Overview of the State of Long-Term Preservation in terms of Reuse, Visualization, and Distribution of 3D Data in Archaeology

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Abstract:

In archaeology, we face a unique situation where our primary research method is destructive; excavation as a recording method can only be conducted once. But with the introduction of modern 3D recording methods, much of the process of excavation can be saved and reused. But at the same time, we must overcome the difficulties of examining sites where the data recorded has been accumulated over vast amounts of time which uses a wide variety of technologies and data standards. These factors combined make reuse of historical excavation data difficult, and reuse of our digital records such as our 3D assets a difficult task. The digital age brings forth questions of future-proofing modern research and data for long term preservation, reuse, visualization, and distribution capabilities. This paper examined the practices and standards currently being utilized surrounding our 3D assets in archaeology and analyzed via a variety of case studies ranging from museums, digital repositories, and archaeological excavations. This investigation includes ethical and theoretical discussion on archaeological data management and long-term digital data procedures while discussing the question of the role of accountability of the modern archaeologist in this modern technological frontier in terms of reuse, visualization, and distribution of these 3D resources we now create. The discussion of data standards and research practice in academic archaeology and contract archaeology vs. other fields with similar long-term projects is also explored. A picture of the current track of data-management in archeology is revealed as well as a solid understanding of the future methodology we should employ as well as the challenges we see in the coming years.

Key Words: 3D Models, 3D Reconstructions, Archaeological Curation, Archaeology, Archives, Databases, Digital Collections, Digital Preservation, Digital Repositories, Data Management, Data Structure, Digital Curation, Long-Term Data Storage

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Chapter 1. Introduction

Modern technologies have brought archaeology well into the digital age, but with this foray, we have now created copious amounts of digital assets that need to be managed for future generations. This new issue is a problem not only for archaeologists but for digital work in general, although archaeology brings along its unique challenges regarding the unifying of data-structures and data-management practices across various countries and regions. So where do we go as archaeologists whose work continues to move further away from “the trowel's edge” into this digital realm? Archaeologists like Matt Edgeworth have been discussing this transition, calling it a shift from spade-work to screen-work, noting that not just our tools but our archaeological assemblies are shifting further into this digital realm (Edgeworth 2014, pp. 40-41).

As archaeologists, we utilize a vast set of digital technologies and tools such as Geographic Information System (GIS), databases, 3D models, software scripts, digital photographs, digital drawings, tables, charts, and a slew of other digital documents. A unified method for managing these assets does not truly exist yet in our field. Every excavation has its distinct practices with unique quirks, and every country has its own standard, which sometimes varies between individual regions. The standards between contract/professional archaeology and academia are at odds and so are the standards between adjacent repositories such as museums vs. governmental agencies as well. With the immense discrepancies in digital data management and needs, how are we as a discipline expected to preserve our work for future generations? The division between the archaeologist and the archival world brings questions regarding the archaeologist's role in making sure the product is accessible when data changes hands. What level of data-management is expected of us? What is the bare minimum of digital data management we as archaeologists should aim at recording to achieve our needs in this discipline? We must find a way to maintain not only our created digital resources but both the paradata and metadata of these resources, so our works can continue to be of use for further generations of research.

The digital nature of modern archaeological resources means that our preservation needs are becoming more and more complicated. With the widespread adoption of GIS technologies into archaeological field practice in the 1990s, we see a need for storing complex 2D digital data in the long term. Over the next two decades, we have seen GIS data adding more details such as 3D components to the system, plus we have begun to heavily utilize 3D models in our recording practice in general. This constant adoption of technology not only increased the amount of digital resources we create but has also brought the difficulty of preservation to a complex enough level that is worthy of serious discussion. To compound issues, the multi-scalarity and temporality of archaeological data also needs to be noted in this conversation beyond the 2D and 3D complexity of our recordings, as it too is a key factor in the growing difficulties of managing our data.

One of the first major forays into digital recording was with the widespread adoption of GIS in archaeology. GIS has changed how we store and manage fieldwork, analyze and process data, and visualize our findings. The West Heslerton Project in Yorkshire, England is a good example of how the introduction of digital methods transferred a variety of roles formerly done without using digital methods to be conducted fully within a geographic information system. This project, which occurred between 1998 and 1999, documents an early shift from simply using GIS to record data to completely managing, visualizing, and analyzing archaeological finds within a spatial database system. All artifacts and features during this project were recorded with a total station and then inputted into their GIS. This use of digital data also expedited the publication process and allowed for the publication of their digital data, which was quite revolutionary at the time (Conolloy & Lake 2006, pp. 39-41). This type of GIS usage is now quite commonly the standard practice around the globe, revolutionizing how we practice mitigation in planning archaeological work, plus increasing the speed and ease of fieldwork recording, as well as giving us a great platform to perform countless forms of analysis.

But with the adoption of all this digital recording, the problem of data management has become a noted issue. We have seen global charters from the likes of UNESCO promoting a digital cultural heritage preservation standard (National Library of Australia 2003) and independent institute standards like the Smithsonian Digital Asset Management System (DAMS) (Smithsonian Institution, “Smithsonian Digital Asset Management System”) enforcing strict requirements at an institutional level. UNESCO’s charter states “The world’s digital heritage is at risk of being lost to posterity. Contributing factors include the rapid obsolescence of the hardware and software which brings it to life, uncertainties about resources, responsibility and methods for maintenance and preservation, and the lack of supportive legislation.” (National Library of Australia 2003, p. 13). Relating to this issue is the concept of us entering a sort of “Digital Dark Age” where much of the digital records from this era are simply lost due to unpreparedness, poor data management, and hardware and software obsolescence.

Adjacent fields to archaeology in the cultural heritage sector have begun filling this void of digital preservation needs. The position of a “digital curator” is seemingly becoming more common in archives, research institutions, and museums. Various academic institutions now even have degree programs in such specialization including the University of North Carolina which was the first to offer a master’s level degree in Digital Curation and Management (https://psm.unc.edu/digital-curation/). But this level of specialized profession and intensive care for digital resources is several steps removed from the archaeologist, with the above-mentioned degree program located outside the humanities and instead, related much more to the Information Technology discipline.

When it comes to these digital assets, how do we as archaeologists meet the needs of digital curation standards? The way archaeologists treat physical artifacts from out of the ground to the museum is always at odds with the museum and curation professionals. An artifact being handled bare-handed, being tossed in a box, and then suddenly being treated with utmost care once it is in the hands of the curation and preservation professionals is a conflicting picture. With digital materials, it is a similar case. We record massive amounts of information in digital formats yet only a small subsection ever makes its way into a carefully organized state-run or institutional database. Many files are lost forever or left to rot on an external hard drive in someone's desk drawer forgotten to time. Making sure that what needs to be saved is actually saved remains a critical component of the entire issue in this discussion.

With this topic of digital curation and preservation being such a large topic with the capability of being discussed in many directions, we need to focus our discussion down. To do this, we will focus on a single data type that has seen rapid adoption and implementation in modern fieldwork; 3D recording and modeling assets. This type of data has become crucial in modern fieldwork, but these digital assets are quite vulnerable to data loss and host a real threat to maintaining long term heritage preservation. 3D data has been on the frontier of triggering new ways to look at our archaeological records for analysis and visualization but using this means that we must look at our data in new ways. These 3D resources in some cases move beyond supplementary materials and become primary sources for future analysis. The ability for 3D assets to become a primary source of analysis makes their preservation and management of the utmost importance, enforcing the need for a discussion regarding our practices of 3D data curation in archaeology. This problem of long-term digital preservation of cultural heritage resources involves far more data types and records than just 3D, yet the unique nature of this data and how it is being used means extra care needs to be taken. These 3D models need to exist beyond our initial reports; they must be capable of existing long term to ensure reuse in a variety of forms. This can be through public visualization in 3D web viewers and an effort to make sure we reach some sort of sufficient level of distribution and publication of the digital data into repositories. But whatever the exact solution is, something must be done so the data does not get lost or abandoned.

Aims

Looking into this topic of digital preservation is a large task, so narrowing down the scope is key to get anywhere beyond surface-level discussion regarding our 3D data and its preservation and reuse. To look closer at this topic, we can look more at how we should be viewing expectations of standardization in digital heritage management more so than a concrete physical practice. Specifically, trying to answer our core question:

Are the current procedures for performing curation and maintenance of 3D data sufficient to ensure long term preservation, reuse, visualization, and distribution within modern archaeology?

How has this 3D component's addition to archaeological data recording increased the complexity of the task of preservation? To examine this, we must identify how 3D data is currently being handled for long term data management in archaeology and how it ideally should be. This will be accomplished by identifying the locations in which we are lacking in the management for 3D data and discussing how projects using 3D digital documentation have made attempts to resolve the issues inherent to such formats.

This investigation will be conducted by examining current practices from various case studies which represent a broad outline of the current state of 3D data handling in archaeology from institution to excavation level. To do this, investigations into the difference between the data management practices of various institutes and projects will be conducted to identify how long-term preservation of our data is being handled. This process will also attempt to find the line where the archaeologist's responsibility ends regarding the issue of 3D data preservation and highlight where the issue transfers hands. Potentially finding any core ways archaeologists determine and flag files for long term digital curation, as not all files are worthy of extreme treatments (McManamon 2013, p. 3).

Previous Research

The inspiration for investigating and exploring this topic is influenced by the concept known as the “Digital Dark Age”. Organizations like Saving European Archaeology from the Digital Dark Age (SEADDA) were specifically designed to investigate and raise awareness of this issue (Saving European Archaeology from the Digital Dark Age, “About SEADDA”) as well as personal experience working in IT and archaeology over the past decade. Digital files are far more fragile than most take account for, and their continued existence is not guaranteed. People in all fields — including archaeology — take the permanency of our works for granted, and any work we conduct will not exist long term in a digital state unless we take steps to make it so.

However, when speaking of the origins of the 3D movement in archaeology, we can go back quite far, with virtualization of archaeology being discussed in the 1980s and early 1990s by Paul Reilly (Reilly 1989, Reilly 1990). Reilly discusses many interesting aspects of 3D usage and theorization at the start of the digital turn. During this period of transferring our recording from the paper to the digital realm, Reilly notes that the first computerized systems regarding archaeological data recording tended to mimic their paper counterparts. This mimicry made the adoption of digital technologies seem redundant until the addition of 3D recording, which overcame the two-dimensional limitations of paper recording (Reilly 1990, p. 133). Reilly also defines his concept of what virtual archaeology would consist of in this new digital frontier, saying that the virtual component would act as a model or replica which was fully capable of acting as a surrogate or replacement of the original. As a result, the virtualization process can simulate archaeological formations. These ideas also brought forth questions of how to accurately simulate archaeological formations and what was required to successfully record this virtualization (Reilly 1990, p. 133). He saw “virtual archaeology” as having a major impact regarding “...the ability of the researcher to interact with the graphical models to enrich greatly the perception of the material under study.” (Reilly 1989, p. 570).

Ideas of how virtualization could be utilized in archaeology continued to be discussed, from simulating the actual act of excavation to virtual reconstruction (Reilly 1990, pp. 133-134). This ability to virtually excavate is seen as a means of not only training future archaeologists but also acting as a means of recording method analysis. By virtually excavating one could discover the optimal method to excavate certain types of features in the field, thus helping solve some of the issues with the destructive nature of traditional excavation (Reilly 1989, p. 571). Beyond models of monuments and features comes the full digitization of archaeological resources. Discussion of the need to bridge the gap between the recording and visualization when moving from the dig to the interpretation phase of an archaeological project. The process of virtually reconstructing sites was still only part of the end interpretation and not as much as a means of interpreting in this time frame of the late 1980s. But the idea that these technologies could be used to "virtually re-excavate" a site to find new knowledge was already being theorized and discussed (Reilly 1990, pp.134-135). The idea of reconstructing an excavation and finds in 3D was already being tested and explored at this time. Although it was far from being readily utilized, the steps towards digitization and virtualization were in motion (Reilly 1990, pp. 135-137).

Colin Renfrew also discusses the origins of this topic of virtualization and 3D in his foreword of Forte and Siliotti's *Virtual Archaeology*, specifically, regarding Maurizio Forte who was one of the leaders in the early virtualization of archaeological sites. The usages of these 3D virtualizations are discussed, beyond the use of simple reconstruction and digital storage, but as integrated pieces of a sort of complex storage system which could be used to assist in determining new solutions and easing the task of reconstruction. The ability to answer new questions with 3D virtualization was discussed beyond simple virtual reconstruction (Renfrew 1997, p. 7). 3D as a medium of knowledge creation has been apparent for decades with Reilly in 1989 discussing the benefit of these mediums, but also the lack of efficient distribution and visualization methods to make it an efficient vehicle of information exchange. The need for infrastructure was apparent, some form of a self-contained system was needed and would require standardization and cross-referencing capabilities (Reilly 1989, p. 578). This idea that to efficiently use this data we require complex infrastructure, some form of the database type system to allow thoughtful access and reuse of these 3D models.

Bernard Frischer discusses the topic of 3D in cultural heritage and states the many potentials of its use in archaeology. Specifically, the big selling point is that "...3D modeling has the potential to mitigate the irreversible and destructive nature of archaeological excavation…", something which until its adoption was simply an unavoidable consequence of excavation (Frischer 2008, p. v). Although 3D visualizations have been in use for some time, the shift from simple model-building to discussing methods of best practice was fully underway by the 1990s (Frischer 2008, p. vii). As we moved towards the late 1990's, digital visualization from 2D to 4D was well underway in both the natural and social sciences; archaeology was no exception to this trend. 3D visualization infiltrated into GIS with FLIDAR allowing large landscape reconstructions and even stratigraphy from historical excavations being reassembled as 3D polygons (Frischer 2008, p. xi). These types of new visualizations are where the 3D realm will begin to make strides in archaeology. Reconstruction is an important usage of 3D technology, but the creation of new knowledge from the virtual is of greater significance. The tools to do such analysis are still in development and Frischer notes we should see these take center stage in the years to come. Although to reach this level of knowledge creation from 3D virtualization we need the development of complete accessible tool kits with standardized user interfaces (Frischer 2008, pp. xiii-xv).

People have long been discussing topics relating to 3D data, and we see people and entities working on ways to mitigate and work through the many hurdles that these new 3D digital data produces for archaeologists. Regarding digital media in general, Costis Dallas asks for us to redefine what archaeological curation is regarding this puzzle. Not just the hardware required, but “which is its object, how it is enacted, and what kinds of technological “mediational artefacts” – not just hardware devices but also methods and procedures, digital services and tools – it entails” (Dallas 2015, p. 179). These new technologies also have associated methods and workflows which need to be preserved to truly maintain this data. With 3D data, this can be considered as the specific technologies used to modify or create the data as well as the workflow itself. Dallas also suggests an epistemic-pragmatic approach to discussing digital archaeological curation. The usage of this data is to create knowledge as well as preserve knowledge. The epistemic action is the usage of the resources to create new knowledge and theory in the practice of digital archival and curation while the pragmatic action is the practice of actually curating and managing the digital resources in archeological work (Dallas 2015, p. 179). Poor curation of these archaeological resources increases the chance to have orphaned archaeological resources, plus resources curated improperly can lack cultural and contextual information beyond what is in the metadata. These scenarios can then give rise to poor reinterpretation or even changing narratives over time (Dallas 2015, p. 180-181).

Current State of 3D Digital Heritage Preservation

Right now, the state of digital preservation of cultural heritage is all over the place. Many countries and regions have private repositories, but the steps needed to make sure this cultural heritage is protected en masse is far from in place. Repositories are a decent step to this conundrum, but they need to exist at a point where they are affordable and readily available to see proper usage. The usability of these repositories also needs to not require the archaeologist to be an IT professional; they must reach the point of being usable to the respective end user.

When we look at the state of digital preservation of 3D data, some big players in establishing standards are major museums and repositories such as The Smithsonian, the Archaeology Data Service (ADS), The Digital Archaeological Record (tDAR), and Europeana. These organizations all maintain some form of standard towards long term management and curation of digital data, with their standards constantly being revised and updated to meet modern needs. However, many organizations are lagging and lack the ability to meet the needs we are seeing around some of today's new digital assets we are creating, such as 3D models.

Many of our digital resources in archaeology are finding their way into third party systems. Sometimes this is done to provide a simple front-end medium for public viewing, but in other situations, it may be the extent of digital stewardship all together. Using these existing external resources makes sense but is dangerous to the long-term storage of our digital creations. Anyone who had dabbled with digital models has probably encountered Sketchfab (https://sketchfab.com), an online viewer, distributor, and sales platform for 3D models related to all fields. Europeana's recent task force (published January 7th, 2020) researched the current state of 3D content in the heritage sector. In this task force, a survey of professionals in this area revealed their means of web visualization choice for their 3D content; the most popular solution was Sketchfab (Europeana Network Association Members Council Task Force Report 2020, p. 14). These various professionals noted Sketchfab and other visualization services as being suitable for lightweight 3D models and quite favorable due to its standardized user experience. The alternative solutions such as self-hosting via software like ISTI CNR's 3DHop are far more capable, but lack the industry and user standardization seen in more commercial variants and have a high skill curve for setting up and utilization to one's needs (Europeana Network Association Members Council Task Force Report 2020, p. 9)

As a result, we see the development of 3D visualization and storage means being developed, yet we are seeing a lacking industry standardization on many fronts. The Europeana task force proposed a call for action to address the short sightings of our 3D data handling regarding their own needs. Specifically as an inquiry towards identifying and establishing standardized file formats, further 3D viewer integration and platforms for delivery, a defined metadata schema relating to 3D, better 3D content labeling, addressing the issue of dead links (specifically in regards to external viewer integration), and to work towards establishing further collaboration (Europeana Network Association Members Council Task Force Report, pp. 40-43). Although this report relates strictly to Europeana take on the issue, it echoes across the field as Europeana exists as the largest European digital repository in the cultural heritage sector.

Chapter 2. Theoretical Discussion and Framework

To discuss this topic of 3D preservation and reuse in modern archaeology, our theoretical perspectives as well as how they will be enacted within various areas of the cultural heritage discipline will be highlighted. This chapter intends to help frame this discussion in a logical light composed of a sound theoretical backing. Doing this will help establish a clear consciousness towards the current thoughts on 3D assets in archaeology and digital assets within cultural heritage.

Theoretical Perspective

If we are to attempt to frame this conversion regarding our preservation, reuse, and distribution of our 3D data in archaeology with some form of theory, an interesting perspective to look at is the concept of “Slow Archaeology” coined by William Caraher (Caraher 2016). Slow archaeology developed in part from Caraher’s past conceptual theories of both “Punk Archaeology” (Caraher, Kourelis, & Reinhard 2014) and his idea of “Archaeology of Care” (Caraher & Rothaus 2016). These theoretical concepts of archaeological interpretation all focus on the importance of place in archaeology and how it reflects in our interpretation and recording of archaeology resources. Caraher has taken these ideas to examine specifically how archaeologists are using digital technologies in the field as well as their ability to influence the creation of new knowledge about the past (Caraher 2019, p. 2). This is a reflexive approach to digital technology being utilized in our modern technologically fueled archaeological practice.

The concept of slow archaeology also has roots in the theories of transhumanism and posthumanism, especially in response to the digital technologies we are utilizing in archaeology. We as archaeologists are one cog in a complex machine composed of many tools. By taking the position of a cog in a greater machine composed of many parts, we are capable of increased labor outputs but with a negative byproduct of disconnect from the products and goals of the projects we take part in (Caraher 2019, pp. 6-7).

This increase in efficiency related to 3D technologies is often cited as a means of increasing the speed and productivity of the archaeological workflow. But with this increase in the speed of recording, we also introduce problems relating to interpretation and preservation of our recordings themselves (Caraher 2016a, p. 44). Commonly in the confines of the discussion of 3D recording methods, this increase in recording speed can be seen in structure from motion technology which allows for recording artifacts, features, or individual strata without necessarily slowing down excavation when compared to the historical method of trench or artifact illustration (Caraher 2016b, pp. 431-432). But this quicker recording also is increasing the intricacy to our data and tends to become a sort of fragmented yet comprehensible recording method. A new step is introduced into our workflow in which the archaeologist needs to reassemble and reinterpret these 3D records outside of the field. The data is then moved between applications and devices to create information usable in the report and the other recording systems. The introduction of this technology also means a level of specialization of users; this is also seen in the data management required to maintain a system capable of storing this data in the long term (Caraher 2016b, pp. 432-433). This suggests that the introduction of these technologies is a double-edged blade that must be accounted for or the improvements gained of these technologies do not necessarily outclass the former “slow” techniques.

Our recording of 3D data also brings forth a reliance on bespoke or proprietary software and hardware to produce viable results. This then goes on to affect the storage and maintenance of these data formats as well. Although the data surrounding a 3D model is not that hard to decode regarding the photographs, point clouds, meshes, and textures, with these aspects being capable of archiving without too much complexity. The larger issue is the models themselves originate from these so-called bespoke or proprietary software solutions (Caraher 2016b, p. 433). Thus, their reuse, or more specifically, their recreation, becomes a hard task to solve. Distribution can also be an issue as file formats and visibility can be limited by the software or hardware used to initially create these assets.

Thus, the idea of slow archaeology calls for archaeologists to take a critical view of the adoption of their tools. This means to critically examine the adoption of new tools and technologies such as 3D modeling, putting it in its own lens which can be used towards how our workflow, interpretation, and methodology will be shaped. The entire digital ecosystem of use needs to be considered when utilizing methods like 3D models in archaeology (Caraher 2016b. p. 435). We are shifting the realm of archaeological interpretation more and more from the field at the so-called “trowel’s edge” to behind a desk at the office (Caraher 2016b, p. 435-436). This shift of place regarding where our point of interpretation resides means the data we record and utilize needs to house enough information to mitigate the “placelessness” that the digital tools like 3D models do not necessarily maintain. When we move from field interpretation to off-site interpretation, the ideas which may be apparent from the physical experience of being at the site of recording are lessened. Of course, interpretation and digital recording can be done in tandem, but if the recorded models are not constructed personally, or simply analyzed later or by a future archaeologist; an aspect of the experience could be missing from the recording. To maintain this intangible idea of place and immersion, the model requires metadata and other associated data to assist the user in achieving a sufficient facsimile of the experience, regardless of the location of analysis. Slow archaeology thus points us towards a way of judging the necessary consequences of our rapid digital tool adoption and inadequate handling of these tools. We can use this lens to critically review the place these tools play in developing our field practices and methodologies relating to their usage (Caraher 2016b, p. 437).

Another lens that is also found in the slow archaeology perspective is the posthumanist and materiality perspectives. This idea is one that many theorists have discussed in which both people and objects have a sense of agency and their relationships between both the object and subject varies. In some cases, an object can impact more agency upon the subject and vice versa (Huvila & Huggett 2018, p. 89). But it is this back and forth relationship of variable influence, a digital agency can be seen in archaeological practice. Our technology influences us in different ways. Within archaeology, we need to be aware of the ways digital technology influences how archaeology is achieved and the extent to which it either helps or hinders us (Huvila & Huggett 2018, p. 91). Within the confines of our usage of 3D, this rubs off on both our means of creating and using these resources. Our work is hindered by the technology itself as well as shaping its design. When related specifically to the discussion of material culture having a give and take between itself and the subject is a core point of this concept of materiality, it is a reflexive relationship between the archaeologist and the things they study (Verhoeven, 2018, p.28). This also includes the tools archaeology use to study, interpret, and record these things; thus, the digital realm as well. So, this introduction of new technology and digital media changes how we view and relate to cultural heritage and material culture, which we see heavily in both Caraher's Slow Archaeology theory and practice.

Theory in Action

The theories mentioned above are active in driving a large response in cultural heritage practice today towards answering or at least addressing the topic of digital preservation of our 3D and other digital resources. Specifically, the ideas of Caraher and his concepts of Slow

Archaeology and Archaeology of Care, both of which tell us to look at our workflow and specifically the technologies we are using to access usage and needs as well as explore how knowledge creation is affected by our technology. This can be seen in various COST action, awareness, and other groups that have appeared in a sort of reflexive response toward the issues of long-term digital preservation and its usage. The European Cooperation in Science and Technology (COST) uses COST actions to enact change in various fields of scientific and technological research and study. These COST actions specifically are "…a network dedicated to scientific collaboration, complementing national research funds." (The European Cooperation in Science and Technology, "What are COST Actions?"). These various organizations help to frame the scope of the issues and establish what questions should be asked about preserving our 3D and digital heritage. These groups are not trying to physically solve the problem of long-term preservation themselves, just raise awareness of the issue and outline potential ways of looking at the problem. Their impact in successfully being measured in the same light is thus not possible but remains here to help establish a frame of reference for our other cases which can be analyzed in a more critical light.

When we look at our more general heritage and COST Action resources, we do find much in terms of the impact of these efforts. The UNESCO Charter, DCC, or SEADDA: all of these are difficult to gauge the amount of impact they have had in contributing towards assisting in making sure 3D heritage is being managed correctly. Simply by them existing and being referenced between organizations means the issue key to this paper is seen within the field and their word is getting out there. But the true nature of the success of these organizations in making an impact towards improving 3D and digital preservation is nearly impossible to gauge.

UNESCO Charter on the Preservation of Digital Heritage

The United Nations Educational, Scientific and Cultural Organization's (UNESCO) Charter on digital heritage preservation is an active attempt to draw awareness and standards towards the needs of 3D and digital heritage preservation. UNESCO tends to be a great resource regarding policy and standards relating to global cultural heritage related issues. UNESCO addressed the issue of digital data curation needs related to heritage back in 2003 (UNESCO 2003, p. 74-77). We were well into the information age at this point, but the extent of technology's influence on archaeology and cultural heritage was still being theorized and constructed. Their analysis of the so-called "Digital Dark Age" and the danger of all our digital data was realized well before smartphones became a thing. UNESCO addressed this issue early on with a simple to understand charter as well as an elaborated supporting document. This is by no word gospel, but one of the earlier public initiatives to help raise awareness of the dangers of the issue of digital preservation to cultural heritage fields.

The UNESCO Charter on the Preservation of Digital Heritage is a sort of call to action towards the needs of data management of all digital assets relating to heritage. The charter provides twelve articles related to digital heritage and the topic of preservation divided into four separate categories. This charter relates heritage to not just archaeology but all cultural heritage (ancient to modern). The categories are “Digital Heritage as Common Heritage”, “Guarding against loss of heritage”, “Measures Required”, and “Responsibilities”; these then contain the twelve articles (UNESCO 2003, p. 74-77).

Under the first category of “Digital heritage as common heritage” are two articles; Article 1 is “scope” and Article 2 is “access to digital heritage”. This section defines what digital heritage is, and how accessibility is key to making it a viable resource. Resources not accessible in the digital realm can very well be treated as not even existing at all (UNESCO 2003, p. 74-75).

The second category of “Guarding against loss of heritage” has three articles, article 3 is “The Threat of Loss”, article 4 is “need for action”, and article 5 is “digital continuity”. This section really starts resonating with this discussion by identifying how easy digital data loss really is, establishing the idea of lack of action and the consequences (The Digital Dark Age), and the importance of constant data management and curation (UNESCO 2003, p. 75).

Their third category “Measures Required” contains articles 6 “Developing strategies and policies”, article 7 “selecting what should be kept”, article 8 “protecting the digital heritage”, and article 9 “preserving cultural heritage”. This section then outlines actions that can be done (much more in-depth in their supporting documentation). This is a section that relates very much towards an average archaeologist, who makes and passes on data towards other heritage professionals for long term storage and curation (UNESCO 2003, p. 75-76).

The final category of this section is “Responsibilities” and contains articles 10 “Roles and responsibilities”, article 11 “Partnerships and responsibilities”, and article 12 “The Role of UNESCO”. This section not only shows how we as archaeological professionals should act, but how all adjacent cultural fields need to act, as well as how UNESCO plans to act. This is then elaborated greatly in the supporting document. We as archaeologists need to look at these ideas when we plan and utilize our digital works (UNESCO 2003, p. 76-77).

This charter provides a quality outline of generalized needs for digital preservation. It does not directly influence reuse, visualization, or distribution and publication of 3D materials in archaeology, but does reveal that these ideas have been considered as necessary ideas regarding our digital assets since the get-go. The needs of making sure our digital materials are accessible, preserved, and maintained have become core to the ideas and practices surrounding these materials.

Digital Curation Centre (DCC)

For another example, we have the Digital Curation Centre (DCC) out of the United Kingdom. It is an internationally recognized organization with a focus on digital data curation. They do not strictly focus on cultural heritage but have many resources and partnerships with cultural heritage institutes and professionals (Digital Curation Centre, “About us”). The DCC was chosen to investigate to examine how 3D models were viewed regarding their curation standards and potential from non-archaeological perspectives. The DCC even has a variety of metadata schema and resources specifically for archaeology outlined on their site. As well as using the ADS as their primary example of a functioning digital curation institute for archaeology (Digital Curation Centre, “Archaeology Metadata Standards”).

Their archaeological standards are all based on British standards with their metadata standard coming from the MIDAS-heritage standard which is widely used in the UK (Digital Curation Centre, “MIDAS-Heritage”). The DCC also references the European non-profit association CARARE and their metadata standards (Digital Curation Centre, “CARARE Metadata Schema”). Overall, the DCC operates sort of similarly to SEADDA. They are not attempting to directly solve the digital curation issues but raise awareness and push users of digital data onto a path of proper digital curation. This is done by the DCC giving guides and resources to do so, making digital curation a matter of accessibility and knowledge sharing. This is acting as a response to issues noted by various individuals around digital curation, and reflexively trying to address the issue.

The DCC does have resources relating directly to geospatial data with whole briefing papers which discuss the reasons and procedures of curating this type of data, noting that this type of data is best existing in a more living state as GIS data, which tends to be used, reused, modified, and edited over time. This is something that makes GIS data so powerful but also a bit of a complex entity to maintain, like any living database system (McGarva, 2006, p. 1).

Although the DCC has many resources relating to digital curation in a variety of fields over many data types, 3D digital models seem to be lacking any specific rules or regulations. Although 3D assets are being widely integrated into many fields, a unified standard does seem to be lacking even from a higher up awareness institute like the DCC, but they manage to outline much of the digital curation needs similarly to the UNESCO Charter with their own charter on digital heritage management (Digital Curation Centre, "DCC Charter and Statement of Principles"). They present ten key principles primarily to spread awareness and advocate good data policy regarding digital curation, thus putting their role in this discussion similarly to the UNESCO charter.

Saving European Archaeology from the Digital Dark Age (SEADDA)

Another organization taking the issue of digital curation and preservation into account is Saving European Archaeology from the Digital Dark Age (SEADDA). This is an organization which aims to address the specific issue of digital data loss regarding archaeological data. Acting as a sort of intellectual taskforce with members throughout Europe whose goal is quite clear from their name: to prevent the archaeological work in Europe from experiencing a digital dark age. Enough people are aware that this type of issue exists that organizations like SEADDA have been formed (Saving European Archaeology from the Digital Dark Age, "About SEADDA"). Unlike Europeana, the ADS, or tDAR; SEADDA strives for awareness more so than directly attacking the topic of how to solve the issue of digital data loss. SEADDA does not have any specific goal toward 3D data but relates to it in a broader sense regarding all digital long-term storage, since it relates to all digital archaeological resources in general. SEADDA was examined from a focus of the scope of their impact on our 3D archaeological recordings in terms of this issue of digital data loss.

SEADDA is not here to fix the problems directly but to act in a capacity of raising awareness. This, in turn, can help 3D models and data towards the long-term goals of continual digital preservation and reusability of digital assets in Europe. Like both the UNESCO Charter and the DCC the act of these types of initiatives is to build awareness of the issue and the state of the problem. Thus, acting as a response from the archaeological and cultural heritage community to try to adapt, inform, and overcome the limitations of current work practices.

They estimate that maybe five European countries have the digital repositories and means to safeguard, distribute, and allow for reuse of their digital archaeological data. Many countries do not even have the infrastructure or means to partake in international or global research initiatives at the level required for what is currently considered necessary for long term digital data curation. The need to establish clear goals and requirements is paramount to prevent Europe from experiencing a digital dark age (Saving European Archaeology from the Digital Dark Age, “About SEADDA”).

The scope of SEADDA is not about some global initiative; this organization is strictly related to European archaeology and resources, yet is still a huge undertaking and has potential beyond something that can be realistically accomplished by a lone group. But raising awareness of the issues of the Digital Dark Age and the sheer importance of data stewardship hopefully keeps pushing archaeologists in the region in the right direction. Organizations like tDAR, the ADS, and Europeana are examples of what the result should be, but their product is not readily accessible or utilized in a variety of countries. Thus, continual advocacy towards solutions is required in this discussion of the long-term preservation of our 3D data.

Chapter 3. Materials and Methods

In order to discuss the state of 3D heritage management in modern archaeology, we need materials to analyze. We will also briefly discuss the issues with standardization and how that will impact our analysis and ability to answer the research questions of this paper. On top of selecting materials, we also require methods to be defined and established before continuing to the analysis.

Materials

The materials consist of a series of case studies to represent both physical actions or collaborative discussion being taken regarding 3D models in archaeology and heritage preservation. The materials will ideally be able to provide a medium to answer the research questions regarding if the 3D data type is being adequately managed as well as if our needs for reuse, visualization, and distribution of these materials are being met. The case studies chosen can be broken down into two categories of either institutional organizations or archaeological projects.

When looking at institutions, three digital repositories and a museum were chosen. These institutions chosen are the Smithsonian Institute, the Archaeology Data Service (ADS), The Digital Archaeological Record (tDAR), and Europeana. Only two of these are specifically archaeological repositories (ADS and tDAR), while the others handle cultural heritage in a more generic sense (The Smithsonian and Europeana). Although the Smithsonian is not a public repository, their internal repositories and digital standards are quite open and thus a good case for analysis.

Regarding our more practical case studies, both the Çatalhöyük and Kämpinge excavations will be utilized. These two projects were both chosen due to their heavy incorporation of 3D recording methods into their research design and were present in the results of the project. With Çatalhöyük being such a long-term project, they did not incorporate this in their initial design but did incorporate 3D recording when technology made it viable. The Kämpinge excavation made use of 3D recording from the get-go and can be seen in the quality of the recording methodology and the results. Both of these excavation projects are still a work in progress but hopefully can still provide a suitable medium for analysis.

Institutions and Repositories

For our first example, the Smithsonian Institute shall act as a museum example due to its position as a world-class institute that is working towards solving the needs of modern digital curation on many fronts. The Smithsonian Institution is composed of 19 museums and the National Zoo and was founded in 1846 using funds from the Englishman James Smithson (1765–1829) (Smithsonian Institution, “About the Smithsonian”). Most of the museums as well as the Nation Zoo are in Washington D.C. while two museums exist in New York City (Smithsonian Institution, “Our Museums, Galleries, and Zoo”). To manage and curate their vast digital collections across all these various museums, the institute utilizes a proprietary system called the Digital Asset Management System (DAMS) (Smithsonian Institution, “Smithsonian Digital Asset Management System”). Even with this being a proprietary system, their supported file formats and submission standards, metadata guidelines, and mission statement are all public. This lays the groundwork for not only the inhouse projects and work at the Smithsonian but also their public-facing collection managers and 3D viewers. Although their 3D management is separate from the DAMS system and located in the Smithsonian 3D Digitization department (https://3d.si.edu/), this system has many public-facing documents relating to its usage, goals, and management system.

When we look at repository standards one of the major entities in this field is The Digital Archaeology Record (tDAR). As far as digital repositories go for archaeological resources, The Digital Archaeological Record, acting as the repository of the Digital Antiquity, is one of the best around. It is a collaborative organization currently centered at the University of Arizona, where both tDAR and Digital Antiquity are being incubated with the potential to become standalone organizations (The Digital Archaeological Record, “About”). With tDar acting as a trans-Atlantic non-profit repository for everything from text documents, images, data tables, GIS data, 3D models, and more (The Digital Archaeological Record, “Preservation”), the repository system is not only acting as an international repository, but also as a tool for both research and public access (https://www.digitalantiquity.org/). Everything from data structures and standards of metadata and the deposited files are outlined and accounted for in tDAR’s documentation and infrastructure, giving not only the users of the service but other members of the cultural heritage industry ideas of accepted needs for long term preservation of this data (The Digital Archaeological Record, “Find, create and share knowledge of our past and present.”).

Following up with another archaeological repository, we have the Archaeology Data Service (ADS), another organization that is very similar to The Archaeological Data Record (tDar) in scope but based in the United Kingdom. The ADS is a well-established online repository for UK based fieldwork data and documentation. Founded in 1996, they have been in the game of digital data management for archaeological resources for some time now. The goal they strive towards is for open usage of their archived material and allow for the continual reuse of these records for future researchers. They also establish well-defined metadata on their data recording policies including many guides relating to long-term digital preservation (Archaeology Data Service, “Our Work”).

And finally, a more generic cultural heritage repository was selected with Europeana. With tDAR in the USA and the ADS in the UK, digital preservation and archiving initiatives are a universal part of modern cultural heritage practice. Europeana is such an institution in Europe but scoped to a broader and more general context than either of our previously mentioned repositories. Europeana has two fronts, the public-facing Europeana and the user and professional-oriented Europeana Pro (Europeana, “About Us”). The public-facing Europeana allows users to explore and use the digital data being curated and stored on their service while the pro allows for professional-level uploading and curation on existing projects and data (Europeana Pro, “Our Mission”).

Practical Excavation Examples

One of the selected practical examples is the Çatalhöyük Research Project led by Ian Hodder who started the project while he was at the University of Cambridge and continued the project once he moved to Stanford University. This project makes for an interesting case study regarding 3D recording and long term digital archaeological curation. The project was composed of 21 years of fieldwork as well as a more long-term digital archive process with the associated Çatalhöyük Living Archive project (Çatalhöyük Living Archive). The entire excavation was recorded and stored in digital formats and will be maintained and publicly accessible for years to come via online databases and the Living Archive. The 3D component did not begin being incorporated into the project until 2013, twenty years into the project (Taylor et al. 2018, p. 8). The project traveled with Ian Hodder, including the Çatalhöyük Living Archive, and all the materials are now in the stewardship of Stanford. The 3D data will be fully viewable and interactable in this Living Archive when it is finally complete, but only a pilot version of the archive currently exists until resources are acquired to develop it further (Çatalhöyük Research Project, “The Project”).

Another practical excavation which heavily dived into the 3D recording realm is the excavation at Kämpinge. This excavation was conducted in the southwestern tip of Sweden and is home to a variety of prehistoric finds. Many of the sites around here date to the Scandinavian Mesolithic, but Kämpinge specifically dates to the middle to late Neolithic between 8500 to 6000 BP (Dell'Unto, Landeschi, Apel, & Poggi 2017, pp. 633-634). This site makes for an interesting case as it represents an excavation where the 3D recording was involved since the get-go. The major significance of the Kämpinge excavation in our discussion of 3D technology is not that of the archaeological remains themselves, but the methodology and technologies utilized in this excavation. These digital technologies and 3D recording methods allowed for the testing of new workflows and unique fully digital recording strategies (Dell'Unto, Landeschi, Apel, & Poggi 2017, p. 632). Many parties involved in the Çatalhöyük excavation were also involved in the Käpinge excavation and were able to transfer their experiences and new ideas into this new fully digital recording of an excavation. This excavation utilized both 2D GIS, 3D GIS, and 3D models to accurately record and preserve the data recorded from traditional excavation methods (Dell'Unto, Landeschi, Apel, & Poggi 2017, pp. 633-634).

Issues with Standardization

Even though the idea of addressing issues of long-term data retention seems like common sense to many, it is a much greater task than most give credit to. Even between the selected case studies, we see the great variation of goals and scope of their collective resources. To try to look at these examples in any standardized system is not viable. Yet to successfully save and store data long term requires a high level of curation and a level of standardization which is rarely seen beyond the state level. So how do we begin to even think about standardizing this practice let alone enforcing it upon an entire discipline? Can this even be done?

In the discussion of the current state of the field regarding 3D data in archaeology and its current lack of standardization, we need to be looking at how online collaboration and visualization are conducted. This topic works as a solid point of entry into this discussion of 3D asset preservation. The needs of digital standardization and management and its role in data sharing and visualization are discussed by Galeazzi and Richards-Rissetto. Their ideas regarding the state of the field on this topic are broken into three parts: “Part I: Web-based Collaborative Platforms and Archaeology, Part II: 3D Web and Archaeology, and Part III: Online Research Infrastructures and Publishing in Archaeology” (Galeazzi & Richards-Rissetto 2018, p. S1). Their discussion is a good overview of where we are regarding the reuse and visualization goals of 3D and the state of current standardization and expectations needed for good digital archaeology to be conducted.

The first part of their discussion outlines trends of web-based integration for projects such as Ian Hodder’s Çatalhöyük Research Project and its abilities regarding its capability of reinforcing a reflexive approach of research via the unified connectivity of the research system (Galeazzi & Richards-Rissetto 2018, p. S3). This unification is only possible with a certain level of digital standardization. 3D data which is to be shared and collaborated on thus requires extensive platforms in which multiple parties can interact together. To have 3D data that is useful in this type of collaboration, a framework must exist for it, either via hardware, software, or both.

Their second topic of discussion brings us to the web-based potential of 3D data in archaeology and the potential of web-based visualization. Specifically, this topic cites such projects as the Archaeo 3D-Viewer which allows both 2D and 3D web-based visualization and Arc-Team Archaeology and their commercial solution. This type of project requires a high level of infrastructure to make it viable but is a step in the right direction towards getting modern archaeology to have access to these visualization tools to allow for reuse, collaboration, and distribution (Galeazzi & Richards-Rissetto 2018, pp. S3-S4). Although they still note that further experimentation and development is needed on this front, specifically around web viewers. HTML5 and WebGL are lending powerful building platforms for such visualization methods. The untapped potential of interactive 3D models incorporating linked datasets, capable of data sharing between parties or even in multi-user collaboration has yet to be heavily explored in archaeology, yet could assist in new interpretations (Galeazzi & Richards-Rissetto 2018, p. S5).

The end of their discussion regards research infrastructures and publishing in archaeology relating to digital media like 3D models. They cite a large problem, that being how the disconnect of many of these viewers and repositories from being directly linked or integrated into final publications is an issue. But they also note the goals of many private repositories such as the Archaeology Data Service (ADS) in the United Kingdom and their goals of not only storing but giving the ability of open licensing of data for reuse. Noting the need for these digital resources to not only be preserved and standardized for distribution but also readily accessible and reusable for maximum effect. Organizations like the ADS also work with other international groups like Europeana (https://pro.europeana.eu/) and ARIADNE (http://www.ariadneinfrastructure.eu/) to achieve organization under some sort of unified interface (Galeazzi & Richards-Rissetto 2018, pp. S4-S5). Regardless, it remains clear that standardization is needed to lead to effective publication and distribution of 3D data.

Beyond the technical issues relating to standardization is simply the issue of accidental human error and idiosyncrasy in their workflow. This causes natural issues in standardization as someone may vary how they handle any step open for human interpretation or input error. However, by eliminating human error, you are also restricting the capabilities of a recording method. This can be seen in projects where digitized documentation is utilized, and what formerly was recorded strictly on context sheets may be recorded in the restricted tables of a geodatabase's data structure, adaptation in the structure must take place to prevent issues which develop around this system (Dell'Unto, Landeschi, Apel, & Poggi 2017, pp. 638-640). Regarding our 3D assets, this can fall into categories like the metadata documentation, which without strict field formatting room for error is always a present risk.

Methodology and Methods

As we move towards the discussion of the methodology and methods which will be utilized in the investigation and analysis of the topic of this paper and its associated materials, we need to frame both why we are looking at this issue and how we will do so. To successfully investigate the research question by establishing a lens of analysis using three key issues relating to long term preservation, specifically the reuse, visualization, and distribution of our 3D data. How to address these specific aspects will be clarified in the methods section.

Methodology of Analysis

To establish a methodology to investigate our topic, we will need to determine exactly how to conduct an analysis of a collection of non-equivalent case studies in the cultural heritage sector which can act as our materials of analysis. Since these are hard to directly compare, we need to determine how we are examining them and why; ideally by framing them all in an identical lens. Specifically, we will investigate two categories and evaluate their handling of the curation and preservation of 3D data in archaeology and cultural heritage. These categories are institutions (museums and repositories) and excavations that heavily utilized 3D data recording methods. Looking at the case studies from these categories with the end goal of identifying not only flaws in recording but also highlighting the solid approaches utilized and to synthesize a set of ideals to outline how we need to handle this universality of 3D data management. Our 3D data and recording methods are becoming increasingly intricate and the storage and long-term handling of these resources need to be adequately seen. Therefore, these case study groups have been chosen, so they can act as the subject being examined through our focused lens with well-defined questions and criteria for studying this issue.

Constructing a solid quantitative numerical representation or metric of a best practice would be incredibly difficult across all these resources, so a more qualitative research approach will be utilized to infer a general sense of best practice. Using this data, the current needs related to the topics of reuse, visualization, and distribution will be explored to establish a fundamental idea of where the problem lies. The digital storage of 3D components and the issues which archaeologists and cultural heritage professions encounter need to be addressed.

Having to stay so general in the view of the digital cultural heritage preservation issue is a required limitation when we look at the specific scope of the problem. We have so many complex data types and variables that go into the establishment of standardization and building of schema which is followed by various institutions as well as specific research projects. By choosing specific areas as to which the problem is more severe (specifically our 3D assets), we can get a more detailed look at this problem.

Thus, a specific lens will be crafted which can help us interpret and examine both the institutions and excavations selected via the specific question:

Are the current procedures for performing curation and maintenance of 3D data sufficient to ensure long term preservation, reuse, visualization, and distribution within modern archaeology?

Looking at each case study we will analyze the institution or project’s ability in handling these three subcategories beyond just long-term preservation. Asking questions regarding these three criteria to evaluate our case studies' ability towards influencing long term preservation. To assist in benchmarking this non-quantifiable issue, we shall ask the following questions:

On reusability of the 3D models:

1.) Is the data available for download?
2.) Is the data easily accessible via search engines or internal query systems?
3.) Is the data in a file format that is not limited to proprietary software or hardware?
4.) Does the data have an open/reusable metadata schema?

On the visualization of their 3D data:

1.) Do these institutes and projects have ways to publicly visualize their data online?
2.) Are their viewers integrated into other media (open source)?
3.) Do the viewers allow detailed model visualization?

On distribution and publication of their 3D materials:

1.) Can the 3D models be cited in an appropriate way?
2.) Can the existing publications using these 3D models be easily discoverable?
3.) Are they suitable for further academic research?

By focusing on these aspects of reusability, visualization, and distribution; we can begin to gauge if the value of our 3D assets is being considered sufficiently. Long-term preservation is the core topic, but these three key aspects are what are needed to sufficiently meet preservation. Our data must be made accessible, as archaeologists a part of our work is to make sure that the topics we explore become a part of the larger collective knowledge of the human past. With 3D models being a new recording method for displaying this collective knowledge, it truly must be handled appropriately.

Methods

Now that an idea of how we will approach the research question has been established, a method of analysis for the material needs to be developed to illustrate and explain this idea of whether our selected organizations and excavations are meeting our questions to a "sufficient" level. Both the methodology and methods used should relate to our theories listed previously, specifically slow archaeology, posthumanism, materiality, and reflexive archaeological practice. These theories assisted in not only establishing the questions selected but toward inferring the sufficiency of what was needed in an archaeological context. These theories help in the assessment of our very qualitative data set of these various repositories and to try to determine if we are reaching a sufficient standard towards the research question of this paper. This degree of sufficiency will be measured by exploring and assessing our materials and then building a form of “grading table” to determine where each case study will be explored around our ability to determine if the questions posed towards the research question are being answered.

To display this quantitative element, we will attempt to grade each case study using the set of associated questions relating to the research question on areas in which we should strive to achieve regarding the reuse, visualization, and distribution of our 3D assets. But what do we deem as sufficient regarding the handling of these aspects? To determine this, we will directly apply the grading chart seen on the following page. This way a quantitative (yet still subjective) value (1-4) can be assigned to each question regarding how well it is addressed by each of our case studies. Of these values, 1 is a complete failure of the question, 2 addresses the issue, 3 would address the issue to an expected minimum, 4 would address the issue and handle the issue beyond the needs of current expectation.

The grading table is broken down for each of our sub-questions of our overall research question. This will be backed by the rubric demonstrating sufficiency on this scale (1-4). The values in the scale should consider theoretical trends as well as expectations of each of the questions as seen from the current practice and ideas seen throughout the discipline. This will help to give a basis of how grading is determined and allow us to compare and judge the chosen case studies as fairly as possible. Hopefully, this helps us gain insight into where we stand in terms of answering the research question and once applied to each of our major topics regarding digital preservation (reuse, visualization, and distribution). An overall comparison will also be conducted showing how digital curation and management of our 3D assets as a discipline land overall. Grading table format and definition of grades can be seen below using the tables seen on the following pages:

Grading of Sufficiency Towards Long-term Preservation

Rubric of Grading of Reuse Capability of 3D Models				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?	No attempt to provide downloadable 3D assets	3D assets are available for download but limited in some regard. Either by size or availability.	3D assets are available for download.	3D assets are available for download and provide full metadata or other additional resources.
Is the data accessible via search/query engines?	The 3D Assets are not accessible via a search or query engine.	Some 3D assets are available via search or query engines. Or all are available, but lake expected search criteria.	The 3D assets are available via search or query engines at the expected level.	The 3D assets are available for search and query and have fully flushed out query capabilities.
Is it in a file format that is not limited to proprietary software or hardware?	The 3D assets file formats available are in proprietary formats.	Some 3D assets file formats are in proprietary formats.	The 3D assets are fully available in open file formats.	The 3D assets are fully available in multiple file formats.
Does it have an open/reusable metadata schema?	The 3D asset does not have any metadata.	The 3D asset has metadata but does not follow a known open/reusable metadata schema.	The 3D asset has an open/reusable metadata schema.	The 3D asset has an open/reusable metadata schema as well as allowing the metadata to be viewed or downloaded in multiple schemas.

Figure 1. This table represents the criteria for grading each of the four sub-questions of the reuse category.

Rubric of Grading of Visualization Capability of 3D Models				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?	No attempt to visualize 3D assets on their web platform.	An attempt is made, but either is offsite or limited to a static visualization such as a screenshot.	A web visualization of the 3D asset is available and hosted directly in context on the site.	Same as previous but extends to allow third-party integration and/or open-source modification of the viewer.
Can their viewers be integrated into other media?	No attempt to allow their 3D viewer to be integrated into other third-party platforms.	An attempt to allow visualization into other media is made. But this viewer is a restricted viewer or limited in file size, quality, or other features.	The web viewer is fully open to integration into third-party sources using available features and assets available.	The web viewer is fully open to integration in third-party platforms. The viewer also is open source and allows customization. The viewer also allows for the usage of custom assets outside of the repository.
Do the viewers allow detailed model visualization?	No attempt to allow detailed model visualization on the web viewer.	Visualization of 3D assets in the web viewer is limited in file size and resolution quality.	The web viewer allows detailed visualization of 3D assets in various scales of quality.	The web viewer allows for full multi-scalar visualization of 3D assets. This means ultra-high-quality models can be shown.

Figure 2. This table represents the criteria for grading each of the three sub-questions of the visualization category.

Rubric of Grading of Distribution Capability of 3D Models				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?	3D assets fail to have sufficient means of referencing. No direct link or reference identifier.	3D assets have a direct link or reference identifier, but no further information.	3D assets have a direct link or reference identifier, plus associated metadata.	3D assets have a direct link or reference identifier, associated metadata, and a defined citation format.
Publications using materials discoverable?	3D assets are not linked to published works.	3D assets have a link or reference to some associated public works or projects.	3D assets have a link or reference to associated public works or projects	3D assets have a link or reference to some associated public works or projects plus a way to add your reference to the source list.
Models in a format suitable for further academic research?	3D assets do not contain enough information (metadata) nor citation method for further academic works.	3D assets meet some citation requirements and enough metadata to utilize the asset.	3D assets have met citation requirements and metadata definitions to utilize the asset.	3D assets have met citation requirements and metadata definitions to utilize the asset. A defined metadata and web visualization of the asset are also available.

Figure 3. This table represents the criteria for grading each of the four sub-questions of the distribution category.

Chapter 4. Analysis

To analyze the five case studies acting as our materials, each will be explored in the direction to attempt to answer the questions described in the previous section. This will also include the grading of each case with an explanation of why they ranked where they did per each question. Together with the grading tables' logic and each case situation will be explored with cited material and theoretical interpretation.

Institutional Solutions

The Smithsonian

When examining the Smithsonian's solution to handling digital curation, we encounter many documents outlining standards and expectations. These documents lay down a solid baseline of what is being done at an institution of such scale to combat the challenges present in digital asset management and to make their resources available to their institute and the public. The Digital Asset Management System (DAMS), accepted file formats, and metadata standards are public and give way for an organized and understandable storage structure.

The metadata standards lay forth information required for all digital data they maintain. In one document, they address digital still images, audio, video, and digital art files, then proceed to list out in a table the required metadata field names, definitions of those names, sample data values, and notes about that field. This gives us insight into what is required to store and maintain this data in their system. (Smithsonian Institution 2016, "DAMS Guidelines for Required and Recommended DAMS Metadata in Digital Still Images, Audio, Video, and Digital Art Files")

The file format standards also address digital still images, audio, video, and digital art files. Another document, which is a tabular format, lists out capture/original format, preservation master, access derivative, file considerations/recommendations, and file attributes/vulnerabilities. This is very useful as it not only describes in-depth all file formats encountered that are utilized by the Smithsonian, what is preferred, the pros and cons of each, and how these formats should be examined (Smithsonian Institution 2019, "Smithsonian DAMS Supported File Formats"). This is information that is quite digestible to lay cultural heritage professionals, and documents such as this help lend to better longevity of digital files and fewer problems when files get handed into a centralized repository or file system.

Metadata standards are crucial in the world of digital data management. In archaeology, we produce a slew of metadata when we record anything. It makes sense to keep our digital data as clear and organized as traditional paper records. Although creating proprietary systems such as the DAMS, the metadata standards, and file format regulations can even be standardized for small scale museums or organizations. But even at a world-class institute like The Smithsonian, we see the system lacking in such areas as GIS and 3D models. Although DAMS lack both, the 3D component of their collections is being handled by a separate department. GIS seems to be lacking from any public-facing entity beyond the odd map or research project.

When looking at the Smithsonian's handling of 3D data, we can also look at their 3D Digitization department (https://3d.si.edu/). This is a fully functional, front-end web viewer for both large scale and small-scale 3D models. The proprietary viewer is still a work in progress, yet hopes to leverage integration beyond self-hosted models and data sets and move toward an open-source model viewer which can not only enhance their collection and resources but also the resources of other researchers and academics (Smithsonian 3D Digitization, “About”).

The Smithsonian 3D Digitization department lives under the Smithsonian Digitize Program Office (DPO) and does have both their Digitization and Digital Asset Management Policy (Smithsonian Institution 2011, “Digitization and Digital Asset Management Policy”) and their Digital Asset Access and Use publicized (Smithsonian Institution 2019, “Digital Asset Access and Use”). Both departments outline how their resources are to be managed, who is involved, what is needed, and what the goals and scope of their existence are. But compared to the DAMS this is still far behind in well-published and defined specifications, but then again it is a work in progress.

If we look at what The Smithsonian has available to the public, the questions posed above can be decently answered. With both the DAMS and the 3D department’s current goals, we see the general idea of reuse is not satisfactorily touched upon. The Smithsonian’s 3D viewer does state goals of opening their viewer and resources, but those are currently not implemented and available. The 3D system is now limited and closed off from external data and scoped to the selection of materials the Smithsonian provides. The DAMS is also a closed enterprise system with small fragments making its way to external viewing. The 3D model viewer is a great visualization tool for their 3D resources yet lacks in its openness to the public and is not reusable yet. Thus, with both reuse and visualization being limited in these systems the ability of publication and distribution via the Smithsonian's systems is currently not viable.

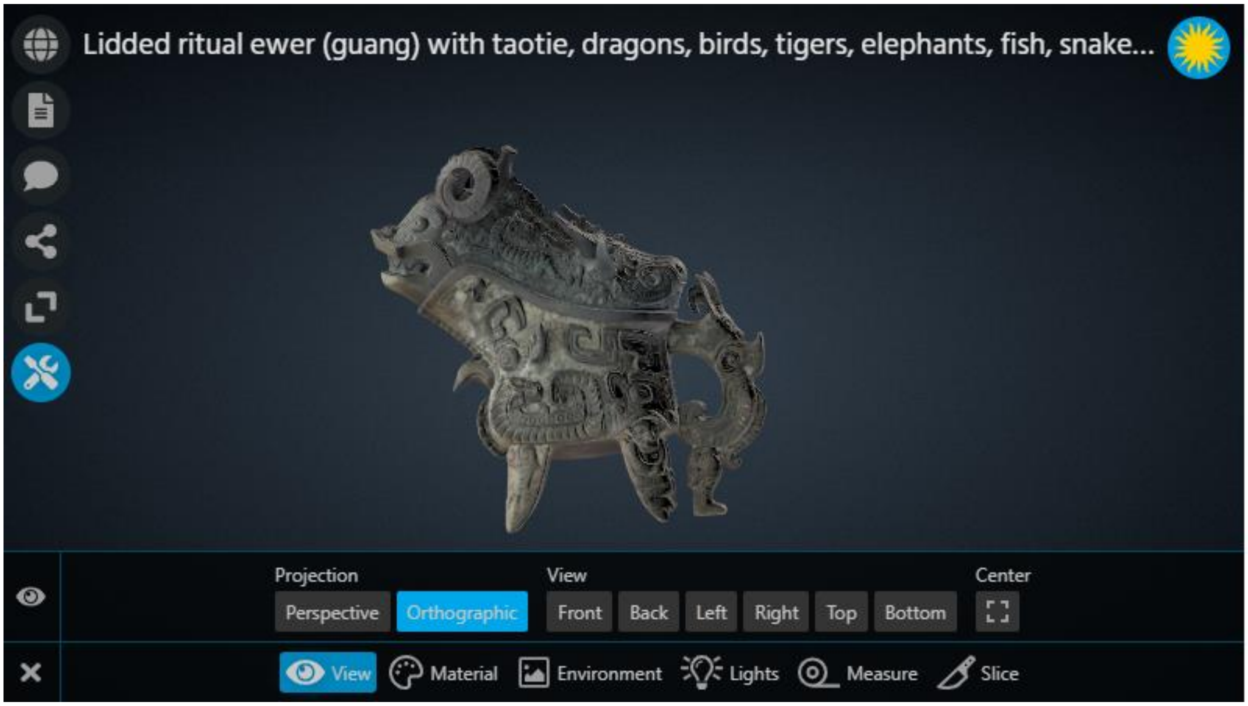

Figure 4. The 3D data published at the Smithsonian use a very functional web viewer. Much functionality expected from offline web viewers is present as well as associated metadata and reference materials (Smithsonian 3D Digitization, "Lidded ritual ewer (guang) with taotie, dragons, birds, tigers, elephants, fish, snakes, and humans).

Regarding the topic of reuse, we see all their published 3D files also being downloadable, as well as the associated metadata of the files. With visualization, the Smithsonian does have a proprietary web viewer that works quite well (Figure 4). The Smithsonian still lacks the diversity in usage due to a limited collection of resources that utilize it and the viewer itself is currently not open for integration into other media. But the viewer does maintain many of the features seen in 3DHop and other comparable quality viewers even matching offline viewers in some regards.

All this information was then analyzed and used in the determining of the grading towards sufficiency of The Smithsonian Institutes' ability to reach the needs for long-term preservation and reuse, visualization, and distribution. Below are a series of tables with the associated rating for each question relating to the long-term preservation of the 3D assets from The Smithsonian Institute. The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of the Smithsonian Institute

Grading of Reuse Capability of 3D Models via The Smithsonian Institute				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			X	
Is the data accessible via search/query engines?		X		
Is it in a file format that is not limited to proprietary software or hardware?			X	
Does it have an open/reusable metadata schema?				X

Figure 5. The Smithsonian Institute has made great strides in 3D visualization and accessibility. Unfortunately, the service is limited to select resources as of now, but what is available is of high quality. The data is available to download and in expected formats, thus landing a sufficient grade of three. The ability to search and query the 3D data is still not amazing but is present so it lands a grade of two. Since the downloadable files do come in multiple formats of expected standards that too earns a three. The metadata for the Smithsonian is very well documented and quite accessible, thus granting it a four.

Grading of Visualization Capability of 3D Models via The Smithsonian Institute				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?			X	
Can their viewers be integrated into other media?		X		
Do the viewers allow detailed model visualization?				X

Figure 6. Overall the Smithsonian Institute is meeting visualization needs. It is unfortunate the collection is limited, but the published materials are very nice and so giving the web viewer a grade of three. The ability to link the viewer into other media is possible but limited with more robust integration and support discussed, thus a grade of two. The visualization is not as powerful as 3DHop, but still is excellent, allows streaming of high-quality models, and even has features found in offline 3D viewers such as a split, lighting shift, and more; thus this quality deserves a grade of four.

Grading of Distribution Capability of 3D Models via The Smithsonian Institute				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			x	
Publications using materials discoverable?		x		
Models in a format suitable for further academic research?			x	

Figure 7. The published 3D materials at the Smithsonian Institute have static web pages, feature catalog numbers, and publication information when applicable, making it sufficient in its citation ability at a grade of three. Some associated publications materials are referenced but not all thus a grade of two for discoverability of related sources. Overall, the metadata provided meets the needs of making the entire resource suitable for further academic research so a grade of three is earned.

Archaeology Data Service (ADS)

Next, we examine the ADS in the same frame of long-term preservation capability via reuse, visualization, and distribution/publication capabilities. All data archived with the ADS is open access and can be uploaded quite easily online via ADS-Easy or OASIS systems, or directly by an ADS digital archivist. Data deposited to the ADS has a onetime fee to help fund the preservation and curation of the data. This is a unique business model but seems to work quite well. Preservation and curation of archaeological resources is not a free enterprise and requires constant funding and maintenance (Archaeology Data Service 2015a, “Guidelines for Depositors”)

Although the ADS is just supporting UK based fieldwork, the ADS also strive towards establishing international infrastructure with such other projects as ARIADNE. The idea of having the ADS expand beyond the UK is apparent in some of these projects, at least in terms of the research capability of their system. it is clear that a strong desire to move beyond geographical research boundaries exists at the ADS (Archaeology Data Service, “Our Work”).

The ADS has their Preservation Policy, Repository Operations, Ingest Manual, Appraisal and Deaccession policy, Risk Register, Information Security Risk Assessment, Systems Overview, Security Overview, Disaster Recovery/Plan, Data Procedures, File Formats, Checklists, Outsource partners, and Roles and Responsibility documentation all available online and accessible to the public (Archaeology Data Service, “Preservation Policy and Repository Procedures”). Of these, some of the most interesting documentation lies in their Data Procedures, which mirrors some of the Smithsonian's Documentation in style. Laying out what can be accepted and used towards various digitally uploaded data from GIS file formats to 3D models and the expected procedures needed to deliver and manage such data. This is concise information on everything from metadata expectations, requested supporting documents, as well as a data structure for storage.

Much of their data structure standards, data management practices, and long-term data retention and curation goals are all publicly available amongst their guidelines (Archaeology Data Service 2015b, “Guidelines for Depositors”). This gives the archaeological community a unique case study of a long term archaeological project which yielded years of data. It is a great place to start looking beyond institutions and repositories on how digital archaeology should be conducted and troubles that arise from technological change and adaptation.

Another role the ADS has taken is working directly with its sister project Internet Archaeology, an open-source digital international archaeology journal. Internet Archaeology (https://intarch.ac.uk/) is a fully functional peer-reviewed, non-profit, and global journal. It was started as a subscription-based journal but has pivoted successfully to the open format it is today in 2014 (Internet Archaeology, “About Internet Archaeology”). This digital journal has the benefit of having the ability to inject digital resources directly into the materials published. The ADS have worked to help host and deliver this associated digital content to such publications to enhance what an archaeological journal can be. (Archaeology Data Service, “Internet Archaeology”)

Another interesting aspect of the ADS to consider is how they are funded. The user uploading data for preservation and storage are charged. They have pricing variables to the file type and the ease of managing, archiving, and curating. (Archaeology Data Service, “Costing Calculator Help”). The cost for the user of the service is not necessarily cheap but funds the entire curation process. The user of the service can also then reuse their resources from the ADS hosted source into their works and link them into their publications.

The need for state-run resources seems to be filled by private organizations and institutions with initiatives like the ADS or tDAR. If the need for data preservation is needed, somewhere in the realm of the archaeological community is a data conscious professional willing to try to do what is right. But with these voluntary preservation repositories not being mandatory, the archaeology community is still at risk of data erasure.

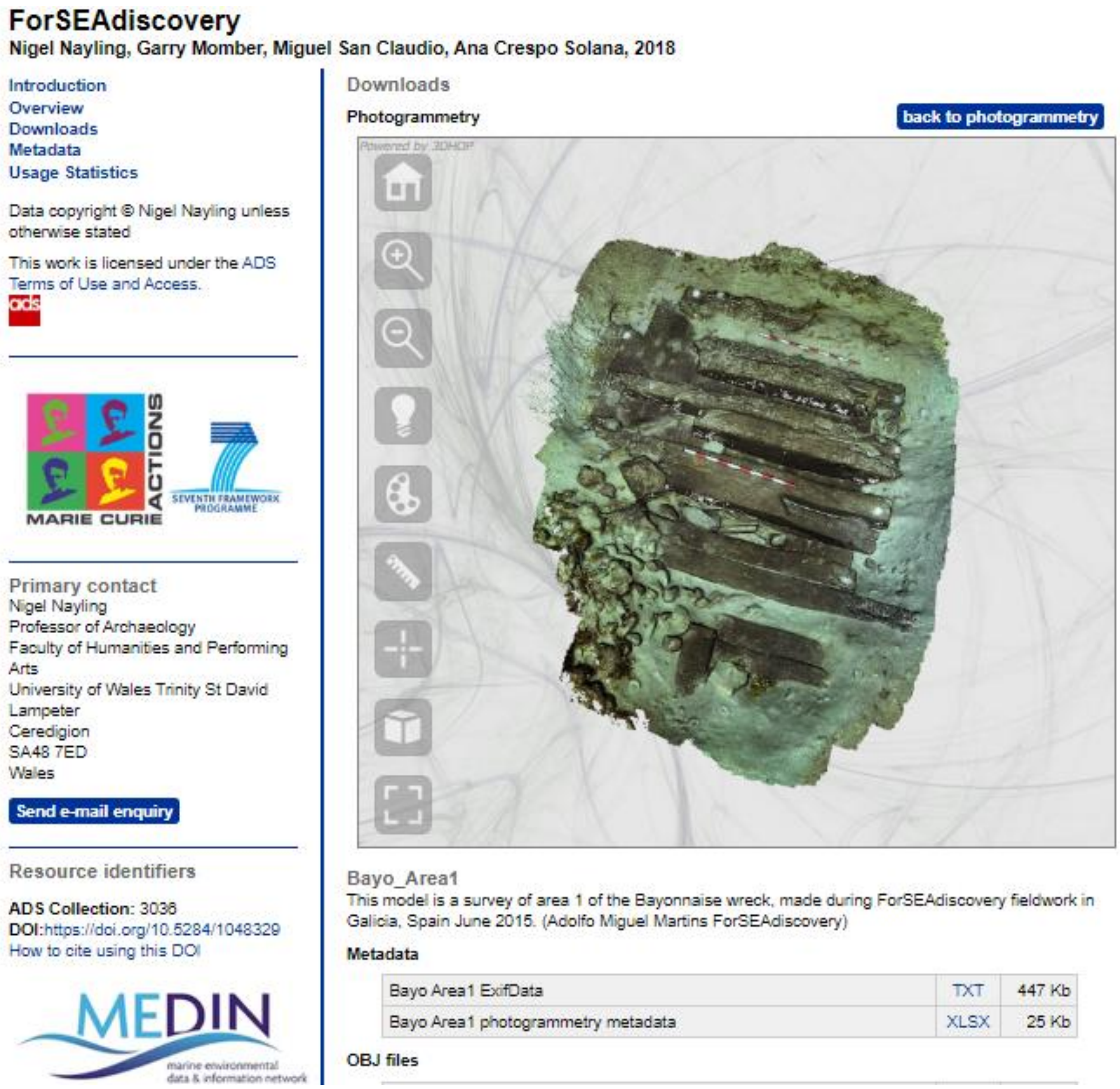

Figure 8. The ADS have a variety of visualizations. Much of the 3D resources have no visualization but some, such as this project by ForSEAdiscovery integrates a 3DHop model into the archive. Metadata is present, the OBJ file is downloadable, and even the source images can be downloaded as well for reprocessing. The ADS collection number, DOI, and static link also prove extremely useful for citing and using this resource for future research (Nayling, N., Momber, G., San Claudio, M., & Solana, A., 2018)

Overall, the ADS does meet the goals of reuse and distribution at nearly the same standards as tDAR. The data is open, so reuse and distribution are viable. Plus, visualization is indeed present, the ADS does have a 3D viewer although limited in use (Archaeology Data Service 2015a, “ADS 3D Viewer”). Various projects have detailed web viewer capabilities using a 3Dhop based web viewer (Figure 8). This 3D viewer is unfortunately not available for all 3D resources and is thus putting the ADS behind in terms of visualization goals. Getting ahold of the 3D data often means you still must result in downloading large files and verifying the files yourself. This requires software, hardware, and technological skills to make use of some of these resources. The full integration of their 3D viewer will bring the ADS to the next level and begin to help us meet the needs required for making storage of our 3D resources on such a repository truly appealing and useful.

All this information was analyzed and used in determining the grading towards the sufficiency of the Archaeology Data Service (ADS) in regards of reaching our needs for long-term preservation via reuse, visualization, and distribution. Below are a series of tables with the associated rating for each question relating to long term preservation of the 3D assets from the Archaeology Data Service (ADS). The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of the Archaeology Data Service

Grading of Reuse Capability of 3D Models via the Archaeology Data Service				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			x	
Is the data accessible via search/query engines?			x	
Is it in a file format that is not limited to proprietary software or hardware?			x	
Does it have an open/reusable metadata schema?			x	

Figure 9. The ADS like most repositories meets the needs for reuse. Nothing feels above and beyond but what is required to make sure data is preserved and present for usage is there, data is downloadable, searchable, in expected formats, with the metadata viewable and its documentation available, thus a solid grade of 3.

Grading of Visualization Capability of 3D Models via the Archaeology Data Service				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?		X		
Can their viewers be integrated into other media?	X			
Do the viewers allow detailed model visualization?				X

Figure 10. The ADS is coming along on visualization. Right now, models are downloadable and some demos for their web viewer exist, thus a grade of two is given as the results are noticeable but not reached yet. The integration of the viewer is likely but not present yet due to the lack of mainstream use of their 3DHop based web viewer, thus graded as a one. The quality of the demos and its abilities via 3DHop is very impressive, thus a grade of four is granted for the ADS on the detail of their viewer.

Grading of Distribution Capability of 3D Models via the Archaeology Data Service				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			X	
Publications using materials discoverable?		X		
Models in a format suitable for further academic research?			X	

Figure 11. The models in the ADS which are present and accounted for can be appropriately cited to a static link so a grade of three and achieving sufficient needs is present. The publications that use the materials are sometimes associated with the metadata but not always so a grade of two is given. Overall, the data present on the ADS is sufficient for continued academic research so a grade of three is granted here as well.

The Archaeological Data Record (tDAR)

The Archaeological Data Record uniquely tries to tackle this crucial piece of the modern archaeologist's day to day struggles by establishing not only the means to digitally preserve, maintain, and curate digital cultural heritage resources, but also the means to use them. Being the function repository portion of Digital Antiquity (an organization that strives for long term preservation of digital cultural heritage resources), we see a very similar structure to the UK based Archaeology Data Service (Digital Antiquity, "About").

The Center for Digital Antiquity operates itself off the reference model of the Open Archival Information Systems (OAIS). This is done to maintain the preservation and usability of the digital data in the long term. The steps currently in place for long term data preservation and maintenance are accounted for, even having a fallback third party repository in agreement to take their data in case of the collapse of their system (The Archaeological Data Record 2017, "Preservation and Curation Policy").

In tDAR's eyes, their infrastructure should "take into account the complete knowledge creation process, which includes research planning, data collection and organization, quality assurance, metadata creation [...], preservation [...], data discovery, data integration, and data analysis and visualization" (Kintigh, Altschul, Kinzig, Limp 2015, p. 3). It is a wholesale solution to the digital collection and visualization process. Although the visualization end of things still has work to be done, they are attempting to solve the needs of a fully fleshed out solution.

Although the reuse of a lot of this data is encouraged, it is not extremely accessible. Both the GIS (The Digital Archaeological Record, "Browse all GIS in tDAR") and 3D models (The Digital Archaeological Record, "Browse all 3D & Sensory Data in tDAR") are stored with ample metadata but don't have a medium for visualization beyond physical downloading. The metadata, basic location data, and maybe screenshots are available if lucky. The actual examination and visualization of these resources require users to download and analyze the data manually on the user's end. Yes, the repository has a robust search system, but it lacks in the visualization department. And especially with 3D models and other sensory data, these files can be quite large. Still even without visualization, having a place to store this data does mean you can cleanly cite your 3D or GIS data for public viewing and reuse.

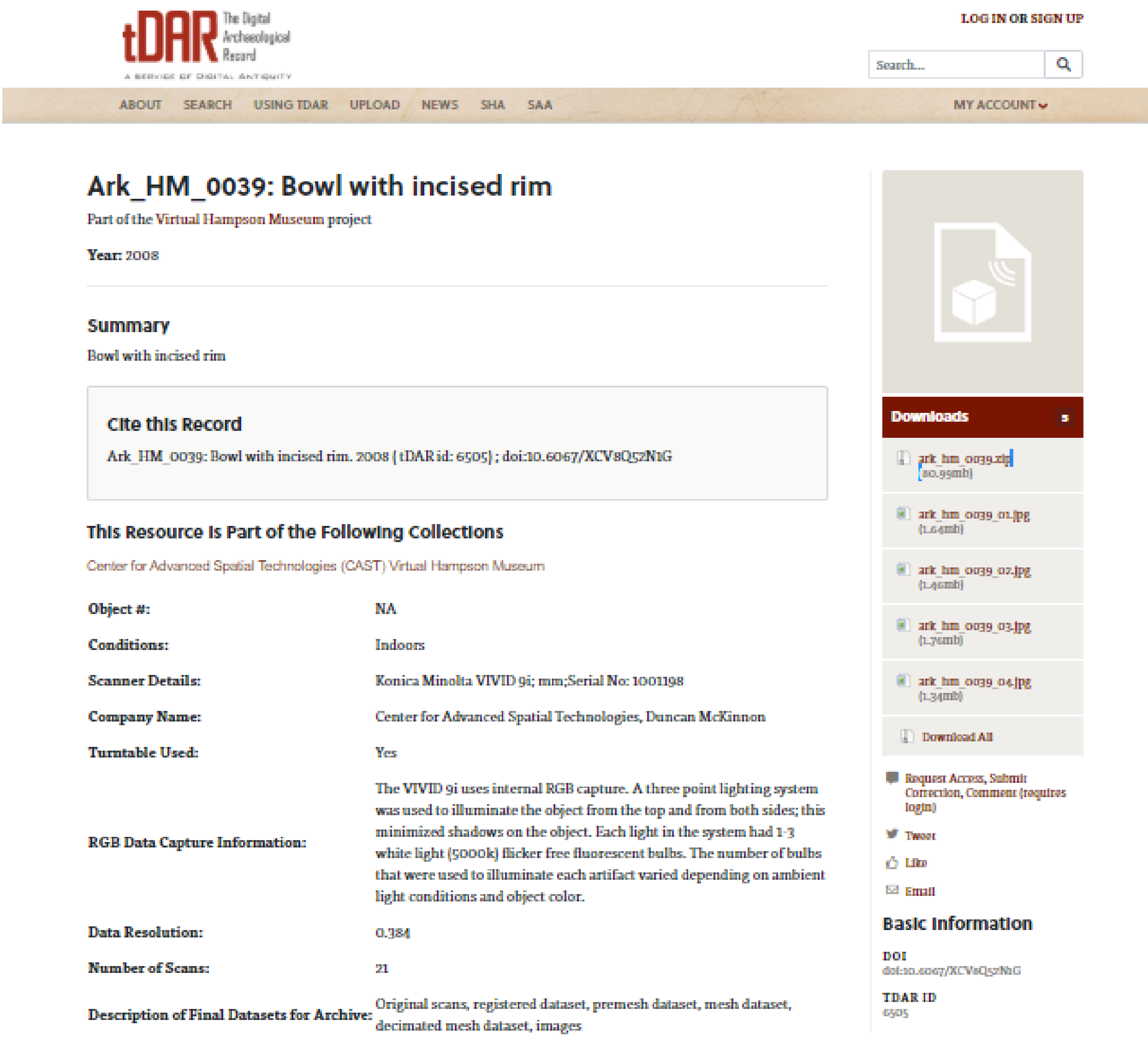

Figure 12. The Digital Archaeological Record can provide ample metadata and associated information for their 3D assets, but a viewer is not present in the current form. Many of the files (even older scans such as this bowl, have everything needed for reuse. All images, scan details, and even DOI are referenced. But as far as visualization only a few screenshots are present, so one must download the file to investigate the model (The Digital Archaeological Record, "Ark_HM_0039: Bowl with incised rim).

Thus, tDAR provides us with where we want to be in terms of reuse needs for our digital assets and 3D models. Acting as a repository and host for this data we see the reuse and distribution needs of our data getting towards a point of true usability. But as stated the visualization of the digital assets held within tDAR is still not there. One cannot simply upload a 3D model to the repository and link it in a viewer into a digital publication via tDAR. Materials uploaded are still static and require downloading to visualize but loads of metadata are present (Figure 12). The ability for tDAR to have 3D web visualization may be reached eventually with either a proprietary viewer or integration of another system that could be utilized. But for now, tDAR successfully handles two out of three of the big needs for our digital data, making it a quite suitable location for the storage of such data.

All this information was analyzed and used in the grading towards the sufficiency of The Archaeological Data Record (tDAR) at reaching our needs in terms of long-term preservation and reuse, visualization, and distribution. Below are a series of tables with the associated rating for each question relating to long term preservation of the 3D assets from The Archaeological Data Record (tDAR). The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of the Archaeological Data Record

Grading of Reuse Capability of 3D Models via The Archaeological Data Record				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			x	
Is the data accessible via search/query engines?			x	
Is it in a file format that is not limited to proprietary software or hardware?			x	
Does it have an open/reusable metadata schema?			x	

Figure 13. The Digital Archaeological Record does meet the needs of a modern repository. All the questions of reuse are met and allow for it to function as a successful product and asset to the archaeological sector. Nothing feels above and beyond so a solid three is given in all categories.

Grading of Visualization Capability of 3D Models via The Archaeological Data Record				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?	X			
Can their viewers be integrated into other media?	X			
Do the viewers allow detailed model visualization?	X			

Figure 14. Unfortunately, tDAR lacks on the visualization front. No public visualization has been achieved yet and that proves to be a large issue among most of these cases. Thus, a rating of one has been given in all categories.

Grading of Distribution Capability of 3D Models via The Archaeological Data Record				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			X	
Publications using materials discoverable?		X		
Models in a format suitable for further academic research?			X	

Figure 15. Although tDAR does lack on visualization, the fact that all public data exists in a capacity to be downloaded and has associated metadata and thus citable (solid three ratings), some publications are referenced (just a two), and the data is of a quality sufficient for further study (another rating of three) shows promise.

Europeana

While both tDAR and the ADS operate strictly regarding archaeological data, Europeana's repository caters towards a wide variety of forms of cultural heritage. Even with the scope of Europeana being quite different, they manage to fill the digital repository niche in Europe. The organization exists as two fronts, the public-facing Europeana and the user and professional-oriented Europeana Pro (Europeana, "About Us"). The public-facing Europeana allows users to explore and use the digital data being curated and stored on their service while the pro allows for professional-level uploading and curation on existing projects and data. But what makes Europeana stand out is the widely available documentation regarding the data structure and goals relating to their repository.

A key point to Europeana's repository system is the well-defined data structure they established, the Europeana Data Model (EDM). This has to do with metadata and data structure to allow for easy sharing, archiving, and curating digital resources to the Europeana community. The EDM is a well-documented standard that rivals the organization and structure seen in with the Smithsonian Digital Asset Manager model, the tDAR, and ADS data structures and data expectations. Although the pivoting of exact standards varies by region and institute, the goal and quality seem to be maintained (Europeana, "EDM Documentation").

The EDM is closer to the DAMS model as it is related to more cultural heritage than strictly archaeological resources. Thus, Europeana is broader and more encompassing of the various cultural heritage fields' needs and expectations than its counterparts. But do these other cultural heritage components differ enough from the archaeologist's needs to be separate or should all digital cultural heritage preservation follow similar standards and expectations?

The work of Europeana to preserve our cultural heritages digital resources is at the professional level expected to achieve such a task. With definitions of the Europeana Data Model defined in every way expected, from use cases, the schema of metadata, and even outlining the roadmap of their entire project (Europeana, "EDM Documentation"). Their roadmap shows much of the transition to their EDM standard from their former ESE (Europeana Semantic Elements), the predecessor to their EDM model which is a much more modern data structure than the previous (Europeana 2014, "Europeana Semantic Elements Documentation"). The transition and adoption of the new model is still a work in progress, with sections already being fully integrated into their system as early as 2014, but much had yet to be adapted. (Europeana 2017, “EDM roadmap”).

Recently the 3D content was accessed via a Europeana task force, which assembled and conducted research and planning focused specifically on the 3D side of their curation and archiving process. Specifically, this task force investigated documentation, publishing standards, visualization standards, and creating standards to make 3D data accessible within the Europeana system. This research was conducted with the hope that at the end of the project they will have FAQs and guidelines for content creators to publish materials via Europeana, to identify viewers and file formats which work within their system, and develop a Europeana Publishing Framework which successfully incorporates 3D assets. (Europeana 2019, “3D Content in Europeana”). This task force achieved a solid overview of establishing the state of the field of 3D and touched base on third party solutions and the general needs of the cultural heritage community via surveys and other means of data acquisition. Their call to action shows an awareness of where they are lacking in terms of 3D storage and visualization as a response to known issues. It is this type of awareness and discussion which helps move us closer to achieving the needs apparent in the industry.

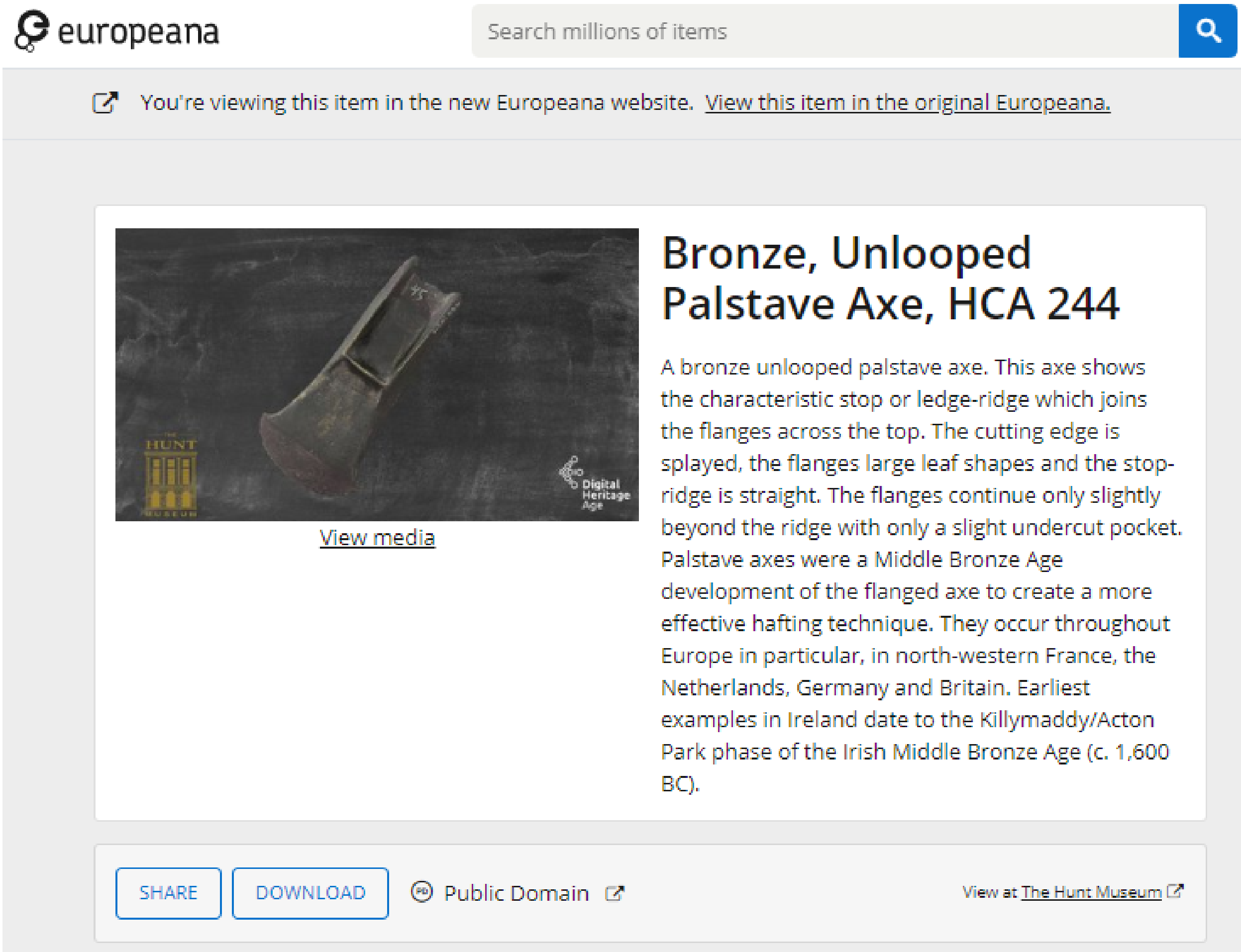

Figure 16. Europeana provides a searchable interface and archives for a large variety of archaeological 3D data. But integrated viewers are still not directly available. Most provide a link to a third-party viewer; this Bronze axe takes you to the item on Sketchfab as part of the Europeana Sketchfab collection. Metadata is provided as well as publishing information, thus making it quite viable for academic reuse (Europeana, "Bronze, Unlooped Palstave Axe, HCA 244").

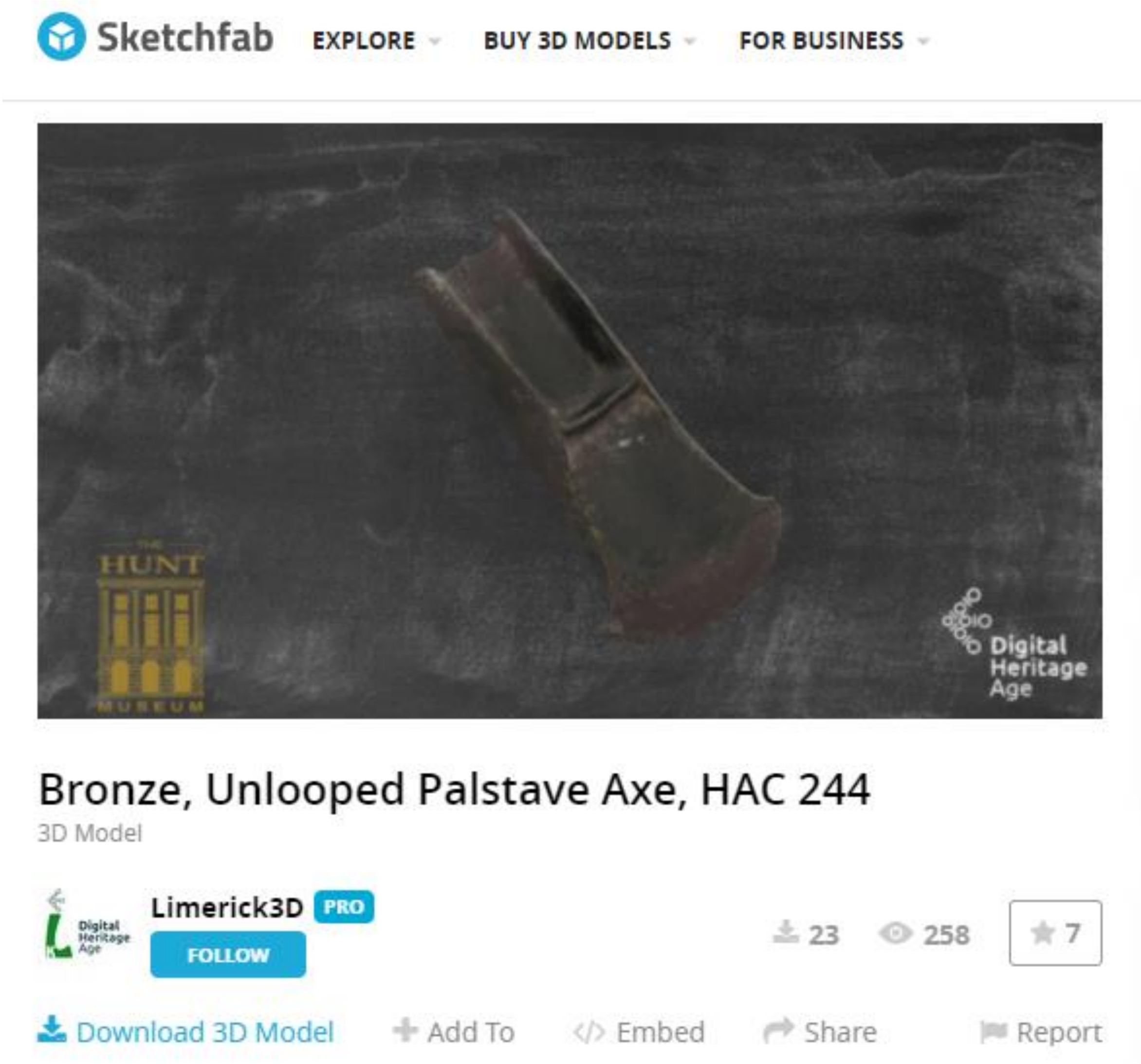

Figure 17. The link from Europeana does take you to an active 3D model on Sketchfab. Unfortunately, Sketchfab is not the most ideal web viewer for 3D models in an academic sense when high-resolution detail is key. Sketchfab can be integrated into other webpages but is not supported on Europeana at this time (Sketchfab (2018), "Bronze, Unlooped Palstave Axe, HAC 244").

It is safe to say Europeana meets the needs of a robust digital repository for cultural heritage. Their standards are well published and quite easy to interpret. They also have great search capabilities making reuse of materials in the repository quick and easy. Basic visualization is met well for most parts, either with images, downloads, or links to third-party model viewers or websites like what is seen in Figure 17. Europeana has made notable achievements on this front. Although their 3D model viewer is not fully integrated, Europeana still has work to do in making sure this type of data is truly accessible. Distribution needs are also met, for the most part, uploaded material can be licensed under different licenses, allowing different amounts of reuse after publication for republication and analysis. Although some 3D models are not for download, only viewing, it still makes for a great resource for getting resources that one wants to make public out to the general population. With the recent projects addressing the shortcomings relating to 3D we are close to seeing a fully capable repository for 3D cultural heritage.

All this information was analyzed and used to determine the grading of the sufficiency of Europeana at reaching our needs in terms of long-term preservation and reuse, visualization, and distribution. Below are a series of tables with the associated rating for each question relating to the long term preservation of the 3D assets from Europeana. The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of Europeana

Grading of Reuse Capability of 3D Models for Europeana				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			x	
Is the data accessible via search/query engines?			x	
Is it in a file format that is not limited to proprietary software or hardware?			x	
Does it have an open/reusable metadata schema?			x	

Figure 18. For reuse, Europeana does clock in at reaching levels that feel appropriate for the needs of the discipline. Data is downloadable (some rare cases it is not), searchable, in various mainstream file formats, and maintains good clear metadata. The 2019 report does address some mild downsides, but overall Europeana meets modern cultural heritage needs and receives a solid three.

Grading of Visualization Capability of 3D Models for Europeana				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?		x		
Can their viewers be integrated into other media?		x		
Do the viewers allow detailed model visualization?		x		

Figure 19. Visualization is interesting with Europeana, primarily due to the inconsistency at which it is done. Links to 3rd party viewers, custom viewers, or direct downloads are present, but not a standard. This is addressed in the 2019 investigative report discussed previously (Europeana Network Association Members Council Task Force Report 2020). Due to the variability and consistency of all these questions being met, a flat two across the board seems reasonable.

Grading of Distribution Capability of 3D Models for Europeana				
Institutions/Repositories	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			x	
Publications using materials discoverable?		x		
Models in a format suitable for further academic research?			x	

Figure 20. Europeana proves itself a very capable platform with distribution capabilities nearly meeting our inferred sufficiency. The models can be cited easily to the link and metadata. With the features page yielding plenty of associated data and an ability to download it is suitable for continued academic research. Many times, publications utilizing the material are referenced in some form, but no mandate or guarantee and no way to add new publications to the material.

Practical Excavation Examples

The Çatalhöyük Research Project

Ian Hodder's 25-year excavation (1993-2018) focused on utilizing a reflexive research approach with the excavation being recorded via a trio of digital technologies (tablet recording, GIS, and 3D modeling) throughout the excavation. These recording methods advanced over time throughout the project and were updated and changed as the project went on (Taylor et at. 2018, p. 1). These digital tools helped to implement the reflexive archaeological interpretation, giving the digital assets a means to be interpreted in a sort of recursive loop, not only to interpret the archaeological aspect but to also critique and modify the usage of the digital tools themselves and how they contribute to further knowledge creation and the reflexive process as a whole (Taylor et al. 2018, p. 2). This recursive loop of introspection on the use and adoption of digital tools follows William Caraher's ideas of slow archaeology, which asks for this same type of critical analysis to take place with our use and adoption of these digital tools (Caraher, 2016a, 2016b, 2019).

Since the introduction of intrasite GIS in 2009, the need for a standardized and organized recording system with integration with the existing relational database system arose. This meant a retooling of existing structure and adoption of ESRI geodatabase systems. By 2011, the site had shifted to a fully digital recording system (Lukas, Engel, & Mazzucato 2018, p. S21). By 2013 the fully digital recording began to introduce a 3D recording method which was used to record the excavation at multiple steps of the excavation as well as to integrate this new data type into the site's digital archive. This data was then integrated into the database and accessible on-site via the tablets of the excavators as they were recording. However, the way this data was to be used continuously changed over the years as the technology advanced and became more cost-efficient, eventually allowing for processing at speeds that enabled use of the 3D Models in a 3D GIS environment. But this project only scratched the surface of the potential of how this extremely new and visually unified system of digital technologies could be employed (Taylor et al. 2018, p. 8).

Beyond simply recording everything digitally and working with it on-site, this extensive digital record must be stored and managed long-term. A digital front end to the project and the databases exist on the project's website (http://www.catalhoyuk.com/). As of now, this online database houses all the project data minus the 3D recordings, although a suitable system to display and allow for the 3D data to be stored, accessed, and reused is underway. Alongside the more standard database system exists an interesting byproduct of this project, The Living Archive. This portion of the project is to act as an open-access research hub to ideally help continue the reflexive methodology of the project to continue as future researchers assess and reinterpret the data recorded over the 25-year project (Taylor et al. 2018, p. 11).

The Living Archive not only will store the more traditional records seen in such digital repositories as the ADS, but will go well beyond the standards, requirements, and capability of the guidelines stated in the ADS. With more static systems like the ADS most of the relationality of the data is lost beyond the structure of the relational database itself, the recorded documentation, or whatever is recorded in Entity-Relationship Diagrams such as those seen in the ADS: Guidelines for Depositors (Archaeology Data Service 2015c, “Guidelines for Depositors”). Repositories like the ADS do allow for reuse and reinterpretation but not at the level desired by the Çatalhöyük Research Project. The data at Çatalhöyük does exist in more traditional static databases from the initial project, but that is not the end goal location for this vast quantity of data that utilizes this unique reflexive approach. (Lukas, Engel, & Mazzucato 2018, p. S22).

The Living Archive takes into consideration the reflexive archaeology portion of the Çatalhöyük Research Project, which was a core methodology utilized in Ian Hodder's research plan, something which existing repositories like the ADS do not necessarily consider. The interpretation, reinterpretation, and reuse of the project are thus incorporated in the Living Archive’s core design (Lukas, Engel, & Mazzucato 2018, p. 522). The Living Archive is still in development and was in development alongside the continued usage of the traditional research database and digital archive. These digital archive’s goal is to be a technologically current and viable endpoint of the excavation, thus, allowing for a robust platform to exist which can be used to integrate technologies such as D3-js, OpenLayers, and ESRI ArcGIS API for JavaScript (Lukas, Engel, & Mazzucato 2018, pp. S27-S28). The visualization of the data on this front is still a work in progress but the end goal will ideally consider the issues of reuse, visualization, and distribution we have discussed thus far.

The ideas core to the project and its reflexive nature are seen in what is the results produced by the project in the open database, living archive, and continued reflexive study loop. This idea that our digital tools should enforce continual reuse and reinterpretation of the data is apparent in the way the reflexive archaeology was conducted in the field as well as with the results of this project. These digital methods influence our archaeological methods and interpretations (Taylor et al. 2018, p. 12). Using the methodology of the Çatalhöyük Research Project helps to bring us closer to meeting our needs of recording and implementation of archaeological data where long term preservation and reuse of our digital work is core to the project. When a reflexive archaeological implementation has used the need for a preserved and reusable system being constructed becomes a part of the project. The reflexive use of the tools means a system is actively developed during the project to allow the data to be accessible and reusable during the project and down the road.

While The Living Archive is still in development, the existence of the public archives and openness of the research conducted puts the Çatalhöyük at the forefront of a project achieving long-term preservation, reuse, and distribution of their work. Although the visualization tools for 3D are not all accessible currently, they are a part of the end goal. Eventually, the Çatalhöyük Research Project will likely meet the goals of reuse, visualization, and distribution required to make long-term preservation possible and meaningful. Although some parts of the 3D recordings are available online and seen in collections shown in figures 21 and 22. This data does not have a web visualization aspect beyond static images, but does provide downloadable models, images, and metadata as well as relevant published materials.

Figure 21. Some aspects of the excavation recorded in 3D can be accessed via public collections produced and hosted online. The collections also include downloads of the models but not public 3D viewers. DOI is referenced as well as static links so the information is citable and valid for future research but is still a work in progress (Lercari, N., Shiferaw, E., Forte, M, & Kopper, R., 2017a).

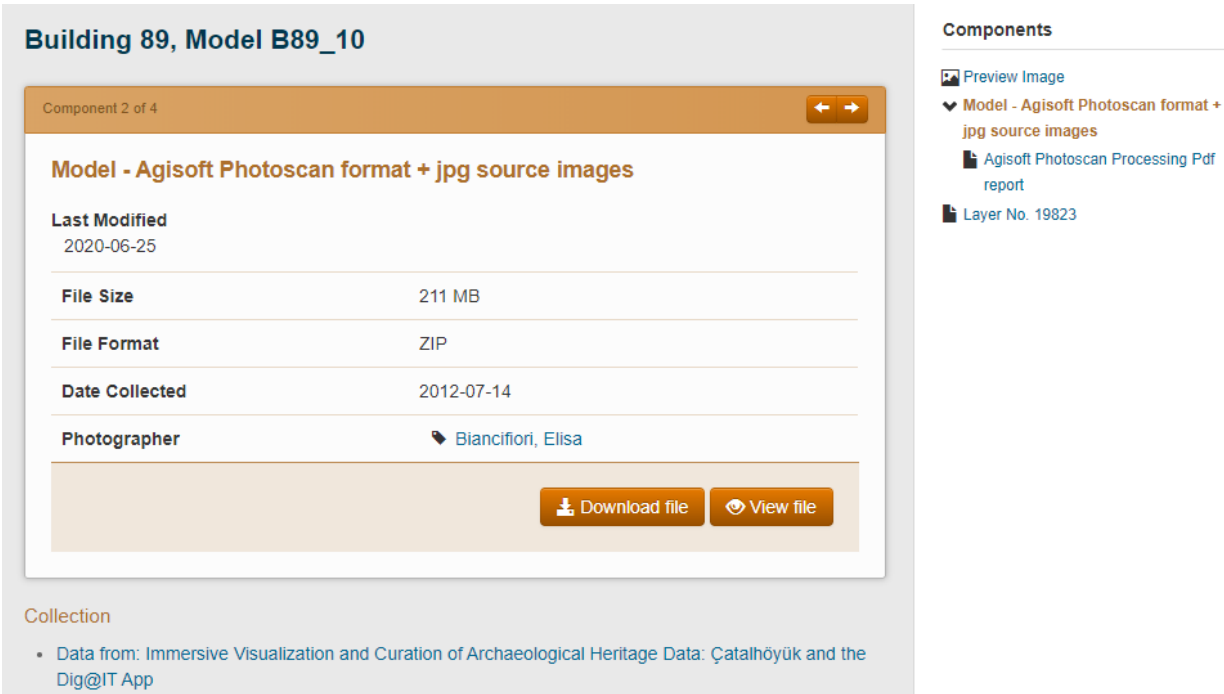

Figure 22. Diving into this collection, the various assets can be explored and downloaded. Everything from metadata, images used, and models produced can be seen and downloaded. But online visualization is limited to static image visualization and no 3D web viewer is present (Lercari, N., Shiferaw, E., Forte, M, & Kopper, R., 2017b).

All this information was utilized in grading the sufficiency of the Çatalhöyük Research Project at reaching the needs in terms of long-term preservation in terms of reuse, visualization, and distribution. Below are a series of tables with the associated rating for each question relating to the long-term preservation of the 3D assets from the Çatalhöyük Research Project. The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of the Çatalhöyük Research Project

Grading of Reuse Capability of 3D Models for the Çatalhöyük Research Project				
Case Studies	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			X	
Is the data accessible via search/query engines?		X		
Is it in a file format that is not limited to proprietary software or hardware?			X	
Does it have an open/reusable metadata schema?			X	

Figure 23. Fragments of the 3D data can be found and downloaded. The Living Archive is incomplete and the primary project databases do not include access to the 3D models. What is available is limited published material, Sketchfab works, and demos. Thus, reuse scores extremely low across the board, yet file format for what is available is quite standard and acceptable. The 3D data present is downloadable, so it scores a three. The search only is being given a two as it is not all centralized and quite convoluted to access. What is accessible does come in expected file formats so a three is given. The metadata also is there for the works available so a three is also granted there.

Grading of Visualization Capability of 3D Models for the Çatalhöyük Research Project				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?		X		
Can their viewers be integrated into other media?	X			
Do the viewers allow detailed model visualization?	X			

Figure 24. The issue continues with our excavation case studies. The projects are incomplete and thus no true web viewer and form of visualization is present. Until the Living Archive reaches the goals, all we have are a few videos of the work in progress, demos, and some data that made it to repositories and Sketchfab. Although extremely limited, some visualization of the project is present, thus landing an insufficient on the visualization front with just a grade of two. But both detailed web visualization and integration are not yet present, so both graded as a one.

Grading of Distribution Capability of 3D Models for the Çatalhöyük Research Project				
Institutions/Repositories	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			x	
Publications using materials discoverable?		x		
Models in a format suitable for further academic research?			x	

Figure 25. For the most part, the data available is sufficient for distribution. Models available can be cited, their projects DOI tend to be accessible, and metadata available thus allowing further research. A solid grade three is given. The available data is still limited but what is present has the data required.

Kämpinge Excavation

At the Kämpinge excavation, digital recording was conducted in a variety of ways, but uniquely saw the input of contexts via the single context method of context sheets in a fully digital environment, specifically into the GIS directly in a geodatabase (Dell'Unto, Landeschi, Apel, & Poggi 2017, pp. 638-639). The recording also utilized 3D models of the trench, captured during various phases throughout the excavation process, which mapped out finds (Dell'Unto, Landeschi, Apel, & Poggi, 2017, p. 636). This methodology meant a copious amount of 3D resources were created through the extent of the project which needed to be handled appropriately.

The data recorded at Kämpinge does not simply represent 3D, but 4D information as well, as it maintains both multi-scalarity and multi-temporal aspects (Dell'Unto, Landeschi, Apel, & Poggi 2017, p. 639). This unique data represents various stages of both excavations but also the time periods from which the material captured represents. This level of complexity in the data draws concern for long term storage. As these systems increase in terms of the amount of information they attempt to maintain and present, the ability to hand this data to other parties becomes more and more complicated. For example, difficulties arise in terms of successfully referencing and storing, such complex 3D and 4D information in a database system.

Figure 26. 3DHop which is being utilized in the Kämpinge project allows for a great deal of customization but has to be manually hosted and advanced features coded into the product using JavaScript. This will be very interesting to see in the final product from Kämpinge but for now, nothing is publicly available. Pictured is an official 3DHop demo (3DHop, "Sigliano Helm").

To create the 3D models used in this type of recording system, photogrammetry was conducted and specification of how this was done was well recorded. Information regarding the specific camera and lens as well as the software utilized to produce the models is noted. How the data will be publicly displayed is also outlined with the usage of the program 3DHop (https://www.3dhop.net), which is an open-source package written in JavaScript by the Visual Computing Laboratory ISTI - CRN (National Research Council of Italy) to manage and visualize high-resolution 3D models. The code for this is open source and can be found at GitHub (https://github.com/cnr-isti-vclab/3DHOP). The models are displayed in a sort of tiling format which allows for fast visualization and load by viewers in a unique multiresolution format utilizing a toolset known as Nexus (http://vcg.isti.cnr.it/nexus/). The models can then be linked to the databases via a web viewer to allow for public access and distribution of the data (Dell'Unto, Landeschi, Apel, & Poggi 2017, p. 641). This is one of the best methods for modern web-based visualization of 3D data present as of now.

This is a very project-specific methodology for hosting and distributing the results of the excavation. Both the 3DHop and the database are hosted outside of some sort of central repository created exclusively for the project. The technological skills required to set up a project using this level of methodology goes beyond traditional archaeology skill sets. Showing that this style of recording is based so heavily on digital and 3D methods not only means that the tools needed are specialized but the tools influence the means of excavation and research. Having these resources available helped positively shape interpretations in ways that more traditional methodologies would never allow. The 3D recording uniquely allows for archaeologists to look at a fragmented excavation reassembled in 3D with the multi-temporality of it glued back together (Dell'Unto, Landeschi, Apel, & Poggi 2017, pp. 643-644).

The 3D recording used at Kämpinge and the interpretation and visualization strategy is reminiscent of the ideas and works stated by Reilly in 1990. The ability to reassemble and reinterpret excavations in 3D has gone from a theorized activity to practice over the past 30 years (Reilly 1990, pp. 135-137). With the planned usage of a public 3DHop visualization, the ability for continual reinterpretation and further research to be conducted on the site stays open.

This project was conducted in a way that taking long term data preservation into account is required. It provides goals for allowing reuse, visualization, and public distribution, thus, meeting the needs of a modern archaeological project utilizing 3D recording methods. But until the full front-end system is online, the accessibility is limited as of now. Like Çatalhöyük, the groundworks, and intentions for these digital 3D assets to be publicly apparent is apparent, but simply not yet available.

All this was considered in the attempt of grading the sufficiency of the Kämpinge excavation at reaching our need. Below are a series of tables with the associated rating for each question relating to long term preservation of the 3D assets from Kämpinge in terms of reuse, visualization, and distribution. The reasoning behind each grade is also briefly noted beneath each respective table.

Sufficiency Analysis of the Kämpinge Excavation

Grading of Visualization Capability of 3D Models of the Kämpinge Excavation				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?	X			
Can their viewers be integrated into other media?	X			
Do the viewers allow detailed model visualization?	X			

Figure 27. Although the plan is in motion to provide ample web visualization, the public front end of the project has yet to be completed. Thus, visualization has only scored a one out of four across the board. I would safely grade visualization on all three questions a three or four once complete, as 3DHop is already proven to provide sufficient detail, integration, and overall usability.

Grading of Reuse Capability of 3D Models of the Kämpinge Excavation				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?	X			
Is the data accessible via search/query engines?	X			
Is it in a file format that is not limited to proprietary software or hardware?	X			
Does it have an open/reusable metadata schema?	X			

Figure 28. With the state of the project still ongoing, it is impossible to grade the actual product. With the 3DHop plans and front-end site, likely all these will be addressed sufficiently or beyond. But until the Kämpinge front end is deployed for the 3D assets, we just must accept that the dream of reuse will eventually come to pass.

Grading of Distribution Capability of 3D Models of the Kämpinge Excavation				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?	x			
Publications using materials discoverable?	x			
Models in a format suitable for further academic research?	x			

Figure 29. With distribution, it is the same as the previous sections. Ideally, we could analyze the results, but no 3D materials connected to the dig are yet accessible via a front-end viewer.

Chapter 5. Results and Discussion

With the analysis of these case studies over, the state of the field begins to become more and more clear. When we examine the culmination of all these case studies, from repositories, excavations, and other aspects of the digital cultural heritage realm, a theme emerges of constant adaptation and reflexivity. Hodder states that when relating to reflexive methods in practice within "...archaeology a critical reflexivity has to deal not just with writing but also with those aspects of method which involve scientific observation and natural science techniques - that is with the laboratory and the excavation trench." (Hodder 2000, p. 5). Thus, these digital techniques and recordings need not simply produce results but also need to be preserved in their entirety, which is clearly what all these cases hope to achieve.

We are constantly changing how archaeological research is conducted and consistently adding new needs and expectations regarding our work. From the needs of simply capturing and creating our digital 3D data comes a great need of preserving its longevity, providing visualization, and continual reuse and exploration as a means of existing as a tool of knowledge creation. These 3D resources are shaping what is considered cultural heritage today and how we should be recording it.

Intrasite GIS and 3D visualization as seen at Çatalhöyük is a step towards reaching the open data, long term preservation, and reusability which is required for our 3D assets in archaeology, although it is clearly in a phase of adoption, and not quite standard practice everywhere. The workflow needed to enforce such solid modern behaviors appears in these reflexive/slow archaeology approaches which actively criticizes and adjusts our usage of our digital tools. We see standards in modern archaeology as not being something that can be widely standardized beyond regions or country level. Guidelines for specific repositories or projects can exist, but we cannot implement universal standards easily. We only can continue to attempt to establish solid ideas of what we need and slowly work towards enacting policy and changes to make those ideas achievable.

With the current state of these presented institutions and projects, we see the intention of answering the needs of long-term preservation, specifically, the goal of making our 3D resources easily reusable, with online web visualization being a common desire, and distribution capabilities being expanded. But both the excavation projects we examined at Çatalhöyük and Kämpinge do not yet have the 3D models fully available to the public. The Smithsonian, the

ADS, tDAR, and Europeana are all trying to allow for the 3D data to be as accessible as possible yet are not to the point where we can safely say we have achieved our goals.

Other entities relating to our question which were investigated do not fit into a realm that can be discussed by the questions thus far. But these areas discussed in the “Theory in Action” section of this paper take the issue of long term digital preservation to heart and do act as a solid background of the state of the field regarding what the current conversations are being had on the topics of long term digital preservation within archaeology. The UNESCO charter, the DCC, and SEADDA are not directly affecting how 3D data in our field is being used in any measurable way. But they do show this discussion continuing, with the need for solving a problem around our digital and 3D resources being present. The ideas are seen in these organizations and how they shaped how we looked at the institutions and excavations which we have actively tried to scrutinize. The archaeological theory of ideas like Slow Archaeology and Reflexive Archaeology lend to our ability to criticize the field and how we need to take our time to adapt to the constantly changing technologies and practices.

Although the analysis chapter broke down and presented how each of the cases selected was able to answer the questions of long-term preservation towards the topics of reuse, visualization, and distribution, an overall analysis was not done. On the next page, the same grading tables will be used to present sufficiency for each case study ,applied to provide overall averaged results to show a rough outline of the current state of the archaeological and cultural heritage field. Since we are not grading on a percentage or fractional base, we will instead round any remainders over half a point up and anything below down.

Sufficiency Analysis of 3D Preservation Overall:

Grading of Reuse Capability of 3D Model Preservation Overall				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Is the data downloadable?			X	
Is the data accessible via search/query engines?		X		
Is it in a file format that is not limited to proprietary software or hardware?			X	
Does it have an open/reusable metadata schema?			X	

Figure 30. Overall reuse of the 3D assets is quite viable. The search capabilities fall short on our excavation examples, but once those projects are complete may yield a different result.

Grading of Visualization Capability of 3D Model Preservation Overall				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Do they have public web Visualization?		X		
Can their viewers be integrated into other media?	X			
Do the viewers allow detailed model visualization?		X		

Figure 31. Visualization still falls short when averaged across the board. The repositories are getting better, with the Europeana task force driving home the need for visualization, but the excavations just do not have finish projects yet and lacked sufficient capabilities.

Grading of Distribution Capability of 3D Model Preservation Overall				
Questions	**Fail, incomplete, not addressed (1)**	**Insufficient, below expectations (2)**	**Sufficient, Meets expectations (3)**	**Exceeds Expectations and Needs (4)**
Can 3D Models be appropriately cited?			x	
Publications using materials discoverable?		x		
Models in a format suitable for further academic research?			x	

Figure 32. We are near meeting the needs to distribute 3D resources successfully. Easily finding associated publications is still lagging but that will surely that will improve with time.

What does this all mean?

It is safe to say we have room to grow regarding making our 3D data and digital cultural heritage resources more adequately preserved for long term preservation in terms of reuse, visualization, and distribution. The tables above (Figures 30, 31, and 32) do show that progress is being made, but certain areas are lacking overall. No surprises were seen when our measurements were averaged together. The institutions and repositories are doing the best to make sure our data is secure, yet it is nice to see that modern excavations are attempting to take the same considerations on their data. The Kämpinge excavation unfortunately could not be evaluated at the same level as it is still a work in progress and nearly all aspects of their digital data are currently not available publicly. Thus, our data is skewed and the averaged rating lower than it will be in the future when the project is finished. If we revaluated in the future, likely this will skew our analysis forward closer to reaching a general level of sufficiency across the board not just due to Kämpinge but Çatalhöyük as well.

Does the Current State of Preservation Meet our Needs?

Based on the information gathered relating to these case studies, it appears that long-term digital storage is successfully being implemented or attempted in some way, shape, or form by all the institutions and projects, though the extent of usage of the storage is still far off in terms of reuse, visualization, and distribution capabilities. This is an issue because if we cannot readily and easily access this data, it essentially does not exist. Yet we are seeing the beginning of where our field can meet the needs of a truly long-term digital heritage which is truly accessible, reusable, and publishable. These institutes and repositories are responding properly to the digital needs regarding these factors, even if maybe we are still lagging in terms of the acquisition and creation of the resources. When going into this investigation was the hope to see either our goal being met or completely failed, but instead, it appears we are really in a transitionary period as of now. The technology and expectations regarding this state of proper 3D digital curation are still catching up to our needs.

Archaeological theory and methods of our current era seem to be moving towards filling gaps where we lack naturally in a lot of our technological usage. The reflexive archaeology being conducted nowadays at sites like Çatalhöyük and Kämpinge help to build digital tool usage that fills in the holes of our research practices to expand our capabilities to the next level. The ideas proposed by William Caraher relating to slow archaeology are appearing as a needed response especially when looking at the institutions, projects, and organizations attempting to be proactive with this issue that was touched on during this paper. But Caraher's ideas only are theoretical, not actual practical application. Having the system to handle the ever-continuing technological wave is far more of a complex and time-consuming issue than just talking about handling it. This need to increase focus on implementing adequate means which properly mitigate the long-term concerns of our 3D data should be more important in the archaeological pipeline. Our work being reusable is crucial to give it meaning in the long term. We must have the means to visualize this unique dataset to others within the field professionally and to the public. The ability to publish and distribute 3D models is still a tough task, and much work remains in making it widely accessible.

Trends Towards Digital Preservation

Digital preservation is becoming further ingrained in the archaeological workflow. Acting as a reflexive response to the needs of the discipline, although a bit slower moving it is occurring nearly all over the world. Our 3D assets are moving closer and closer to a truly preserved and reusable state. Not just in terms of existing on a shelf or being available for download, but for being an active component in web visualization and future research by becoming an asset that can be easily incorporated into publication either via links or citations without requiring users to download large files and utilize expensive software.

Source and Research Limitations

Source and research limitations are always encountered in any project. Somewhere along the way, things will not work out as planned regarding research, or material will not yield expected or desired results. When exploring the research question of this paper, of course this managed to be the case in a few areas.

Primarily, a limitation encountered was simply the standardization issue mentioned when exploring the materials. Standardization is not realistically possible at many national or international scales when looking at digital preservation and management capabilities of 3D resources. Direct comparisons do not exist between institutions conducting digital heritage management nor even specific projects in some cases. We can only look on a broader scale at general needs being met by the recording standards and the ability to meet expected goals and expectations of institutes for projects, but it is not a quantifiable comparison.

Another issue is that documentation standards for institutions or projects are not always fully available to the public. Sometimes a complete look at how their recording and upkeep of the digital data has been conducted is available, and other times only a partial glance at the data management system and its data model and schema utilized. This is especially true with private museums. The Smithsonian, for example, reveals how their system is structured, but the system itself is not publicly available. Although this issue is not always related to intentional limitations around proprietary systems but simply that the information is not currently available at this time. So, the comparisons made between the selected case studies towards the current ability to meet 3D management needs must be based on just a sample of available resources. Only a surface-level look can be observed in some cases.

Trying to compare and create and analyze these various institutions is also very difficult as their goals are not unified. Each case study is unique, and their goals based on regional expectations or project needs. Comparing these differences is not a quantifiable analysis so a broader approach to seeing if goals and expectations to the field are being met by these institutes and projects had to be conducted. So, by taking a step back and a full glance at the issue at large, the attempt to establish if we are on the right track was able to be made.

Future Research

If this project continued or the scope was increased, more case studies could be analyzed and perhaps further resources beyond just 3D explored regarding long term data preservation. Originally this paper was to include all digital resources utilized in both archaeology and cultural heritage to investigate where we lacked across the board. This proved to be too large of a task for a master’s thesis but would be interesting to see.

It would also be interesting to examine this topic from a more technical perspective. It would be interesting to explore how long-term preservation of digital resources looks from a true IT perspective as well as various other perspectives outside of archaeology. Diving into this angle of study would have been too great and only tangentially related to archaeology, but still would be useful in gleaning more ideas on how archaeologists can and should handle their digital assets more successfully.

With Kämpinge and Çatalhöyük excavation results being unfinished, the analysis of these excavations towards the research question suffered. Perhaps in another paper, the sufficiency of the Kämpinge excavations response toward the long-term preservation of their 3D assets can be evaluated properly in terms of reuse, visualization, and distribution. Based on the current research around this project, the results would likely be the in line with what was originally envisioned when choosing the excavation case studies. The same goes for the Living Archive and the rest of the Çatalhöyük Research Projects long term assets which could not be fully evaluated at their current stages.

It also would have been interesting to focus more heavily on excavations that utilized 3D recording methods and see how more stacked up against formal repositories and the selected excavations in this paper. Unfortunately, this was unable to be added due to the time and length constraints of a master’s thesis. But surely many more projects using 3D resources are available for investigation, and although likely on a smaller scale, maybe could have been more sufficient materials for analysis in this paper.

Chapter 6. Conclusion

The purpose of this paper was to investigate the current state of our 3D model management within the current archaeological practice and cultural heritage fields to attempt to answer the question:

Are the current procedures for performing curation and maintenance of 3D data sufficient to ensure long term preservation, reuse, visualization, and distribution within modern archaeology?

The analysis of the selected case studies relating to archaeology and cultural heritage gave valid insight into the state of success achieved in general within the discipline. The main issue confronted was comparing so many varied institutions and projects within the cultural heritage pipeline when direct comparisons were impossible. None of the organizations discussed in this paper can stand for a one on one comparison and thus answering this question is more of attempting to get a feel for the state of the field. The big subsections of the discussion were to attempt to gauge the ability of how reuse, visualization, and distribution were handled specifically. Making sure data exists long term is indeed a core part of the discussion but making sure the data saw some form of usage beyond storages what makes it possible and meaningful in the long term.

Regarding **reuse,** we looked at the ability to download 3D files, accessibility to them via search/query engines, file format, and hardware limitations, as well as their metadata schema. Organizations like the ADS, tDAR, and Europeana we saw the ability to download is achieved for the most part. They also had adequate query systems to find the data. File format, hardware requirements, and metadata schema was also typically published. The excavation projects chosen were still up in the air on these fronts. They mention attempting to achieve this but had not succeeded in making it publicly available yet.

On the **visualization** of 3D data in the field, we tried to see how publicly the 3D assets were viewable online, if they could integrate their viewers into other media or if viewers were integrated from other sources, and if the viewer met adequate standards of visualization. The institutions tended to either be “works in progress” or relied on integration from a third party or external viewers beyond the ADS and The Smithsonian. Excavations had plans for visualization, with Kämpinge having a solid goal of a 3DHop viewer, bringing true high-quality visualization of their models to the public in due time.

In regard to our current ability of attaining sufficient **distribution** of our 3D materials; looking into the 3D model's ability to be cited appropriately, the discoverability of publications using these 3D models, and their suitability for further academic research was glanced at. The institutions do provide adequate means of citation. Although finding linked related sources is not always apparent as well. But the issue does still lie in the visualization and reusability means, which still can be troublesome depending on the repository or project. Downloading a full 3D model from the Archaeology Data Service (ADS), just to take a personal look at a recording is still cumbersome, and until web viewer integration is fully adopted, we do see a sense of lacking on this frontier.

By choosing to try to quantify the sufficiency of these issues towards each organization we have brought to light a way to easily gleam where the discipline lands. This proved to be an interesting project for the sake of examining a widespread issue and trying to establish the current state of the issue. Of course, we could have gone in many directions in how the analysis was conducted, with my original scope of this project being too broad and including all digital assets in the cultural heritage field. This wide-angle began to drive the paper towards a heavy IT angle strictly only covering how metadata was being created and standardized and the technologies which were being used in these repositories within the cultural heritage pipeline. This original lens did not fully allow the ideas behind what drove such decisions to be explored, nor the reasoning behind such decisions. Hopefully, the narrower focus of this paper on just 3D asset preservation allowed a greater exploration of the archaeological theory and message behind such decisions.

Overall, this state of the field analysis shows we are still in the middle of a digital shift towards adequately handling out 3D resources. If we could combine all these repositories, 3D software, and work practices into a single system we may have a system that adequately meets our needs, but unfortunately not yet. In years to come, the issues we have seen in these various institutions and excavations lacking will likely be resolved. Things like task forces to address the issue are seemingly quite common. The COST Action projects, awareness groups, and general mentality show a branch of the cultural heritage world striving to achieve the needs for this datatype. Large scale regional standards and expectations for reuse of these resources will likely become commonplace as a means of visualization are refined and narrowed down. The global expectations towards making sure these digital 3D assets are available for future researchers and the public usage with long-term storage with accessible means of usage and visualization does not seem like a far-off dream.

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