repository or museum, but are instead available for any user with an Internet connection to download.

Usage Controls

As with access controls, there are multiple forms and methods of usage controls that repositories can use to protect the actual content of digital collections. They prevent copying, moving, altering, and unauthorized sending of the content once the user has

been granted access. As with access controls, Eschenfelder and Agnew (2010) studied several different types of usage controls as well as which ones were most commonly used by museums, libraries, and archives in the US. A few of the most common types they designated are discussed below, as well as their applicability to 3D models.

Watermarks

Watermarks involve placing some kind of semi-transparent logo, copyright, or name on top of a digital image so that anyone who attempts to copy, move, or send the image will not be able to claim it as their own. This method can be effective for digital images of artworks, documents, or other two-dimensional objects, but is not applicable to 3D models. Watermarks also prevent the user from using the image fully, since viewing is impaired by a semi-transparent mark across the image. This would hinder the purpose of creating 3D models for archaeological research in the first place—as Eschenfelder and Agnew (2010) have pointed out, "best practice sources caution that use of visible watermarking as a control technology can interfere with legitimate viewing and use of works." There are forensic watermarks, however, which Eschenfelder and Agnew define as "placed in hidden areas of digital files, such as low-level noise areas of an audiovisual file, where they will not impact the user experience but which enable both control of digital file use and tracking of downstream uses on the web." This type of watermarking could be adapted to 3D models to help both digital and analogue repositories keep track of the model files once they are in the hands of the researchers/users.

Disable Copy and Save Features

This type of usage control involves using scripting to disable the ability for the user to right-click on the digital image and save or copy the digital file to his or her own computer. This makes it possible for curatorial institutions to put up images of their collections without fear that users will copy the images without permission. However, once again, this is not highly applicable to 3D models since downloading the file is necessary in order for the researcher to use the 3D model in the first place.

Random or Temporary URLs

This method involves creating a random or temporary URL to access the images or digital files for a collection. In this method, the curatorial institution would provide a specific user with a temporary or random URL so that he or she could view the digital data they requested, but the URL would expire after a designated amount of time or he or she would not be able to access it again using the same URL. This prevents users from sending the URL to unauthorized people. This method could be useful for 3D models of collections, if a random or temporary URL was created to access a web page where the users could download the 3D file only once. However, this doesn't prevent the user from sending the 3D file once downloaded to other people.

Low-Quality Resolution and Thumbnails

This method is used very frequently by museums, libraries, and archives alike (Eschenfelder and Agnew 2010) to give users a taste of what exists in their collections without revealing all details, encouraging users to pay a visit to the institution itself. This

method involves presenting digital images of low resolution or quality or of very small size, so that users can see some aspects of an artifact but nothing in major detail. For obvious reasons, this method will not work for archaeological repositories that are not museums, since its primary objective is to encourage people to visit the physical institution and see the collections first-hand. For research, low-quality or small images are inadequate, especially for 3D models.

Copyright Concerns

Along with access controls and usage controls, curatorial institutions often have to develop methods to maintain copyright laws while sharing digital files of collections on the Internet. This is especially true for archaeological repositories, which hold many held-in-trust collections with private or corporate owners. Eschenfelder and Agnew (2010) include some methods of copyright or moral claim assertion in their survey of access and use control methods used by US museums, libraries, and archives, which are discussed in terms of their applicability to 3D models below.

Pop-Up Copyright Warning

This method involves scripting a pop-up copyright warning or caption to appear whenever a user accesses the digital file. The warning may inform users that reproducing, copying, or sending the digital file to unauthorized users is illegal, or clarify that using the content for scholarly purposes under the Fair Use policy is allowed (Legal Information Institute), depending on the copyright license of the collection. The warning may also indicate that the collection/3D model is under a Creative Commons License,

and so may be reused or redistributed as long as the owner/source is cited and may possibly require a copy of all derivative work from the content (Bertacchini and Morando 2013:66). This method can be highly useful for repositories to assert the specific usage conditions of 3D models of copyrighted collections.

Click-Through and Signed End-User Licenses or Agreements

This method involves scripting a pop-up or other dialogue box that details copyright parameters, much like the previous method; the exception is that this method also requires the user to accept the parameters by clicking an “agree” or “ok” button or giving an electronic signature. If the user refuses to agree with the copyright parameters, then the pop-up or dialogue box is closed and access to the content is removed. This method contains all of the benefits of the previous method, with the added benefit of clearly and undeniably holding the user accountable for following the copyright parameters.

As the above sections have shown, access controls are much more useful for archaeological repositories wishing to control 3D digital models than usage controls. Usage controls tend to manipulate the digital file itself, often rendering it useless for research purposes. Therefore archaeological repositories should look to access controls, such as requiring user accounts or network IDs, to make their 3D digital models of sites and artifacts secure online. Forensic watermarking is the most promising form of usage control for 3D models, and should be explored further to help keep track of 3D model usage patterns on the Internet. Archaeological repositories can also make great use of

copyright control tools to make sure that users of copyrighted 3D models are aware of copyright restrictions and are responsible for obeying them. Though Eschenfelder and Agnew's 2010 study showed that only about 20% of US museums, libraries, and archives used copyright controls, they can be much more useful to archaeological repositories which deal less frequently with individual, for-profit creative works and more with scholarly, not-for-profit works that have more lenient copyright restrictions.

tDAR's Access and Use Control Methods

To demonstrate how these methods can be used by repositories housing 3D models, an analysis of the access and use controls employed by tDAR is presented below. Some of tDAR's methods are not directly translatable to analogue repositories with digital collections, but essentially every method used by tDAR could be expanded or adapted to work for different analogue repositories in a variety of situations.

Access Controls or Usage Controls?

As mentioned in Chapter 2 of this thesis, tDAR requires all users to create an account in order to download or contribute digital files from/to the repository database, indicating that it relies on the "account registration" access control. Creating the account does not require approval from the tDAR staff or the staff of any other research or curatorial institution, meaning that any member of the public may create an account. This type of leniency is acceptable for a digital repository because all collections are digital files, meaning that even the most irresponsible member of the public could not harm an actual artifact through misuse. Analogue repositories could also employ the same

leniency towards access to their digital collections; they could create an open account system for viewing their database of digital 3D models of collections, but require a stricter permission process to view the physical collection housed at the repository itself or to gain access to site location data or other sensitive information. tDAR does require that an email address be given at the time of registration, meaning that if any user were to violate copyright law they could be contacted easily by the tDAR staff.

tDAR does not employ any kind of obvious usage controls. Photographs do not have watermarks—at least not watermarks that were placed on the image by tDAR itself. As in the example of Ark_HM_0002: Small Jar (the 3D model used for the MeshLab example in Chapter 2), the images of the actual jar on the catalogue page have right-click copy and save features enabled. The "small jar" page does have thumbnail photographs of the actual jar, but users can click on them to view them in larger size and in regular resolution.

Copyright Controls and Contributor Choice

Along with these access controls, tDAR employs several kinds of copyright controls. On the account registration page, tDAR's Terms of Use are written at the top of the page and indicate that by creating an account, users agree to being held responsible for following them (tDAR 2013 "Terms"). This is similar to the click-through or signed end-user agreement method discussed above, with the exception that it has no actual button to indicate consent or electronic signature and is not presented in pop-up or dialogue box format.

The terms of use presented on the account registration page also indicate that "Unless otherwise specified with respect to a particular file, use of this information is subject to the conditions of a Creative Commons Attribution 3.0 Unported License" (tDAR 2013 "Terms"). The paragraph goes on to detail the specific ways in which account users of tDAR can use the digital collections:

> Users acknowledge and agree that they will only copy or distribute tDAR content or use it in derivative works or otherwise (e.g., to publish or otherwise distribute an argument based on analyses of these data) under the following conditions:
>
> 1. Users must accompany all uses and applications of this content with proper citation and attribution (as provided on the tDAR metadata page).
> 2. For any redistribution of tDAR content, users must clearly include proper citation and attribution information and make clear to others the license terms of this work.
> 3. Users must not use tDAR content in ways that could be reasonably expected to lead, directly or indirectly, to damage to the archaeological record.
> 4. Users acknowledge that neither The Center for Digital Antiquity nor its sponsors and associates guarantee the accuracy or usability of the content and further agree that they may not hold any of these parties liable for any direct or consequential damage arising from their use of tDAR or its content.
> 5. Users are responsible for ensuring that their use of tDAR and its content is consistent with applicable law. [tDAR 2013 "Terms"]

These points clearly define for users the parameters of Creative Commons Licensing and indicate which situations are appropriate for users to copy, redistribute, or alter any

content in the digital repository. Placing them on the same page as the account registration ensures that those wishing to search or contribute to tDAR are aware of the policies. This is a simple method that can be used by any repository wishing to create digital models of its collections to be available on the Internet.

The second type of copyright control used by tDAR is by allowing contributor choice in deciding the public availability of submissions. On the "Upload and Contribute to tDAR" page, tDAR specifies several different options for making access to files stricter than the default option, which is allowing files to be publically viewable and downloadable. Figure 7 is a diagram provided by tDAR, along with an explanation of

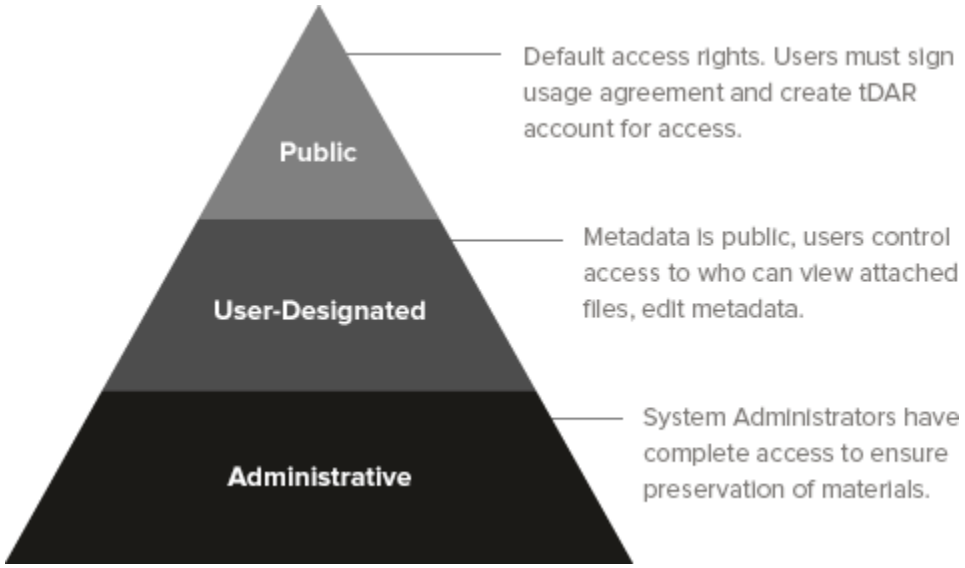

Figure 7. The tDAR pyramid of levels of access. (tDAR 2013 "Upload")

the different options available. They include "Limiting access to designated users," meaning the user who uploads the digital files to tDAR has control over who may see it by providing permission; "Marking files as confidential," again requiring any person who wishes to view the information to request special permission from the uploader to access

it; and “Embargoing access to materials for 4 years,” meaning that the data won’t appear to other users in the database until four years after it is submitted (tDAR 2013 “Upload”).

This method of contributor choice may not translate directly to analogue repositories wishing to create digital models of their collections. The physical collections the models represent may have stricter copyright rules on them already, or the repository itself may have certain rules about allowing sharing and altering of digital files. Since most contributors to analogue repositories will be submitting a physical collection, they may not have certain rules in mind for access and use of a 3D digital version of that collection. However, as mentioned in Chapter 2, more and more archaeological documents are “born” digital, so the contribution process to analogue repositories like CAS or TARL and to digital repositories like tDAR may not be so different in the near future. Analogue repositories will always have the added concern of accessioning the physical collection itself, but if more archaeologists create 3D digital models during the excavation process, analogue repositories should develop digital databases to store that data as well as to make it easily available to researchers around the globe.

In conclusion, there are a variety of methods archaeological repositories can employ to ensure the safety and proper use of 3D digital models. Access controls are the most applicable method, as shown by tDAR, because they avoid manipulating the 3D models or digital images themselves to preserve their research integrity. Forensic watermarks are a type of usage control that is potentially highly useful for controlling 3D archaeological models on the web, but more development must be done before they can be widely applied to 3D models and not just digital photographs. tDAR has also shown

the usefulness of copyright control methods in preserving copyright parameters, as well as the ability of online repository databases to allow the contributors to decide the public availability of their collections. All of these methods and resources prove that fears of being unable to control archaeological data and 3D models online are legitimate but easily assuaged. Museums, libraries, and archives have paved the way in digitizing collections, and now it is time for archaeological repositories to follow suit, adapting the methods of control used by the former three to meet their unique needs.

Chapter 4

Potential Problems with 3D Modeling and Digital Collections

"Without a doubt, certain types of cultural heritage materials will be under-represented, if represented at all, in worldwide digital heritage collections."

Katrine Mallan and Eun Park

Thus far this thesis has discussed the major ways that digitization of archaeological collections through 3D modeling can alleviate many of the problems associated with the curation crisis. This last chapter addresses some of the problems and concerns with creating, documenting, and relying on 3D digital models for archaeological research. These issues are perhaps the reason why more digitization of collections hasn't occurred already, but hopefully in addressing them and discussing them this chapter can show that these problems are either temporary until better technology arrives or solvable through careful planning and mindfulness.

There are two major categories of concerns with 3D modeling. The first category of problems falls into the realm of archaeological field work, and are concerns that practicing archaeologists face with creating 3D models in the field. The second category falls into the realm of curation and digitization of existing artifacts, and represents concerns that curators and repositories face when digitizing collections. Both types of problems must be addressed and solved if 3D digital modeling is ever to be used on a large scale for research; archaeologists must be aware of the benefits of 3D modeling

techniques in the field and be able practice them, and repositories must be able to store and disseminate the digital information once accessioned. The era of miscommunication and separation between the two entities must end for the sake of expanding the possibilities of archaeological research in the future.

Hardware and Software Requirements

Many archaeologists are wary of immediately adopting new techniques in the field because of the often expensive and expansive hardware and software requirements. Archaeologists are typically extremely aware of the monetary costs required for purchasing specialized equipment, and are also aware that the field is often a dangerous place for sensitive technology. Outdoor field conditions are not always ideal, and extreme care must be taken to protect digital devices from the elements on a daily basis. Added on to the extra time and care needed to protect digital devices in the field is the necessary time needed to train project members in their proper use. Specialized equipment is often not user friendly nor is knowledge of its use widespread. Because of this, many archaeologists hire specialists temporarily to use certain equipment for specific tests rather than taking the time to learn how to use it themselves. This method of hiring specialists could also work for 3D digital modeling, and in fact is already the standard practice for 3D scanning. However, 3D modeling is simple and unspecialized enough for this to not be necessary.

Fortunately, 3D modeling does not actually require highly specialized equipment. As Dell'Unto et al. (2010) state, "the quality of the resolution [of the 3D model] is usually accurate even with the use of off-the-shelf digital cameras." Ask (2012) and

Dellepiane et al. (2012) also emphasize that only a standard digital camera was needed to create sufficient 3D models in each of their respective projects. When observing Dr. Stephen Black of Texas State University-San Marcos and his team create 3D models for the Ancient Southwest Texas Project, I noted that they were using standard digital cameras as well (Figure 8). The team members also used professional cameras in some areas with less light to obtain higher-quality photographs, paired with simple LED lamps and light poles to provide some artificial lighting. They then kept the equipment inside a simple camping tent to prevent dust and debris from damaging them. In total, all of their equipment did not exceed the cost of purchasing a 3D laser scanner or other more specialized equipment to create 3D digital models. As mentioned previously in Chapter 1, the more complicated the structure, feature, or excavation, the more difficult it will be to create 3D models and may therefore require more expensive equipment. For most archaeological excavations however, simple digital cameras and inexpensive artificial lighting fixtures should be sufficient.

Figure 8. Charles Koenig of the Ancient Southwest Texas Project creating a 3D model with a standard digital camera. Author's photograph, 2014.

In terms of software, there are ample photogrammetry/Structure-from-Motion programs to choose from. Many of them are discussed in Chapter 1, along with 3D viewing software like MeshLab in Chapter 2. Using the software does require a little practice, but remains highly doable and does not take an extensive amount of time.

Monetary Costs

Aside from hardware and software, monetary costs are one of the largest concerns for archaeologists in all realms, beyond 3D modeling itself. Incidentally, monetary costs are also a large concern of repositories as well. As mentioned in the previous section, 3D modeling does not require highly expensive equipment, and there are plenty of free 3D modeling software programs available on the Internet. However, monetary costs still remain for archaeologists for acquiring computers with enough processing power to create 3D models and storing large amounts of photographs and data. Repositories' concerns lie in having to hire specialists or extra staff to aid in digitizing their collections, as well as web designers to help organize and create an efficient digital repository system available online. According to Bertacchini and Morando (2013:62), "in moving…their collections from the analogue to the digital world, museums face substantial fixed and sunk costs, but the cost of reproducing and distributing digital images is close to zero."

Unfortunately, 36 CFR 79 does not provide clear funding sources for curation of archaeological collections, nor does it require and provide funding for digitization of collections (Campbell 2011:27). This leaves many analogue repositories without the needed funds to begin digitizing collections on a large scale. Museums are in a slightly better position to do this because they can adjust admission prices to help cover the digitization costs (Bertacchini and Morando 2013). Archaeological repositories do not have frequent enough exhibits or visitors to rely on this source of income, and must instead charge collection producers and owners more for curation. tDAR is fortunate in that all of its collections are already digital at the time of accessioning, and so only needs to charge contributors to cover the costs of maintaining and updating servers.

While monetary costs still exist and are still a major obstacle in integrating 3D modeling fully into archaeology, the technical advances within the last decade have shown that costs will continue to decrease. Newer, cheaper forms of technology will continue to develop, lowering overall costs for archaeologists and repositories alike. These new technologies, such as 3D modeling software, 3D printing, and virtual reality, also increase public interest in archaeology and inspire more people to visit museums and heritage sites, generating more income for archaeological preservation (Bertacchini and Morando 2013:63). Also, as more and more digital repositories like tDAR are created, the more options archaeologists and researchers will have for curating data that is "born" digital at a lower cost. Therefore, it can be assumed that monetary costs for creating and disseminating 3D models for research will continue to decrease over time.

Lack of Standardization and Larger Project Context

These obstacles are ones that deal more on the side of using 3D models for research rather than in their creation or maintenance. As Ask (2012) points out, "There is still little standardization regarding the documentation of sources and interpretation processes leading to the creation of a virtual model, which causes 3D visualizations of the past to still have the connotation of lacking credibility." Though Ask is talking more about 3D reconstructions or visualizations of sites rather than basic 3D models of the sites themselves, the same problem still applies. There is no standard procedure that every archaeologist is advised to follow when creating 3D models, though the models are made through essentially the same process of digital photogrammetry from photographs. Some archaeologists may document their photographs differently, or may fail to label

anomalies or disparities in the models, causing confusion for other researchers studying them later. If researchers cannot decipher the labelling system or find explanations of features in the models, then their value for research significantly decreases. If archaeologists are to incorporate the practice of creating 3D models into their normal field excavation procedures, there needs to be a standard method of documentation and practice; or, at the very least, a clear description of the method used.

The second obstacle along these same lines is the lack of larger project context. Often archaeologists only curate already digital records or photographs from an excavation in digital repositories like tDAR, but not digital forms of the rest of the collection. This means that researchers wishing to study the excavation only have a small portion of the total collection of documents, artifacts, or reports from the project. The researcher would have to find the physical repository where the rest of the project collection is housed, and then go through the loan or access request procedures to study them—the limitations of which were discussed in Chapter 2. Therefore, in order to make digital collections-based research viable, either the collection creator/owner or the repository must digitize *all* of the collection, including the artifacts found. There are some obvious issues with this solution that go back to the discussion of monetary costs mentioned above. Fortunately, efficient means of accomplishing this solution do exist, such as archaeologists incorporating digitization into the excavation process rather than attempting to digitize everything afterwards. But this change in archaeological practice will take time to become fully standard, and so as a result using digital collections for research will also take time to become fully accepted. The change *is* occurring though, as

more and more archaeologists are realizing the benefits of digitization in the field (Ask 2012; Dell'Unto et al. 2013; Dellepiane et al. 2013; Henderson et al. 2013).

Unequal Representation and Access

These final two problems with 3D models for research are ones that repositories and museums must address rather than field archaeologists. They are also problems that focus more on future consequences rather than immediate issues. Unequal representation refers to the idea that only certain types of artifacts are considered "important" enough to be digitized, thereby marginalizing certain histories or areas of research; Mallan and Park (2006) touched on this issue in the quotation at the beginning of this chapter. They describe the current selection process for digitization of cultural heritage items, stating that "The *Guidelines* [*for Digitization Projects*] finds that selection criteria generally fall within three categories: content, demand, and condition" (Mallan and Park 2006:210). They go on to state, however, that most curatorial institutions focus the most on "permanent value" or "uniqueness" of a collection or artifact when deciding whether or not to digitize it (Mallan and Park 2006:210). This means that any collection or artifact that isn't perceived as "special" or "popular" by the general public is left un-digitized, inadvertently discouraging researchers from seeking them for research out of pure ignorance of their existence or difficulty with access.

It is logical to see why museums and repositories may take this approach at the current time, since digitization of artifacts through 3D modeling is still relatively new and costly. However, this mindset cannot continue forever. If archaeologists only cared about the "special" or "popular" artifacts, there would be a much smaller understanding of the

past today. Museums and repositories need to be making the effort to digitize a variety of different types of artifacts, not only to diversify the 3D model pool for research, but also to express to the public that all artifacts are important and to show them how archaeologists can learn extensive information from the most seemingly ordinary items. As Mallan and Park state, "access to a balanced representation of all cultural heritage materials is required if digitized collections are to serve collective remembering, locally, nationally, or internationally" (2006:215).

Unequal access is also an important issue that repositories and museums must be aware of proceeding into the future of digital collections. As this thesis has demonstrated, digital models of artifacts and excavations actually improve access by allowing researchers from around the globe to view collections and share information instantaneously. Mallan and Park even state that:

> Since digital files can be accessed by anyone with an Internet connection, digitization enables unlimited access to collections located in exotic, remote, or otherwise inaccessible places. When the geographic location of the collection or the user is no longer an impediment to access, cultural heritage collections are not restricted to those people who have the resources to travel to see analogue collections, and may benefit a much broader non-traditional audience. [Mallan and Park 2006:206]

However, there are some other issues of access that arise despite all of this. As Mallan and Park point out, the dominant language of the Internet is English, meaning that linguistic minorities are often neglected or excluded when trying to access and use digital collections. Mallan and Park go so far as to call this a new form of cultural imperialism

(2006:2013). There is also a significant difference in access between developed and underdeveloped countries, where people may not only be at a disadvantage linguistically but also technologically. Unfortunately, these divisions also tend to run along ethnic lines, meaning that some ethnic groups may be barred or discouraged from accessing their own cultural heritage. Mallan and Park emphasize how the problem of lack of context (mentioned in the previous section) reinforces ethnic divisions:

> Hedstrom takes the importance of context further and suggests that digitized collections that remove cultural heritage materials from their context and provenance could "reinforce dominant master narratives of progress, nationalism, ethnic superiority, patriarchy or technological determinism, or whatever those making decisions about what to digitize decide to emphasize." [Mallan and Park 2006:214]

This means that museums and archaeological repositories must take ethnic, linguistic, and technological minority concerns into account when digitizing collections and providing access to them online. Of course repositories cannot provide computers or Internet service to people in underdeveloped nations, but they can provide content in multiple languages or sponsor outreach programs to cultural minorities with connections to the digital collections. Dawson et al. (2011) provide a good example of this when they describe inviting several Inuit elders to view some virtual reality reconstructions of ancient Inuit and Thule houses, along with plans to bring the virtual reality equipment to First Nations schools to show to Inuit children. This kind of outreach ensures that ethnic and linguistic minorities are aware of the benefits of 3D models for research and have access to them.

All of these issues with using 3D models for research are ones that can be solved in the near future. Technological advances, reduced costs, and greater availability of access are all solutions that are rising on the near horizon for archaeology. None of these problems will be solved on their own, however, meaning that archaeologists and curators alike must recognize their existence and consciously pursue solutions. There could be other issues, technical or ideological, that arise in the future from integrating 3D models into standard archaeological research, but the archaeological community should and can be prepared for handling them. These most prominent issues are the major obstacles holding back widespread digitization now, and once they are eliminated, unprecedented opportunities for new research and learning will be the global reward.

Conclusion

"Beyond self interest, we share an ethical responsibility to make available the results of our work."

Keith Kintigh and Jeffrey Altschul

This thesis has shown some of the major ways that the curation crisis is damaging the future of archaeological research; difficult access to collections is not only removing their potential for research, but also undermining the ethical and moral responsibility to preserve the history of the world for posterity. Lack of standardization and funding make it difficult for repositories to grant easy access to their collections, and many archaeologists are trained with a prejudice against collections-based research from the start. Furthermore, as archaeology proceeds into an ever—increasingly globalized world, access to collections in foreign places remains extremely difficult, time-consuming, and costly. The future of archaeology lies not in isolation of data or discouragement of research, but in a wide discourse of global voices and perspectives that necessitates open access to all archaeological information.

Fortunately, an end to these problems is in sight with the application of 3D models for research and digital curation. Thus far, 3D models have been used in a variety of ways by archaeologists to help inspire and educate the public about the past, but they are only just now beginning to become integrated into the standard excavation process

and scholarly archaeological research. As 3D models appear more frequently in archaeological studies, hopefully more and more archaeologists will realize the benefits of using them as surrogates for actual artifacts that are difficult to access and sensitive to damage. In the past few decades, technological advances like GIS, ground penetrating radar, and satellite imagery have greatly improved and empowered the archaeological experience, and 3D modeling is no different.

That being said, it is incredibly important for archaeologists and researchers to have a secure and reliable place to store all of this new digital data while allowing others to use it at the same time. Digital repositories like tDAR are meeting the needs of the new generation of archaeologists by providing an online environment for immediate sharing, storage, and use of digital archaeological data. The Internet comes with dangers, however, such as issues of copyright and illegal downloading, sharing, or copying. Monetary costs are also still a major problem with creating and curating 3D models, but as technology continues to improve, costs will continue to lessen. Fortunately, all of the major problems with 3D modeling are ones that have foreseeable solutions, meaning that the widespread benefit of 3D modeling far outweighs the current costs.

3D models truly are a gift to the future generations of archaeologists by providing for them a means to study excavations as they happened and experience artifacts as they were, all preserved in a digital snapshot of time. Archaeology could be very different today if our predecessors had had the ability to create and preserve 3D models of sites that are now destroyed and artifacts that are now lost. The present generation does have the means to do this, however, and so must take on the responsibility of ensuring a better future of equal access and unlimited potential for archaeological research.

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