News from our Members:

The Kyrenia Ship Three-dimensional Modelling Project

Jeremy Green, Daniel Adams, Andrew Woods

In 1965, Andreas Cariolou, a Greek Cypriot diver, came across a mound of amphorae in 33 m of water off the port of Kyrenia, Cyprus. Unfortunately, he lost the position and rediscovered it in 1967 when he showed it to a joint archaeological team from the University of Pennsylvania Museum and the Oxford University Research Laboratory for Archaeology. Between 1967 and 1969 the shipwreck, a 4th century BC merchant vessel was excavated under the direction of Michael Katzev. The cargo consisted of about 400 amphorae and 20 millstones. After these had been excavated, the remaining hull, almost 75% of the original, was excavated, conserved, and rebuilt in Kyrenia Castle where it can be seen today. During the project over 7000 underwater photographs were taken of the site using 35 mm black and white film.

The advent, in early 2000, of programs that allowed processing of digital images to generate digital 3D models revolutionized the archaeological recording of sites, both on land and underwater. The technique was first explored by this team in 2016 on the 3D reconstruction of the wreck of the Dutch VOC ship *Batavia* photographed in 1971–74 (Woods et al. 2020) and in 2017 on the Cape Andreas tile wreck in Cyprus that was surveyed and photographed in 1969–70 (Green 2019). The success of this reprocessing of legacy photographic data suggested that it could be applied to the very large collection of Kyrenia Ship photographic material.

The HIVE (Hub for Immersive Visualisation and eResearch) at Curtin University in Western Australia had been involved in developing 3D models of wreck sites using photogrammetric 3D reconstruction techniques for several years including work on the wrecks of HMAS *Sydney* (II) (1941) and HSK *Kormoran (1941)* (McCarthy 2016), HMAS *AE1* (1914) (Woods and Hollick 2018), and *James Matthews* (1841) (Adams et al. 2021). The HIVE was contracted to develop several models of the Kyrenia Ship, the idea was to combine 3D models of the site from different points in time to show the progress of the excavation. In addition, CAD models of the amphora and millstone cargo were then linked to the 3D models to obtain further information about how the cargo was stowed and how the ship broke up on the seabed.

The project involved cataloging all the underwater photographs that were taken in the three seasons to create seven layers corresponding to 1967; early-, mid-, and late-1968; and early-, mid-, and late-1969. Thus, there was a sequence from the discovery up to when the hull was completely uncovered, prior to it being dismantled. Towards the end of this work the HIVE team was made aware that there was photographic coverage of the reassembled hull in Kyrenia Castle done by Drew Fulton in 2018. This made it possible to rearticulate the starboard section of the hull in its correct position, effectively joining the two parts of the hull together.

The project has been extremely interesting and rewarding, and these new results allow archaeologists to consider, how the cargo was originally stowed, how the ship broke up, and to compare the reassembled hull with the distorted hull on the seabed, and to take measurements on the underwater site.

This work has largely been due to the talents of Daniel Adams, who performed the image processing,

Figure 1: *The 3D CAD model depicting the cargo arrangement for the Kyrenia ship.*

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with Jeremy Green supplying advice about the photography and the site, and Andrew Woods, the manager of the HIVE, providing technical advice on the programs utilised.

The availability of digital 3D models of multiple layers of the excavation also allows us to virtually rebuild the arrangement and three-dimensional layout of the cargo. By registering each individual excavation layer to the next and aligning individual CAD models of each individual cargo element in each 3D model layer, we were able to build a complex 3D CAD model of the cargo which reproduced the three-dimensional arrangement of the cargo.

To widely share the results of this project, the full 3D model, including its individual layers, has been uploaded onto the HIVE website using Sketchfab 'The leading platform for (sharing) 3D and AR on the web' and is available at the following address: <HIVE.curtin.edu.au/kyrenia>. The Kyrenia 3D model web page needs a little explaining. Unlike most Sketchfab models which consist of only a single object or single layer, this Kyrenia wreck site model has multiple parts—eight individual underwater layers, one layer showing the rebuilt ship at Kyrenia Castle, and two layers showing the cargo (CAD rendered amphorae and millstones), together with two additional viewing options. To facilitate the interpretation and analysis, users can switch between layers or have several layers on at the same time and rotate the model to a desired angle. This is an innovative use of the Sketchfab platform and allows users to interactively explore the full wreck site.

The process has involved connecting each layer together, starting from the site when it was first discovered (1967) and before excavation (L0), joining the 3D L0 to the L1 (early 1968).

This then was repeated through L1 to L2 (mid 1968), L2 to L3 (end 1968 where millstones first appear), L3 to L4 (early 1969 second millstone layer), L4 to L5 (mid 1969 hull ceiling planking uncovered), L4 to L5 (late 1969 hull fully uncovered). It will be noted that at L5, the hull shows bow to the left, with a large port section and a smaller disarticulated starboard section, indicating that the hull had broken into two parts. It was then possible to join the starboard section to its original position on the port side. This rearticulated model was then connected to the 3D image of the rebuilt ship in the Kyrenia Castle. So, each layer has been carefully connected to the next, so that the sequence of excavation can be seen and how the ship broke apart. It is an interesting exercise to select the 'Hull parts joined together' layer and view the ship from one end so that the keel is horizontal. This is the orientation of the ship when it was wrecked and had not broken into two parts.

If you now turn on the L0, you will see how the seabed has built up over time. Now turn on L6 and see how the ship collapsed.

The process of 3D CAD model of the Kyrenia ship cargo was only possible because the site had been so well photographed during the excavation stages and individual layers could reveal the three-dimensional position of items in the wreck. It should be noted that the amphorae were almost all the same Rhodian style. Fixing the CAD models in place was a complex process, requiring first that the 3D model was imported into Rhino, a CAD program, and an individual CAD model of each amphora was placed in alignment with amphorae as they appeared in each 3D model layer of the excavation. In many cases there are common amphora between the various layers which are then linked together to avoid duplication and

Figure 2: *A screenshot showing the present-day seabed with the level that the ship was at when it sank, showing how the seabed has built up over time from the 4th century BC.*

determine a fixed single location when duplication occurs. Thus, in Level 0 (L0) there were, say, 20 amphorae and in L1 there were 35 amphorae.
Some of the L0 amphorae were removed and did not exist in L1, some were common between the two layers, and some existed in L1, but not in L0. The common amphorae were thus linked the amphorae from the two layers together. This process was repeated through the layers thus linking all amphorae from the different layers together. The wireframe models were rendered and can be seen in the 'Amphorae models' layer of the Kyrenia Sketchfab webpage.

Additionally, the millstones were modelled in the same way, although in this case they were not all identical, but as each individual millstone had been measured and a CAD wireframe of the appropriate size had been made by Sheila Matthews for each millstone, the process was straightforward. These 3D models create new opportunities to re-examine the Kyrenia Ship.
Not only is it possible to make measurements on the underwater site, now long gone, but also to compare the shape of the hull on the seabed with the reconstructed hull, to see how much of the underwater site had been distorted over time.

In addition, the distribution of the cargo can be examined and reassessed as the original cargo plans were made from single photographs, that were then used to estimate the relationships between the amphorae and millstones. Accurate orthographic plans of the underwater hull structure can now be created from the 3D model. The relationship between the site when it was first found (L0) and the hull (L5) can tell us more about the change in the seabed since the third century BC. This work provides opportunity for a new understanding of the Kyrenia Ship. To view the model, visit the following page: **HIVE.curtin.edu.au/kyrenia**

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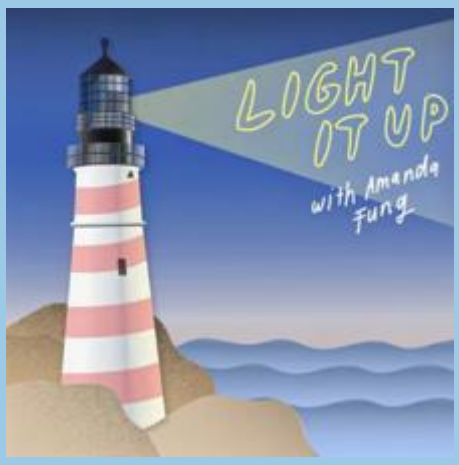

Podcaster Amanda Fung has released her fascinating new series on Australian lighthouses. The **Light It Up** podcast covers everything you want to know about Australian Lighthouses including what it was like to live at a lighthouse, shipwrecks, and harrowing tales. Amanda chats to AIMA members Cosmos Coroneos and Mike Nash in episodes 3.1 and 3.2, about maritime archaeology and shipwrecks. Check it out at www.lightituppodcast.com

AIMA Vice President Maddy McAllister has been interviewed recently on the **Big Deep** podcast, so keep an eye out for its release! They also have a great episode with maritime archaeologist Jim Delgado about what shipwrecks can tell us and all about his time exploring the Titanic. Head to www.bigdeep.com or visit their socials.