4-2020

Virtual Reality of Underwater Nessebar

Caleb O'Brien
DePauw University

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Honor Scholar Program

Class of 2020

Advisor: Dr. Pedar Foss

Committee: Dr. Rebecca Schindler and Mr. Michael Boyles

<u>Acknowledgements</u>

I personally want to thank everyone who had helped me with the project, which has been almost a year in the making and involved learning new skills on my end in multitude of fields.

I want to thank Dr. Nayden Prahov of the Balkan Heritage Foundation for letting me go on the trip that inspired this work and helping obtain information for the project. I also want to thank Pavel Georgiev of the Bulgarian Center for Underwater Archaeology for teaching me how to create photogrammetric models and even provided a model for an area that I was unable to create a model of. Without them, this project would not have happened.

I also want to thank my Mr. Michael Boyles and the Tenzer Center interns for teaching me how to use Unity, which at the beginning was over my head. Without Michael this project would be in a vastly different form since he helped make sure it stayed within the realm of feasibility and made sure there would be something for me to turn in.

I also want to thank the Honor Scholar Program, along with their benefactors for not only giving me the opportunity to do this year long project but also funded my trip overseas that inspired it all.

Last, I want to thank Dr. Pedar Foss and Dr. Rebecca Schindler who helped me write this paper and gave challenged me with new ideas that I had to include in this paper. Without them pushing me as hard as they have the past four years, I do not know if I would have been able to complete this year long project.

Thank you all.

Introduction

In the summer of 2019, I took part in an underwater archaeological excavation through the Institute of Field Research (USA) and the Balkan Heritage Foundation (Sofia, BG). At this excavation, I learned how to document sites underwater. One aspect that the project lacked was public outreach about an entirely submerged site. How would one preserve or display sections of the city wall to the general public? At the dig I also learned photogrammetry, a documentation technique, that can reach out to the public in the form of virtual reality or augmented reality. However, every virtual underwater archaeological experience that I could find or read about was severely limited in scope, since there was at best a virtual 'movie' allowing no user input and little information to make sense of what I was seeing. In response, I resolved to create a virtual dive experience of the Black Sea sites at Nessebar, Bulgaria.

This dive experience will differ from previous attempts in several ways. The first is that this will be a virtual reality experience – that is, an experience in which the user operates an entirely virtual platform (in this project a computer). This format will allow users to 'swim' through the different sites in the Black Sea all while encountering explanatory. This form of display is different from others that either only allow visualization of the site through a model with no ability to 'move,' or put the user on a predetermined pathway.

This thesis begins telling the history of Nessebar from the foundation of its ancient city to the modern-day development that has threatened the site. This history makes clear why this site is an excellent choice for a virtual tour. I then show the public outreach problems facing maritime archaeology, which virtual technologies may alleviate. Afterward, a cost-benefit analysis demonstrates the benefits and problems of my virtual tour. I conclude by summarizing different arguments both for and against utilizing digital technologies to share maritime culture.

Finally, I list the detailed steps I took to create the virtual tours along with my reasons for

choosing to implement certain technologies.

The History of Nessebar

Figure 1: "Large Nessebar Maps for Free Download and Print | High-Resolution and Detailed Maps." Accessed April 28, 2020. http://www.orangesmile.com/travelguide/nesebur/high-resolution-maps.htm.

The site of modern-day Nessebar sits on a peninsula approximately 850 meters long and

350 meters wide, connected to the mainland by a narrow isthmus. During antiquity this peninsula

was much larger, extending up to 180 meters further, as evidenced by the presence of structures

that far into the sea.[1] Causes for erosion of the land are threefold. First, the land along the Black

Sea coast is subject to high amounts of rain, which creates runoff, and as a result the surface of

the land erodes into the sea. In addition to surface erosion, the peninsula has been subjected to

waves that loosen the lower layers of soil, causing undercutting of loose soil. Lastly, since

antiquity, terraces and walls have been built on the shoreline to minimize erosion only to have

prompted more erosion in the long-term, due to the weight they have imposed on the unstable

soil.[2]

Evidence shows a Thracian settlement on the peninsula in the 12th century BC. This

evidence includes ship anchors made of stone in the vicinity of where the two ports are believed

to have been. Based on the number of anchors found, the amount of trade during this period

seems to have been high, which implies that this town had existed even earlier than the 12th

century BC as an important coastal town on the coast.[3] Subsequent evidence for Thracian

settlement is a grey-ish/black pottery that has been found, dating from the ninth to the sixth

century BC.[4] There are also fortification remains. Excavations have discovered a Thracian-era

fort at the neck of the peninsula and along a section of the coast.[5]

Starting in approximately the fifth century BC, Greek colonists founded the settlement of

Mesembria. As Strabo tells in his history, the town was originally named Menebria. Strabo

claims that this name combines the name of the founder and a Thracian word meaning town:

[1] Preshlenov, H., "Messambria", in Grammenos D.V. – Petropoulos, E.K. (eds.), *Ancient Greek Colonies in the Black Sea* 1 (Thessaloniki 2003), p. 158.
[2] Preshlenov, "Messambria," p. 159-160.
[3] "The Archaeological Museum Hall One – Messambria and the Thracians." Museum Ancient Nessebar. Accessed December 13, 2019. https://www.ancient-nessebar.com/html/main_en.php?menu=sights_arheolo_purva.
[4] Ibid.
[5] Preshlenov, "Messambria," p. 160-161.

"εἶτα τὸ Αἶμον ὄρος μέχρι τῆς δεῦρο θαλάττης διῆκον· εἶτα Μεσημβρία

Μεγαρέων ἄποικος, πρότερον δὲ Μενεβρία (οἶον Μένα πόλις, τοῦ κτίσαντος

Μένα καλουμένου, τῆς δὲ πόλεως βρίας καλουμένης Θρᾳκιστί· ὡς καὶ ἡ τοῦ

Σήλυος πόλις Σηλυβρία προσηγόρευται, ἥ τε Αἶνος Πολτυοβρία ποτὲ

ὠνομάζετο)·

Then comes the Haemus Mountain, which reaches the sea here; then Mesembria,

a colony of the Megarians, formerly called "Menebria" (that is, "city of Menas,"

because the name of its founder was Menas, while "bria" is the word for "city" in

the Thracian language. In this way, also, the city of Selys is called Selybria; and

Aenus was once called Poltyobria)."[6]

Other ancient historians have come to similar conclusions with slight changes in the name of the

town. St. Stephen, for example, states that the name of the founder was King Melsa and calls the

town Messambria.[7] Strabo notes that Dorian Greeks colonized the area and there is uncertainty

when it comes to determining which settlement sent out those colonists. Strabo states that

Megara founded the town.[8] Herodotus meanwhile says that Chalcedon and Byzantium founded

the town:

"Πρὶν δὲ ἀπικέσθαι ἐπὶ τὸν Ἴστρον, πρώτους αἱρέει Γέτας τοὺς ἀθανατίζοντας. οἱ

μὲν γὰρ τὸν Σαλμυδησσὸν ἔχοντες Θρήικες καὶ ὑπὲρ Ἀπολλωνίης τε καὶ

Μεσαμβρίης πόλιος οἰκημένοι, καλεύμενοι δὲ Κυρμιάναι καὶ Νιψαῖοι, ἀμαχητὶ

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[6] Strabo. *Geography, Volume III: Books 6-7.* Translated by Horace Leonard Jones. Loeb Classical Library 182.
Cambridge, MA: Harvard University Press, 1924.
[7] Steph. Byz., entry 'Mesembria'.
[8] Strabo. *Geography, Volume III: Books 6-7.* 1924

σφέας αὐτοὺς παρέδοσαν Δαρείῳ· οἱ δὲ Γέται πρὸς ἀγνωμοσύνην τραπόμενοι

αὐτίκα ἐδουλώθησαν, Θρηίκων ἐόντες ἀνδρηιότατοι καὶ δικαιότατοι.

But before he came to the Ister, he first subdued the Getae, who pretend to be

immortal. The Thracians of Salmydessus and of the country above the towns of

Apollonia and Mesambria, who are called Cyrmianae and Nipsaei, surrendered

themselves unresisting to Darius; but the Getae, who are the bravest and most

law-abiding of all Thracians, resisted with obstinacy, and were enslaved

forthwith."[9]

Herodotus also asserts that the reason for colonization was refugees fleeing the Persian Empire

following the Ionian revolt:

"Βυζάντιοι μέν νυν καὶ οἱ πέρηθε Καλχηδόνιοι οὐδ᾽ ὑπέμειναν ἐπιπλέοντας τοὺς

Φοίνικας, ἀλλ᾽ οἴχοντο ἀπολιπόντες τὴν σφετέρην ἔσω ἐς τὸν Εὔξεινον πόντον,

καὶ ἐνθαῦτα πόλιν Μεσαμβρίην οἴκησαν.

The people of Byzantium, and they of Calchedon beyond, did not even await the

onfall of the Phoenicians, but left their own land and fled away within the Euxine,

and there settled in the town Mesambria."[10]

To reconcile this discrepancy, some modern authors have suggested two colonizations, one

around 519 BC led by Megara, and another around 493 BC led by Byzantium and Chalcedon.[11]

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[9] Herodotus. *The Persian Wars, Volume II: Books 3-4.* Translated by A. D. Godley. Loeb Classical Library 118. Cambridge, MA: Harvard University Press, 1921.
[10] Herodotus. *The Persian Wars, Volume III: Books 5-7.* Translated by A. D. Godley. Loeb Classical Library 119. Cambridge, MA: Harvard University Press, 1922.
[11] Krzysztof Nawotka. "Melsas, the Founder of Mesambria?" *Hermes* 122, no. 3 (1994): 320-26. www.jstor.org/stable/4477024.

As a Doric Greek city, Mesembria became an important strategic city along the Black Sea coast, along with an important mint due to the presence of bronze and silver nearby. It seemed to have close ties to the Athenian state since it is included on a tribute list from 425 BC. Scholars have suggested that this relationship was started during Pericles' expedition to the Black Sea and this is the reason for the Mesembrians minting coins to the Attic standard.[12] Yet despite this relation to Athens, Mesembria's location required the city to pay tribute to local Odrysian and Thracian rulers to allow the city to remain independent.[13]

Independence was threatened when Philip II began preparing for his Persian War. Needing to secure the homeland, Philip II used the towns on the coast of the Black Sea as areas to protect against the Thracian and Odrysian Kingdoms. The towns kept their nominal independence through Philip II's reign to Alexander's governor Lysimachus. Under Lysimachus' rule the city became an important staging ground for wars against the tribes surrounding the town and thus became firmly under the rule of the Macedonians. The city gained its independence after Lysimachus died during a battle; the city responded by mass minting of gold and silver coins in commemoration.[14]

Despite the town becoming independent again, the aftermath of Alexander the Great led to a huge power struggle in the region. To prevent Ptolemaic Egypt gaining too much influence, the Seleucid Empire sent troops along with a general to Mesembria as a deterrent. Despite this military presence the town was still threatened by neighboring Celtic tribes and to appease them began minting coins for these tribes with Celtic shields and other Celtic symbols.[15]

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[12] Preshlenov, H., "Messambria." Pg. 178-180.
[13] Ibid.
[14] Ibid.
[15] Ibid.

In the second century BC the overarching problems of the region were not mitigated as new military powers appeared, namely: The Roman Republic, Pontus, Pergamum, and Macedon again. After a war between Pontus and Pergamum, Mesembria took part in peace talks headed by the Romans which secured Mesembria from their local threats. In response, Mesembria, "against the norms at the time"[16] began a war again their neighbor Apollonia (modern day Sozopol). During this war, the Mesembrians were able to conquer one of the villages of Apollonia, yet during an attack on the main city were defeated. This defeat led to the Apollonians retaking all that they had lost.[17]

As the 2nd century BC wore the Mesembrians looked for new protection, which led them to side with King Mithridates of Pontus along with most of the Thracian coastal cities. Mesembria, in this new alliance, served as a port to send Celtic mercenaries to Pontus, which made the city a prime target for enemies of Pontus.[18]

In 72 and 71 BC, the Romans began to conquer the cities along the Black Sea coast during the Third Mithridatic War.[19] After seeing their rival, Apollonia Pontica (modern-day Sozopol), get destroyed, Mesembria submitted to the Roman general Marcus Terentius Lucullus in 71 BC.[20] Gaius Cornelius was appointed *praefectus civitatis,* and since the city did not have an official treaty with Rome but had just surrendered to a legion, Cornelius had the powers of a military governor. Instead of keeping the city under conquered status, Gaius Cornelius gathered

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[16] Preshlenov, H., "Messambria," pg. 180 What the Preshnelov means by 'norms' at this time is unknown, but based on context it seems to be that the norms of warfare during this period was to not turn on cities that you had been allied with as Apollonia and Mesembria had a shared history and had sided together many times as they are located within eyesight of each other.

[17] Preshlenov, H., "Messambria." Pg. 178-180.

[18] Ibid.

[19] Preshlenov, Hristo. "Mesambria Pontica." In *Roman Cities in Bulgaria*, 1:493–536. Sofia, BG: Prof. Marin Drinov Academic Publishing House, 2012.

[20] Prahov, Nayden. June 25, 2019.

delegates from the city and allowed them to forge a formal treaty with the Romans. This treaty

gave the city of Mesembria several rights that were rare in Roman territory, including exemption

from taxes.[21] The next governor of the region, Gaius Antonius Hybrida, ruthlessly plundered the

province, leading to open revolt in the western reaches. Although Mesembria did not take part in

the revolt, its Roman garrison did. This revolt led to a power vacuum, which the northern Getics

(a tribe in the region) used to advantage by attacking the province.[22]

After the attacks of the Getae, the Romans restored order under Marcus Licinius Crassus

the Younger in 29 and 28 BC, and later Vicinius in 3 and 2 BC. Following these expeditions, the

region of Thrace, including the town of Mesembria, was incorporated fully under Roman rule. Its

connection to Rome appears on many coins of the period that depict the face of Augustus Caesar

on the obverse, with local gods of Mesembria on the reverse. Further Romanization is evident

during the rule of Claudius, when a local leader, Gnaios, built a statue depicting the emperor

alongside Herakles and Hermes.[23]

After Dacian Wars, Trajan and Hadrian established the provinces of Moesia Inferior and

Thrace became established in the conventional provincial system. This affected Mesembria,

which lost several of the special rights it had received and became only important for the land it

controlled rather than as a trading port. The reason for this change was the incorporation of

Anchialos (modern day Pomorie), the center of the Odrysian Kingdom into the Roman fold

which was the most developed city on the Black Sea coast.[24] To combat there loss of status at the

beginning of the second century AD, the city of Mesembria joined a coalition of several coastal

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[21] Preshlenov, "Mesambria Pontica," 493-536.
[22] Ibid.
[23] Ibid.
[24] Ibid.

cities to distinguish themselves from the rest of Moesia Inferior cities. This gave every previous polis between Mesembria and Istria (located in Romania) higher Roman legal status due to their established urban tradition compared to other cities in Moesia like Troesmis. These cities celebrated this elevated status by venerating the imperial cult, which eventually led to the emperor Hardian visiting the region around AD 124.[25]
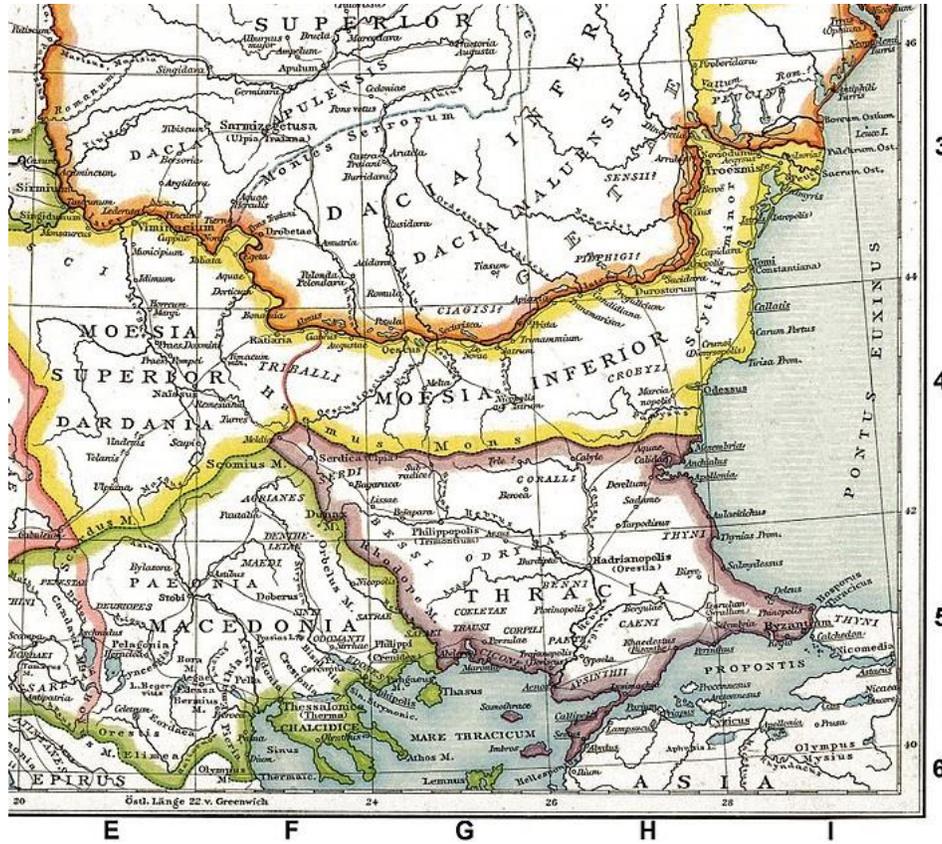
Figure 2: Droysen, Gustav. Deutsch: Die Unteren Donauländer Zur Römerzeit. Alte Historische Karte Aus Droysens Historischem Handatlas, 1886. 1886. Allgemeiner historischer Handatlas in 96 Karten mit erläuterndem Text Bielefeld, Velhagen & Klasing 1886, S. 16.
https://commons.wikimedia.org/wiki/File:Roman_provinces_of_Illyricum,_Macedonia,_Dacia,_Moesia,_Pannonia_and_Thracia.jpg.

Administrative change once again took place in the third century AD. Unlike previous reforms which upset the people of Mesembria, this reform simply put Mesembria in the territory of Thrace as opposed to Moesia Inferior. This change appears to not have created many problems

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[25] Preshlenov, "Mesambria Pontica," 493-536.

for the citizens of the city and appears to have eased the burdens of governing the province by putting the border of Moesia Inferior as the only responsibility for troops stationed in Moesia while troops in Thrace were controlled the routes that entered into southern Moesia Inferior.[26]

Along with the 3rd century administrative reforms, major events in the town took place as a result of the 'Crisis of the Third Century.' The 'Crisis of the Third Century' was a period in Roman history with several civil wars as breakaway empires formed amid economic and military turmoil.[27] During this time, both the provinces of Moesia Inferior and Thrace became some of the most endangered provinces in the Roman Empire as troops were taken from the border to secure the breakaway. To stop the invasions on the border military units were brought in along with auxiliaries which led to the need for more money to pay the troops. Since Mesembria historically minted coins, they reopened that mint to create bronze coins to pay these new troops. Uniquely the coins minted during this time were not standard and are considered 'military coins' since they were soley used to pay troops in the area. While only seventeen types of coins were minted under the reign of Gordian III (AD 238- AD 244) but under Philip I (AD 244 – AD 249) and Philip II (AD 248 to AD 249) this amount doubled to thirty-four types of coins. As result of the inflation this minting of coins in the AD 240s caused, the coins were taken out of circulation and the Mesembrian mint was closed for the final time.[28]

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[26] Preshlenov, "Mesambria Pontica," 493-536.
[27] Mark, Joshua. "The Crisis of the Third Century." Ancient History Encyclopedia. Accessed April 28, 2020. https://www.ancient.eu/Crisis_of_the_Third_Century/.
[28] Preshlenov, "Mesambria Pontica," 493-536.

After Constantinople was founded in AD 330 and the capital of Rome was moved to this new city, Mesembria became more important than ever to the Romans. Since the city sat along the coast of the region, along the route many nomadic tribes took, it became a major military position for defending Thrace from the north. During its militarization, Mesembria could be compared to an island as it frequently was only able to communicate with Constantinople via sea routes. Through the navy this town became a supply point for the military and constantly had troops moving through to provide defense along the Thracian border. To support the remilitarization, Rome rebuilt the city walls as well as the harbor, both of which had fallen into disrepair..[29] Culturally Mesembria experienced a change as the populace converted to Christianity and the people built the Church of St. Sophia, named after the cathedral in Constantinople.[30]

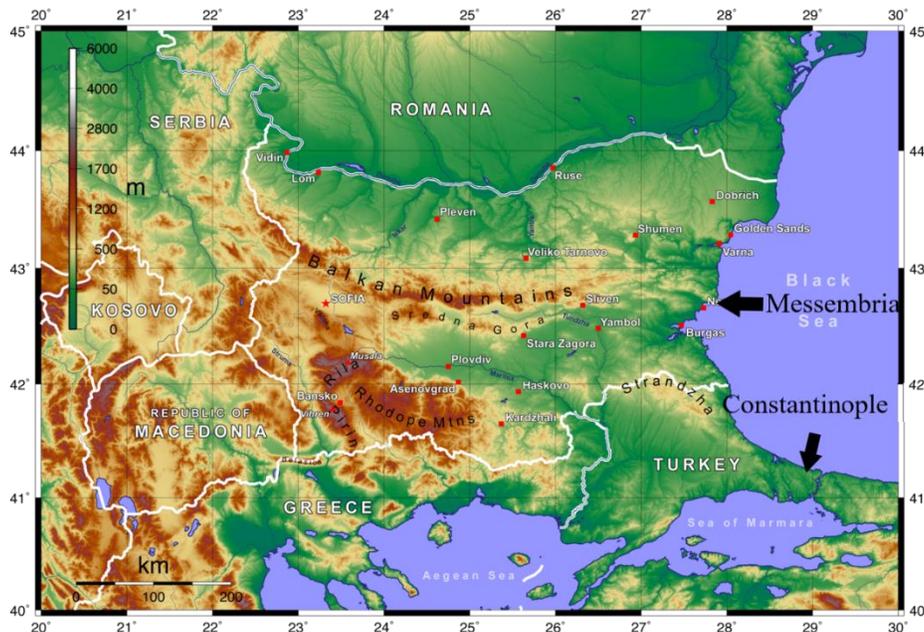*Figure 3: Equestenebrarum. English: Topographic Map of Bulgaria with English Labels, Created with GMT and Elevation Data from the SRTM. February 5, 2008. Own work.*
https://commons.wikimedia.org/wiki/File:Topographic_Map_of_Bulgaria_English.png.

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[29] Preshlenov, "Mesambria Pontica," 493-536.
[30] "Museum Ancient Nessebar." Accessed March 12, 2020. https://www.ancient-nessebar.com/html/main_en.php?menu=his.

In the mid-fifth century the final city wall was built, which is the wall that is seen upon entering city today. This wall followed the previous walls and thus is along the coast and was part of the major border fortifications that defended the Late Roman Empire. However, due to the nomadic assaults through this region, the Roman Empire, at this point the Byzantine Empire, began to lose control.

The Romans lost the settlement for the first time in AD 814/815[31] when the city surrendered to Khan Krum of the First Bulgarian Empire.[32] Following this conquest, the city became part of many empires and many different conquerors: Byzantines, Bulgarians, Turks, and even Crusaders until its modern history started.[33]

For the sake of this paper I will not elaborate on the medieval and post-medieval history of the site. The reason is that the latest finds that I took part in researching were built in the fifth century and to my knowledge no finds from these later periods, other ship anchors, have yet been found underwater. However, its modern history should be summarized to explain issues the town faces. In 1983 the city became a UNESCO World Heritage site due to its "outstanding testimony of multilayered cultural and historical heritage."[34] Despite this designation threats from mismanagement and looting are present. The 2018 UNESCO Mission to the city found that despite the designation and previous recommendations to halt construction on the peninsula, the

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[31] This date is highly contested with others believing the city was brough into the First Bulgarian Empire in AD 812. The AD 812 date is suggested both by another article discussing the architecture of churches in the city and the local city museum. However, I chose the later date as this date was both suggested and taught by Dr. Prahov when I was there and was in the majority of articles written in English on the city. This, however, is a biased choice since the majority of English articles on the city were written by Preshlenov.

[32] Preshlenov, "Mesambria Pontica," 493-536.

[33] Prahov, Nayden. June 25, 2019.

[34] Centre, UNESCO World Heritage. "Ancient City of Nessebar." UNESCO World Heritage Centre. Accessed April 29, 2020. http://whc.unesco.org/en/list/217/.

city had continued to urbanize and faces "specific and proven imminent danger."[35] The city also faces an issue with looting: restaurants frequently use artifacts as décor and many stores sell artifacts. Due to these threats, Nessebar is a prime site for new methods in display to preserve the cultural history better

Issues Facing Underwater Archaeology

Maritime culture seems out of touch with the general public, despite the best efforts of those involved in its preservation. In the United States, the National Parks Service (NPS), National Oceanography and Atmospheric Association (NOAA), and to a lesser extent the Department of Defense (DOD) and Bureau of Ocean Energy Management (BOEM) oversee maritime culture. As NOAA says in its objective for the preservation of maritime culture, its work involves allowing divers and dive clubs to dive on sites, creating museums for artifacts removed from the site, and using the sanctuary designation to protect sites.[36] By examining the issues faced by maritime heritage: inaccessibility for most people (sometimes even inaccessible to people even with SCUBA training), preservation of whole sites being unreasonable, and finally the current attempts at 3D imagery having insufficient outreach, I show why a new method of display for maritime heritage is needed.

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[35] World Heritage Committee. "Report of the Joint UNESCO World Heritage Centre / ICOMOS Reactive Monitoring Mission to the Ancient City of Nessebar Bulgaria, 22 to 26 October 2018." *UNESCO*, 14 2019. https://doi.org/10.1111/j.1755-5825.1973.tb02107.x.
[36] Delgado, J. P., Van Tilburg, H. K., Terrell, B. G., Marx, D., Marzin, C., Gittings, S., Kiene, W., Grussing, V., and Orlando, P. (2016) How NOAA's Office of National Marine Sanctuaries engages the public in the ocean through the science and management of maritime heritage. *Aquatic Conserv: Mar. Freshw. Ecosyst.*, 26: 200– 212. doi: 10.1002/aqc.2643.

Despite their efforts, public display at actual sites has been limited to people who can SCUBA. Studies have shown that in the United States, approximately one percent are certified to SCUBA, limiting the number of people who can visit these sites.[37] When compared to the rest of the world, this number is almost half of all registered SCUBA divers. Having such a low amount of SCUBA divers worldwide, access to these sites is limited to 0.078% (six million people) of the world population.[38] This not necessarily a problem until one realizes that around the world, dive tours are a main form of outreach. In the United States, both Florida and the Great Lakes do maritime heritage outreach. Florida hosts the Florida Maritime Heritage Trail (a series of places along the Florida coast where one can visit and dive)[39] and a mooring program (a program designed to place dive buoys at all wrecks in the sanctuary) is located at Thunder Bay that allows divers quick access to the sites.[40] With three million SCUBA divers in the United States, this form of access is justifiable, but poses difficulties in cases like Nessebar, which has a significantly reduced base of people able to visit the site since it is not in the United States.

The issue of accessibility for underwater heritage sites can be acute even for those who SCUBA. Under PADI (the largest SCUBA certification company) there are two forms of certification: 'Open Water Diver' and 'Advanced Open Water Diver'. PADI's 'Open Water Divers' permits a maximum depth of sixty feet (eighteen meters) while 'Advanced Open Water Diver' gives access to a maximum depth of one-hundred and thirty feet (forty meters). Due to this difference in maximum depth if a SCUBA diver wants to be able to reach deeper wrecks

[37] Corra, Elden. "Scuba Diving Participation in 2014." The Dive Lab. Diver Alert Network, December 17, 2014. https://thedivelab.dan.org/2014/12/17/scuba-diving-participation-in-2014/.PADI

[38] Diving Equipment and Marketing Association (DEMA). "Fast Facts: Recreational Scuba Diving and Snorkeling," 2019.

[39] Florida Department of State. "Florida Maritime Heritage Trail @ Florida OCHP." FLHeritage. Accessed February 27, 2020. http://info.flheritage.com/maritime-trail/.

[40] NOAA. "Thunder Bay National Marine Sanctuary | Mooring Program." NOAA. Accessed February 27, 2020. https://thunderbay.noaa.gov/shipwrecks/moorings.html.

they must attend another set of classes which (beyond making sure divers to these depths are

safer) also lowers the amount of people to view the sites.[41]

Table 9-7. No-Decompression Limits and Repetitive Group Designators for No-Decompression Air Dives.

Depth (fsw)	No-Stop Limit	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
10	Unlimited	57	101	158	245	426	*										
15	Unlimited	36	60	88	121	163	217	297	449	*							
20	Unlimited	26	43	61	82	106	133	165	205	256	330	461	*				
25	1102	20	33	47	62	78	97	117	140	166	198	236	285	354	469	992	1102
30	371	17	27	38	50	62	76	91	107	125	145	167	193	223	260	307	371
35	232	14	23	32	42	52	63	74	87	100	115	131	148	168	190	215	232
40	163	12	20	27	36	44	53	63	73	84	95	108	121	135	151	163	
45	125	11	17	24	31	39	46	55	63	72	82	92	102	114	125		
50	92	9	15	21	28	34	41	48	56	63	71	80	89	92			
55	74	8	14	19	25	31	37	43	50	56	63	71	74				
60	63	7	12	17	22	28	33	39	45	51	57	63					
70	48	6	10	14	19	23	28	32	37	42	47	48					
80	39	5	9	12	16	20	24	28	32	36	39						
90	33	4	7	11	14	17	21	24	28	31	33						
100	25	4	6	9	12	15	18	21	25								
110	20	3	6	8	11	14	16	19	20								
120	15	3	5	7	10	12	15										
130	12	2	4	6	9	11	12										
140	10	2	4	6	8	10											
150	8			3	5	7	8										
160	7			3	5	6	7										
170	6				4	6											
180	6				4	5	6										
190	5				3	5											

* Highest repetitive group that can be achieved at this depth regardless of bottom time.

Figure 4: US Navy. US Navy Diving Manual. Vol. 7. Naval Systems Command, 2016. https://www.divetable.info/workshop/USN_Rev7_Tables.pdf.

Even if the site is one-hundred and sixty feet below the surface and you have obtained an

'Advanced Open Water Certification,' bottom time is still limited. As the graph above shows, the

deeper one goes, the less bottom time, regardless of air left. The right of this graph shows that

when a diver is at ten feet of sea water (FSW) their bottom time is unlimited. Further down the

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[41] PADI. "Become a Certified Scuba Diver FAQs." PADI. Accessed February 27, 2020.
https://www.padi.com/about-padi/become-certified-scuba-diver-faq.
Furthermore, this section also brings forth a very interesting debate on accessibility and if it is necessarily a good thing. As more people visit a site it is more likely to be destroyed and have more possibilities for accidents. This however, is part of the reason why virtual sites should be better seen: they both provide more access than the physical site but also eliminate the problems associated with people visiting the site.

graph, dive time begins to taper off: fifty feet has ninety-two minutes of bottom time, seventy feet has forty-eight minutes of dive time, one hundred feet has twenty-five minutes, and finally one hundred and fifty feet has only eight minutes for dive time.[42] Since dive time is limited, time at the site is also limited and for some large sites this limitation prevents many people from visiting.

For instance, Thunder Bay National Marine Sanctuary in Michigan hosts seventy-eight shipwrecks. Of these, twenty-nine are beyond one hundred feet in depth, limiting visitation time to less than twenty-five minutes.[43] Such brevity leaves much to be desired. This is especially true if coupled with water conditions at these depths being generally worse, making a proper visitation even longer.

Maritime heritage also faces a lack of effective outreach. Thunder Bay's efforts include photogrammetry models for people unable to visit the site. As mentioned above, this is helpful since over a third of the sites are either below the depths of conventional SCUBA, or at a depth that limits viewing time immensely. The photogrammetry models are available to anyone with an internet connection. However, this system has several key failures.

The first failure surprisingly is lack of access. The models are free for anyone to use but are hard to find. On Thunder Bay's website, if one clicks a shipwreck, they open a webpage that includes basic information on the site including tonnage, date, and pictures. Lacking are links to 3-D models on Sketchfab. On Sketchfab, I found several models of sites in Thunder Bay, but the only reason I knew to search there was due to conversations with people who have worked there.

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[42] US Navy. *US Navy Diving Manual*. Vol. 7. Naval Systems Command, 2016. https://www.divetable.info/workshop/USN_Rev7_Tables.pdf.
[43] NOAA. "Thunder Bay National Marine Sanctuary | Shipwrecks." Thunder Bay National Marine Sanctuary. Accessed February 28, 2020. https://thunderbay.noaa.gov/shipwrecks/welcome.html.

Accordingly, the models have very few views. Of the twenty-three models published by Thunder Bay, only three have more than one thousand views with most (fourteen) having two hundred views or less.[44] Therefore, there is a clear lack of outreach despite the efforts. It is probable that most people who visit the museum or even the website have no idea that these models even exist.

The Thunder Bay photogrammetric models also present very little information. The most visited model from Thunder Bay, the Cornelia Windiate, has a short description that tells the depth of the wreck, length, tonnage, when and who built it, and the date of the sinking. Besides these numbers the description also includes a short about how the ship was sunk: "For many years, the story of the Windiate's disappearance was a mystery. It was thought to have gone down in Lake Michigan, since it was spotted there in a fall gale and was never seen again. More than 100 years later, the wreck was discovered deep in Lake Huron's waters. The ship is in nearly perfect condition with masts upright, cabin intact, and the yawl boat lying alongside the stern. The Windiate is now thought to have sunk because heavy seas covered the decks in ice causing it to settle slowly to the bottom of the lake. No signs of the eight crewmen have ever been found."[45] From these descriptions visitors to the website learn about basic information about the wreck and only begin to learn of the wider story that this ship has. For instance, having pointers that explain what certain parts of the ship are or where artifacts were found would provide information allowing people to better relate to the wreck as opposed to only seeing a non-descript model with no connection to the information. The few people who do view this

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[44] NOAA. "3D Models by Thunder Bay National Marine Sanctuary (@thunderbaynms)." Sketchfab. Accessed March 9, 2020. https://sketchfab.com/thunderbaynms/models.

[45] *Cornelia Windiate - 3D Model by Thunder Bay National Marine Sanctuary (@thunderbaynms) [C95f4e1].* Accessed March 9, 2020. https://sketchfab.com/models/c95f4e16a41d4bae88acd8bb1d0b7a42/embed?autostart=1.

model have little understanding of why this ship is important and why it is protected in the Maritime Sanctuary.

Finally, the models are not interactive. The Thunder Bay models offer rudimentary movement: you can move an individual model around on an axis. This form of movement also allows users to view the model from different angles and move the focal point of the camera to new locations. Furthermore, these models have 'points-of-interests' that users can click on to get more information. Despite this potential for more information on specific points of the model, these models only have specific photographs of that area. The Cornelia Windiate has five of these points of interest: the ships wheel, the cabin staircase, a photomosaic, and two images showing the divers working on the site.[46] Although this is a form of interaction, it simply is not enough to truly catch the attention of users in a meaningful sense.

Another virtual site preservation helped inspire my thesis: The Virtual Dive from the Black Sea Maritime Archaeology Project (MAP). Located on Anastasia Island in the bay of Burgas, this display highlighted several of the shipwrecks found by the researchers who took part in the Black Sea MAP.[47] When I visited this exhibition, they had a computer with a virtual reality headset hooked up which allowed users to 'tour' the sites. Much to my dismay, this project had all the issues all the issues mentioned before: accessibility, information, and interactivity.

Accessibility took two forms: physical inaccessibility and online accessibility. Since the museum was located on an island the only way physically to get to the display was to board a

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[46] *Cornelia Windiate - 3D Model by Thunder Bay National Marine Sanctuary (@thunderbaynms) [C95f4e1].* Accessed March 9, 2020. https://sketchfab.com/models/c95f4e16a41d4bae88acd8bb1d0b7a42/embed?autostart=1.
[47] "VR Experience Shows the Sunken Ships in the Black Sea - Novinite.Com - Sofia News Agency." Accessed March 11, 2020.
https://www.novinite.com/articles/193501/VR+Experience+Shows+the+Sunken+Ships+in+the+Black+Sea.

ferry which left a few times a day, limiting who could go to the museum. My group was an example of this, since we had to plan in advance how to get to Burgas on time for the ferry and then leave the island with time to get back to Nessebar. Without our supervisors arranging transportation, this visit would have been extremely difficult to make. Along with physical inaccessibility, there is no online version of the sites, forcing to travel to the display, which moves from museum to museum.

When it came to the information presented for the virtual tour of these shipwrecks, there was even less of information compared to the Thunder Bay shipwrecks. For these wrecks, the only information was what the researchers had begun calling these wrecks and their depth. This is not the fault of the archaeologists, as these wrecks have little information known about them other than approximate dates and what historic nation they came from. However, even without specific information on each individual vessel it would be still possible for researchers to publish information regarding the time period these ships were being used in and what potential cargos and stories these ships could tell us.

The lack of interactiveness was of special importance for me. In the MAP Black Sea models, interactiveness was absent –the entire project had a set path. Users could not stop and look at individual shipwrecks, or even control where they wanted to look. Individual users might want to look at different parts, but entire sections of the shipwrecks, such as the sides, end up unseen. Although I was glad to see this effort, its lack of interaction was unimpressive; I was better informed by the miniature plastic models on hand.

Due to all of these issues, I decided to create a virtual dive for Nessebar. This virtual dive eliminates these problems since it is interactive – users choose where to explore and what position they want to be in. Furthermore, my solution also allows greater access to information

about sites that are underwater since I have incorporated a user interface that gives information specific for each object.

Problems and Solutions Specific to Nessebar

Nessebar, due to its location, has several issues plaguing its display of cultural heritage, some of which have been mentioned above. However, its location also provides benefits for other methods of display other than the virtual display that I have created. To discuss some of these methods, along with their benefits, I will first discuss the specific challenges that Nessebar faces in displaying its underwater heritage.

Site depth is not one of them. As the site's depth is only five meters deep at maximum, the issues facing physical accessiblilty do not in Nessebar.

However, Nessebar does face issues when it comes to the tourists who visit the town. Nessebar is located near Sunny Beach (4.5km), one of the most popular vacation locations in Europe. Ranked as the cheapest vacation spot in Europe, Sunny Beach brings in several million tourists a year and for 2018, 3.6 million tourists visited the beach in the first half of the year.[48] Many tourists come from Sunny Beach to the city of Nessebar as a day trip for its restaurants and cultural heritage. Since the people visiting the town are not 'cultural tourists,' different methods of display attract visitors to cultural heritage. For the many historical churches in the town, open tours are quite popular. However, similar numbers did not crowd the archaeological museum in the town which houses the artifacts from the submerged ancient sections of the city.

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[48] Propertyshowrooms. "Bulgaria Welcomed More than 3.6 Million Tourists in the First Half of 2018," August 14, 2018. https://propertyshowrooms.com/bulgaria/news/bulgaria-welcomed-more-than-36-million-tourists-in-the-first-half-of-2018/.

For the city of Nessebar to depict their underwater heritage, it is imperative that new methods of display are tried. One such new display would be my virtual dive, which offers a new appreciation of the underwater heritage since it would be more entertaining than it currently is. Besides my project, other methods could include dive tours (which are currently being planned), snorkeling, and possibly glass bottom boats or walkways.

The first and most realistic possibility would be to have a dive tour. A dive tour would not be hampered by physical inaccessibility since the sites rest only a few meters underwater and would not require specialized training or limited dive time. The only accessibility issue with dive tours would be that most do not SCUBA. The team of researchers on the site have already begun talks with the local dive shop, Angel Divers, to do a dive tour of some of the archaeological sites. However, using the local dive shop for the tour is not uncomplicated. As I have previously dived with Angel Divers, I can say that in general I was happy with the quality of the experience. This group could easily set up a dive tour for the site and communicate with people what they are seeing and its significance. However, as Nessebar experiences millions of tourists from all over Europe, issues with communication may occur – Angel Divers only has one full-time guide plus a seasonal guide for the summer. These two men combined speak Russian, Bulgarian, and English but due to the diverse nature of the visitors, it would be hard to communicate with all people who visit the site. I believe that this drawback can be easily overcome by having another guide or two if the tours become more popular and it becomes feasible to do so. A supervised dive tour of Nessebar would be quite beneficial and allow more people to experience more local history.

Perhaps even better than having a dive tour, would be a snorkeling tour. Like a dive tour, a snorkeling tour allows people to be in the water visiting the sites of underwater Nessebar.

However, it comes with a big benefit that SCUBA does not have: availability to almost everyone. If snorkeling was done on the site, any person who visits the beach would be able to visit the site with very little effort. Unlike SCUBA, snorkeling would allow people to visit the site independently and not have to schedule a tour in advance. Snorkeling can also have better language outreach since all that would be needed is a sign telling visitors what they are seeing and the significance of the walls. However, snorkelers would not have answering. Snorkeling also limits people to not being able to see every aspect of the site since users will remain some distance (at most 5m) away from the sites.

The final method of in-person display would be glass bottom boats or walkways. Both of these would be valid options as the location of the sites could easily have a platform built over them or small boats go over them revealing the underwater wall. Having glass bottom boat tours would offer information given by knowledgeable people. However, this would once again lead to a language barrier as tours would have to be set up based around common languages. A glass platform, or walkway, on the other hand would allow people to see the site at their own leisure and can have posted signs in multiple languages showing what people are seeing.

In choosing any of these options, another benefit arises: public outreach through maintenance. Unlike the churches and other sites located on the peninsula, the sites that are underwater will need constant maintenance. Due to the ecosystem around Nessebar, seagrass, oysters, and other marine organisms grow throughout the year and cover the site. As I learned over the summer, cleaning can take days, it needs need to occur at least once a year for the site to be continuously exposed for viewing. An annual cleaning would allow the people of Nessebar the opportunity to volunteer, giving locals an intimate relationship to the site which could potentially help diminsh the looting of the sites which is prevalent. Not only could locals get

involved in such a process, but vacationers, students, and all other people could be recruited giving people a unique experience to be a part of the history of underwater Nessebar.

Ethical Concerns

The use of digital display in archaeology and specifically underwater archaeology has become a debated topic. Some academics say that the use of digital display can lead to huge gains for the public (such as accessibility) when it comes to public outreach and others state that this technology has several drawbacks (such as leading some areas to be more privileged than others), a review of this debate is in order.

The most widespread concern for digital display in archaeology is a blurring of what might be regarded as 'real' versus what is 'fake.' As Galeazzi notes, the issue is a loss of context. Digital recreations can be great tools, but they often lack context for several reasons. For instance, models often do not show the seascape around the site, which offers a sense of scale that is only possible at the site.[49] Although a lack of context is valid issue, I do believe that this can be mitigated by including a wider area, including more of the seascapes and site plan. Furthermore, Galeazzi questions whether a recreation should be labeled as 'real' or 'fake.' Although Galeazzi recognizes a virtual site is not the same as an actual site, there is concern that it may not be viewed as a 'fake' since it is actually a detailed duplicate of the original. A recent example of this is the reconstruction of portions of Palmyra since its destruction by ISIL. The Palmyran arch was completely digitalized and then recreated physically, only smaller.[50] So how

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[49] Fabrizio Galeazzi, "3-D Virtual Replicas and Simulations of the Past "Real" or "Fake" Representations?," *Current Anthropology* 59, no. 3 (June 2018): 268-86.
[50] The Institute for Digital Archaeology. "History of the Arch." Accessed February 26, 2020. http://digitalarchaeology.org.uk/history-of-the-arch.

we should handle such objects: as copies of the original, new artworks entirely, or as the object itself?[51] These concerns highlight several issues regarding how digital artifacts should be displayed and labeled. Should they be treated as extensions of the site or as something else entirely? In my opinion they need to be viewed as extensions of the site, but not as important as the real site.

In the context of my project, if this issue is left unaddressed, can lead to a major problem with looting. Already in Nessebar, many restaurants, hotels, and stores display artifacts from anchors, sections of wall, and amphorae that most likely came from the coasts around the city. If unaddressed, implementing this technology could give another cause for these people to take artifacts since there is potential for the to view artifacts as not as valuable since there is a copy in the local museum. To counter this, I believe balance that both values the use of the digital display, but also gives the actual site purpose needs to be achieve. The real site and the virtual display should work in tandem.

Technologies also have cost access issues. Although governments generally preserve cultural heritage, access issues remain. Low income areas, for example, may be unable to implement these technologies due to economic limitations and technological illiteracy.[52] I think that cost is a definite problem with digital technologies but it is still cheaper than in-person visits or a more traditional method of outreach: books. This article also mentions that even places that have the most funding can still have problems with digital heritage. As Colley notes, these projects can end up being failures and thus a large amount of money spent on the project can be

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[51] Galeazzi, "3-D Virtual Replicas and Simulations of the Past "Real" or "Fake" Representations?," 268-286.
[52] Sarah Colley, "Ethics and Digital Heritage," *The Ethics of Cultural Heritage,* 13-32. New York, NY: Springer (2014).

for nothing.[53] However, I find this argument lacking since it could be said that anything has this problem and thus nothing should be tried.

For my project, I think cost is a factor in implementation. At current expense levels, some places could not use my project since it does require computers, and for future versions, VR headsets. However, these technologies are both becoming more inexpensive which should eliminate this problem in coming years.

The potential threat of editing or re-writing is another concern for digital conservation. If digital outreach is a closed system and only archaeologists can edit the information and everyone else can just view it, the technology is not completely accessible to people, and it only shows the archaeologists' narrative.[54] This can become a problem when the archaeologist who made the digital project may have one interpretation and other archaeologists have another. In this case, the creator would have a virtual monopoly on the interpretation and can minimize other potentially valid solutions.

The benefit of a closed system is to would be prevent people from incorrectly or maliciously editing information; Colley points to an example: the indigenous people of Australia who still have difficulty documenting their history. Non-indigenous people began changing the history of the aborigines to fit a narrative that was against the aborigines.[55] The other way to have the technology set up is open, or available for anyone to edit. Colley notes that this form of sharing would allow technologies to be circulated easier and have more people viewing them as a result.[56] Other benefits of this could be keeping up to date in technologies and features, as

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[53]Colley, "Ethics and Digital Heritage," 13-32.
[54] Ibid.
[55] Ibid.
[56] Ibid.

specialized knowledge emerges. Competing theories could begin with equal weight in discussion since all theories could be included in open technology. However, this can also lead to issues. For example, the archaeology could be hijacked. A solution needs the benefits both from closed open systems. A possible solution could be having several databases that allow archaeologists to upload their site and interpretation but allows others to view the heritage and edit it to allow others to make their own interpretations of the sites.

The last issue that is worth bringing up is the issue of interpretations in public archaeology. As Dr. Schindler pointed out to me, there is a concern in public archaeology about interpretations. The way she put it; public archaeologists run into the problem of having to both a need for interpretations while also having issues with them as well.[57] Using this as a jump off point I also discovered another major concern for my public display in archaeology since I view my project as a public archaeological project.

Richardson and Almansa-Sanchez both discuss the ethics of public archaeology in their article. In this article they note that many previous archaeologists have noted that beyond excavating, processing, and evaluating data that a public archaeologist also has another role: "the examination of the relationship among the many interpretations of past human activities and contemporary society."[58]

This additional role taken up by public archaeologists leads to a 'double edged sword' that leads to a contradiction. On one side they say that a role for public archaeologists is to get the public excited about archaeology and that the current way to do this is to offer an

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[57] Rebecca Schindler, pers. comm., 2020.
[58] Lorna-Jane Richardson & Jaime Almansa-Sánchez (2015) "Do you even know what public archaeology is? Trends, theory, practice, ethics," *World Archaeology*, 47:2, 194-211, DOI: 10.1080/00438243.2015.1017599

interpretation of the site that brings the public to it. However, public archaeology also wants the

public to consider their own interpretations about a site, which is hard to do when they already

have an interpretation planted in their heads. However, the solution for this per these authors

seems elusive. If archaeologists do not publish their findings and interpretations, then they

violate the ethical codes that are supposed to govern archaeology. At the same time, it also seems

that creating a more open ended or uninteresting interpretation of a site would lead the public to

find archaeology as uninteresting and not worth their time nor money. For a solution the two

authors just note that the only way to mitigate the problem is to be careful with how

archaeologists should create interpretations and to put more focus on the people and not the sites

themselves.[59]

Methodologies

My project for a virtual dive uses the following software: Agisoft Metashape, Unity, and

Visual Studio 2019. Agisoft Metashape is a photogrammetry software that succeeds Agisoft

Photoscan. Unity is a free software engine that allows users to create video games and

simulations. Another option is Epic's Unreal Engine used by the iMare Project (a similar digital

heritage project done off the coast of Cyprus).[60] I chose Unity for this project due to its previous

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[59] Lorna-Jane Richardson & Jaime Almansa-Sánchez (2015) "Do you even know what public archaeology is? Trends, theory, practice, ethics."

[60] Skarlatos, D., P. Agrafiotis, T. Balogh, F. Bruno, F. Castro, B. Davidde Petriaggi, S. Demesticha, et al. "Project IMARECULTURE: Advanced VR, IMmersive Serious Games and Augmented REality as Tools to Raise Awareness and Access to European Underwater CULTURal HeritagE." In *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection*, edited by Marinos Ioannides, Eleanor Fink, Antonia Moropoulou, Monika Hagedorn-Saupe, Antonella Fresa, Gunnar Liestøl, Vlatka Rajcic, and Pierre Grussenmeyer, 805–13. Cham: Springer International Publishing, 2016.

educational utility for Universe Sandbox™,[61] NASA's Eyes on the Solar System™,[62] and the underwater game Subnautica™.[63] The hardware is AMD Ryzen 5 3600 and Nvidia RTX 2060 workstation. For pictures to create the models I used a GoPro Hero 5, taking shots continuously every three (3) seconds.

My photographic method involved cleaning the objects or sites and removing anything that could interfere with the photos. In one of the models that I created, this was difficult, due to currents, and in that case seagrass interfered with the shooting. Despite that low-quality model, I decided to keep it to demonstrate the effects of not having decent photographic conditions. To keep models scaled, I used several measuring sticks (rebar that has been taped to mark one meter). However, as I did not have scales in a two of the models, I referenced bricks that are roughly the same size (30 centimeters) and used these bricks as a scale bar. This created a scale that is accurate, however not entirely precise. These scale bars are further marked by depth to the nearest tenth of a meter, as calculated using an Aqualung i550c Dive Computer. After setting up the area for photography by setting up scale and clearing the area, I initiated photography.

When taking pictures of the sites, I swam at a very slow pace around the site three times making sure photos overlapped with each other by at least 30%. While swimming it was crucially important to stay as steady as possible, which I found difficult due to the waves, since I was located in shallow water (roughly three meters deep). After circling the sites three times, I then started from a location and swam in an 'S' fashion over the site, going one direction. I then

[61] "Creating the Universe with Unity." Unity. Unity, January 8, 2014. https://unity3d.com/learn/resources/talks/creating-universe-unity.

[62] Brown, Dwayne, and Stephanie L Smith. "NASA Gives Public New Internet Tool To Explore The Solar System." NASA. NASA, September 2, 2011. https://www.nasa.gov/home/hqnews/2011/sep/HQ_11-288_System_Eyes.html.

[63] "Rev up Your Engines." Rev up your engines | Computer Graphics World. Accessed December 13, 2019. http://www.cgw.com/Publications/CGW/2015/Volume-38-Issue-1-Jan-Feb-2015-/Rev-up-your-engines.aspx.

repeated this same route again to ensure adequate coverage. Next, I oriented myself and swam above the site, this time going perpendicular to the previous step, twice. This final step completed the imaging for the larger sites. This process took me approximately 30 minutes at each site but depended entirely on the size of the area.

For photogrammetry of smaller locations, namely the brick pile (site 3) and column (site 4) I used a different method. After cleaning the object and surrounding area, I placed scales and began photography. As mentioned above, I did have issues with the small brick pile due to its location very close to a dock, and thus waves kept bringing seagrass (which I was unable to clear) into the images. Photography for these objects began by setting the camera on time-lapse and moving around the object three times, making sure all four sides were sufficiently covered. After getting the sides of the object photographed, I took images going from above creating a 'C' like shape. Finally, I traced the same shape in a perpendicular fashion. These models took significantly less time – only about 10-15 minutes per model.

After obtaining photographs for the models, I exported the files from the camera. File-sets must only contain images from each individual site or object. To mark when different sets of images ended, I took a single picture of my hand between each site/object. After sorting the file-sets, I began the photogrammetry process. An optional step here can remove the green look of the model to make it appear as if it were not located underwater. The reason for editing the model in this way is to 'clean' the image and allow objects to be more easily identified, but, for the virtual dive I did not take this step, for which one can use Adobe Photoshop or Raw Therapee. The first site (credits to Pavel Georgiev for creating this model) used this additional processing. To do this using Raw Therapee one, imports all the images into the software and selects them. Then one batch edits their color (Open up 'batch edit' and 'click color'). At this

screen select white and let the program automatically edit these photos, which gives them a white

white appearance. Once this is done save the photos and move on to create the models.

The first step in creating a photogrammetry model is to align all of the photos. To do this, open up Agisoft, select 'workflow,' select 'add folder' and select the folder with the photographs wanted for the model. Next, click 'workflow' and this time select 'align photos.' When the pop-up appears to select the quality of the model (try medium quality to cut down on the polygon count[64] for later steps, saving much time). However, if time is not an issue, higher-quality models can be constructed. The software creates an 'aligned model,[65]' or 'sparse cloud.[66]'

Once the images are aligned (the software identifies points of commonality amongst all images), which may take several hours, it is possible to clean up the model and remove unneeded sections.[67] The first step in cleaning up a model is to go to 'model' and select 'gradual selection.' In this menu select 'projection accuracy' and move the slide to encompass approximately 10% of all points. Delete these points and then go to the 'tools' menu and optimize all the cameras. Once this is done, repeat all the previous steps again. Then open the 'model' menu and select 'reconstruction uncertainty.' Once again move the slider to select roughly 10% of the remaining points and delete them. Follow this up by optimizing cameras again before repeating the process over again with 'reconstruction uncertainty.' Finally, go to 'model' and select 'reprojection error.' Once again select and delete 10% of the points. Reoptimize cameras, do this final step

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[64] Polygons are the shapes that make up a 3D graphical image and are composed of vertices. A polygon count is the total number of polygons in a frame.

[65] An aligned model is the term for all the images being aligned to create a very rough 3D depiction of the object of the photographs. Since this model is made up of only as individual points of commonality between photos the object appears as if it is mostly empty space; this gives the name 'sparse cloud.'

[66] See above

[67] Unneeded sections of the model include sections that appear to be floating such as any part of the photographer or something that may have appeared in a few of the photographs. This step is very useful for 3D printing as it makes sure there is a contiguous model and not floating sections.

again, and the model will be cleaned up as best as possible. By doing all of these steps points that give off abnormalities that can affect the model's appearance are deleted. This reduces future inaccuracies while also speeding up future steps as there are fewer points to work with.

After preparing the models, put them into 'dense cloud.'[68] To do this, select 'workflow' and then 'build a dense cloud.' Once again, keep this on the 'medium' setting to save time. Once the dense cloud is created then finally one can create the final model by selecting 'workflow' and 'build the mesh.' Once this model is completely rendered there is an optional step to scale the models, which I did. For the large sites, there are the scale bars in which one finds the model and adds a point to each end. Then in the reference tab, select both points. With both points selected, right click and 'create scalebar.' For the model for which I did not have scale bars, I created scales based on the brick sizes, which are roughly the same amongst all sites. After creating the scales, refresh the models to allow the scales to take effect. With the models now done, export them into '.obj' and their textures into '.tif' for Unity. The total time involved to create the models was roughly three hours for following the manual time and making repairs, and several days for the models to render (limiting computer usage during this time).

Once in Unity, create a new 'scene,' and import all the models along with their textures: 'assets,' 'import assets,' and then select the folder with the models and textures. After this, select the models and place them in the scene by simply dragging them from the asset bar below. When placing these models, they will not have the textures and instead will be grey. To fix this issue create a new material in Unity by right clicking in the 'asset bar,' select 'create,' and then 'material'. Select this material and make both 'Albedo' and 'Detail Albedo x2' the image for that

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[68] Dense cloud is an updated form of the model after sparse cloud. In this version connections are made between some of the points that includes coloring of the model.

model. Then all that is needed is to take this new material and apply it to the models by dragging

the material onto the model. This is a much shorter process than making the models, but since I

had to troubleshoot and figure out exactly how to fix the textures of the model, I did spend

roughly two hours learning how to fix the models being grey and another two hours texturing all

the models. I also had an issue with the version of Unity that I was using and had to recreate the

scene a second time. I advise caution to those creating projects like this; make sure that a stable

version of Unity is being used and not one that will be updated. If one uses the most recent

version of Unity, be prepared for issues that may require the 'scene' to be recreated.

After importing all the models, I began work on camera and player movement. This

begins by creating a capsule for the player: click 'GameObject,' '3D object,' then capsule. Then

move the main camera into the capsule using the arrows on the camera or capsule. At this point,

the main camera must be a 'dependent' object to the capsule to make sure that they stay together.

To do that in the 'hierarchy' on the left, place the camera underneath the capsule. Then I created

a code that controls player movement and another that controls camera movement. This code

was then applied to the camera and capsule through the 'inspector' on the right of the screen. In

my code for the game, I simplified the movement, so the camera only moves forward, backward,

and side to side (not up to down). My reasoning behind this design decision was to create a

'snorkel version' of the site. It takes some time to create the code and debug it unless one simply

downloads publicly available code. I had to learn basic coding and watched several videos on

how to set up these two systems. It took four hours to create each code, making this the longest

single step in the process.

Upon completing player movement, my focus moved to the visual and learning aspect of

the virtual dive. I have changed the camera lighting towards a soft grey to minimize glare, since

the player is close to the white background of the models. Camera lighting is changed by

selecting the 'directional light' on the 'hierarchy.' In 'inspector' click the color and change it to

the preferred color. The biggest visual difference has been to add fog, which creates an

underwater effect and limits visibility, by opening the 'window tab,' 'rendering,' and finally the

lighting settings. In this new window, scroll down to find 'other settings' and add a fog and

select the preferred color. The fog in my scene has been carefully chosen to simulate the

underwater environment in the Black Sea, which increases the immersive experience. Smaller

objects have also been placed on a pedestal to increase visibility so users can more accurately see

smaller objects and notice their details.
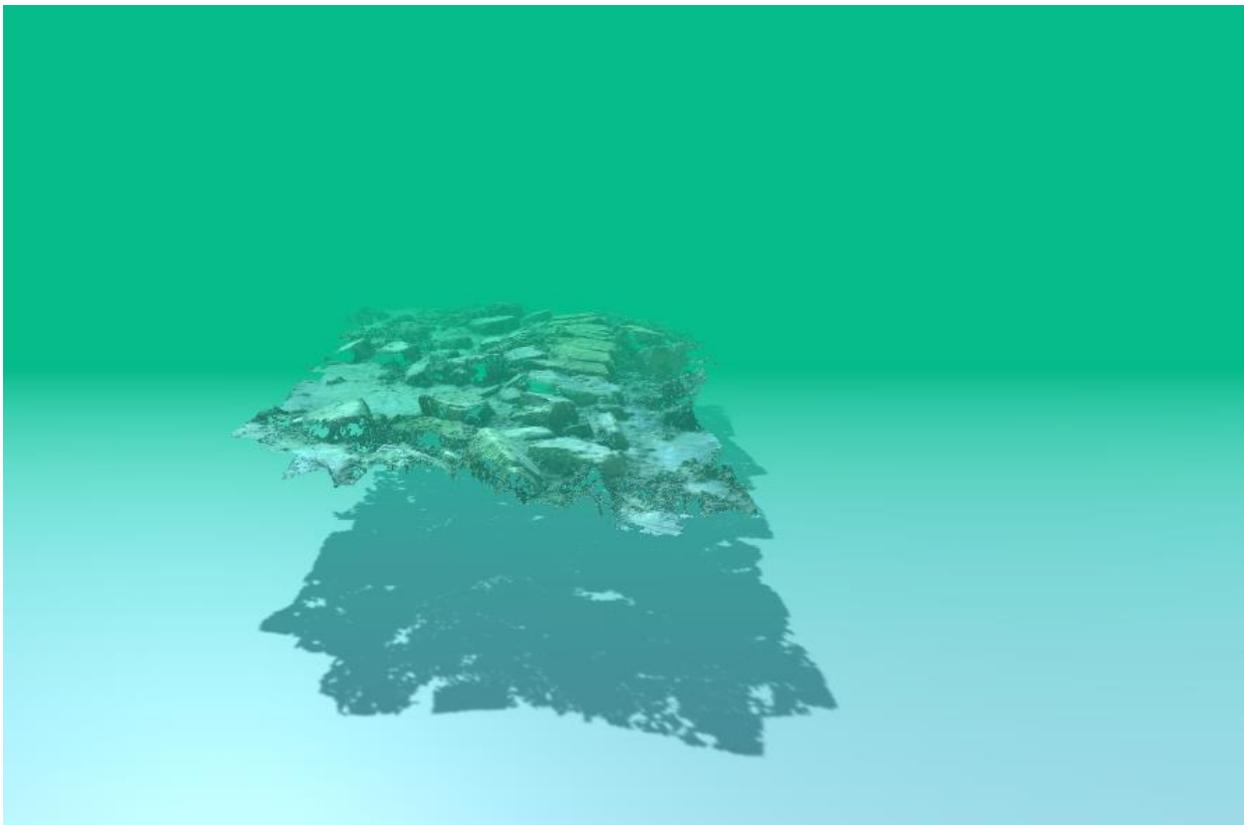
Figure 5: Image showing the lighting and fog effects

Lastly, the sites have been placed semi-accurately to where they actually would be. In the simulation, distances between sites are traversed by a 'teleporter' between the different bays in which we excavated. To create the teleport system, I wrote another code that made the teleporter and the teleport location the same spot, creating a one-way teleport sequence along the path the user will follow. This code was then applied to cube objects placed near the bays: 'GameObject,' '3D object,' 'cube.' These cubes then had their 'mesh renderer' turned off in 'inspector,' making them invisible. Since the teleporter itself is invisible, I added a 'bubble' effect through the 'particle system' in the 'effects' tab of the 'GameObject' menu to the teleporters. This effect was chosen specifically for the project as bubbles are common in SCUBA and thus not something that feels misplaced. These bubbles also helped with pathing, as users could just 'follow the bubbles' from location to location.

Figure 6: The 'Bubbles' that appear in the teleporters

Following the creation of the path, I continued developing pathing. One major issue that I noticed in basic testing was the ability for users to get off track and out in the middle of 'nowhere,' with no way to return to the sites. To mitigate this problem, I implemented invisible barriers around all the teleporter areas, which allow users to swim around freely, but stop movement when the sites become no longer visible. This involved placing a series of 'cubes' (in the same process as above) that surrounded the swimmable areas, turning off their 'mesh renderer' and making sure the 'box collider' was turned on in 'inspector.'

Now that pathing was completed, I began working on the 'user interface' (UI) of the scene. I chose to create two types of UI: one to tell how to use the software, and another dependent on location within the scene. To implement the UI I opened up 'GameObject,' selected 'GUI,' and then 'text.' Once the text was opened the program changes from 3D to 2D; text boxes float on the screen, which I moved to the top left corner of the screen. This step also required an important change in the project since the text first appeared very fuzzy. To fix the low-resolution of the text, I had to rescale the scene from a 4:3 aspect ratio to a 16:9 aspect ratio. By doing this the entire scene achieved better quality and will run better on more computers since 16:9 is the native aspect ratio of most modern computers. The main UI appears in the top left corner of the screen, tells the user what controls to use, and provides basic information such as how to follow the path.

The secondary UI took much longer to create since I also had to create a code that set the UI as a 'trigger:' only appearing when a user was near an object. I then set each object for this type of UI which would relate specific information regarding the site/object one is looking at in the top right corner of the screen. To get wording right for this type of UI and be useful, I have

had several people test the software and tell me what information is important to keep for each object. I also decided here to have small amounts of information instead of large paragraphs. My reasoning for this decision was to maximize viewing of the object by minimizing text and to encourage users to read only small amounts of text instead of large paragraphs.

Future Plans

Although I currently have a working program for the virtual display of underwater archaeological sites, I do believe that this project can be continued an improved upon in the future. As of now there are three specific things that need improvement: implementing VR headsets, better user interface, and better graphics.

As I originally planned on having this project use VR headsets, I would love the project to have this capability. Having this capability gives this project more immersion and allows people to be able to physically 'look' at the different sites using their own heads. Although I do recognize that this software and hardware does pose an accessibility issue since few people have VR headsets, I believe that having it would attract users at locations such as museums. As Michael Boyles pointed out, it is possible to set up a system of rigging that would hold users above the ground, giving even more immersion by creating the feeling of being suspended in water. Having rigging coupled with the VR headset would create a highly immersive and realistic simulation for museums.

Alongside VR headset capabilities, I also want to improve the user interface to display more information. One way in which I could do this would be to have pictures, whether that be with reconstructions of the area or images of the area, in the text boxes so users are not put off by large walls of text. However, this envokes the concern of not being truly 'public' archaeology as

I would be showing what my interpretations of the site are and not leaving them open. Alongside the text boxes, I also want to change the way the pathing works. Instead of having the different sites all along a teleportation pad, I'd like to try a central point that contains the smaller sections as a kind of museum, from which one could teleporter to any of the sites. This form of teleporting would blend a virtual museum with the virtual dive.