

The remote sensing survey off Malta – approaches to the mapping of an island’s territorial waters

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Abstract: The Malta Shipwreck Project, conducted by the University of Malta (UM), is aimed at surveying Malta’s territorial waters, in order to create a map of archaeological remains located on the seabed. Since 2018, this work has been executed using an Autonomous Underwater Vehicle (AUV). Its main payload is an Edgetech dual-frequency (600/1600 kHz) Side Scan Sonar. Due to the capabilities of this particular AUV (stability and battery autonomy), it is able to produce images that are of much higher definition than traditional towed systems. Another advantage is the doing away with long turns associated with working with a ‘towed fish’. In this paper the authors highlight the methodology established by the UM’s team, with the aim of being able to document a site in detail from the discovery until verification stages.

Keywords: AUV, survey, remote, Malta, sonar

1. Introduction

Since 2005, the University of Malta (UM) has been carrying out the Malta Shipwreck Survey Project (MSP). The main aim of this project is to survey all of Malta’s territorial waters, with the primary objective of creating an exhaustive archaeological map of the seabed. Such information facilitates the decision-making behind the management of Malta’s underwater cultural heritage (UCH). This paper provides an overview of the approaches utilised in the context of the MSP.

2. Method

The approach used is that of conducting a ‘blind’ survey that involves the mapping of previously unexplored areas using the 400 or 450 kHz frequency sonar. This phase entails the use of broad parameters when it comes to the range of the sonar, and generally sees the sonar being ‘flown’ relatively high off the seabed in order to avoid potential obstacles and hazards that may be unmarked on navigational charts. Data from this initial phase area analysed and a target list is drawn up. Selected targets are subsequently surveyed using different parameters, which include a higher frequency (900 kHz or higher), shorter ranges, and the sonar being ‘flown’ closer to the seabed. This permits the acquisition of high-quality sonar imagery of selected targets.

3. Early work

Since 2005, the primary survey tool has been side scan sonar technology, a well-known and established method for archaeological mapping at sea (Quinn 2011). The approach, however, has differed over the span of the last two decades. Initially, the UM used towed systems – a Klein 3900 (455/900 kHz) system and an Edgetech 4125 (400/900 kHz) system. Both were utilised with a DT Marine winch with 500 metres of armoured cable. The towed systems worked well in waters down to approximately 160 metres, however, such depths required over 400 metres of cable deployment.

The main disadvantages are:

- The limitation of reachable depths due to cable length;
- The time needed to implement turns between survey lines;
- The quality of data is impacted by vibration from the cable as well as surface weather conditions;
- The possibility of gaps in the data due to surface traffic and interference with navigation.

Between 2014 and 2017 the UM collaborated in a number of projects with Vulcan Inc. and Harvey Mudd College, both of which provided the use of an Automated Underwater Vehicle (AUV) with a payload that consisted of a side scan sonar. The advantages of using an AUV over a towed system include:

- Significant time gains due to quicker turns between lines;
- Cleaner datasets due to the absence of cable vibrations and the interference of surface weather conditions.
- The disadvantages include:
 - The cost of an AUV;
 - Inability to see data through a live-feed (as one does with a towed set-up).

Exposure to AUV's over this four-year period resulted in the UM's purchase of an AUV, made possible through SINTEGRAM.¹ Since 2018, the UM has operated a Teledyne Marine Gavia Offshore Surveyor (Fig. 1).



Fig. 1 Teledyne Gavia Offshore surveyor AUV (photo: Teledyne Marine Technologies Incorporated)

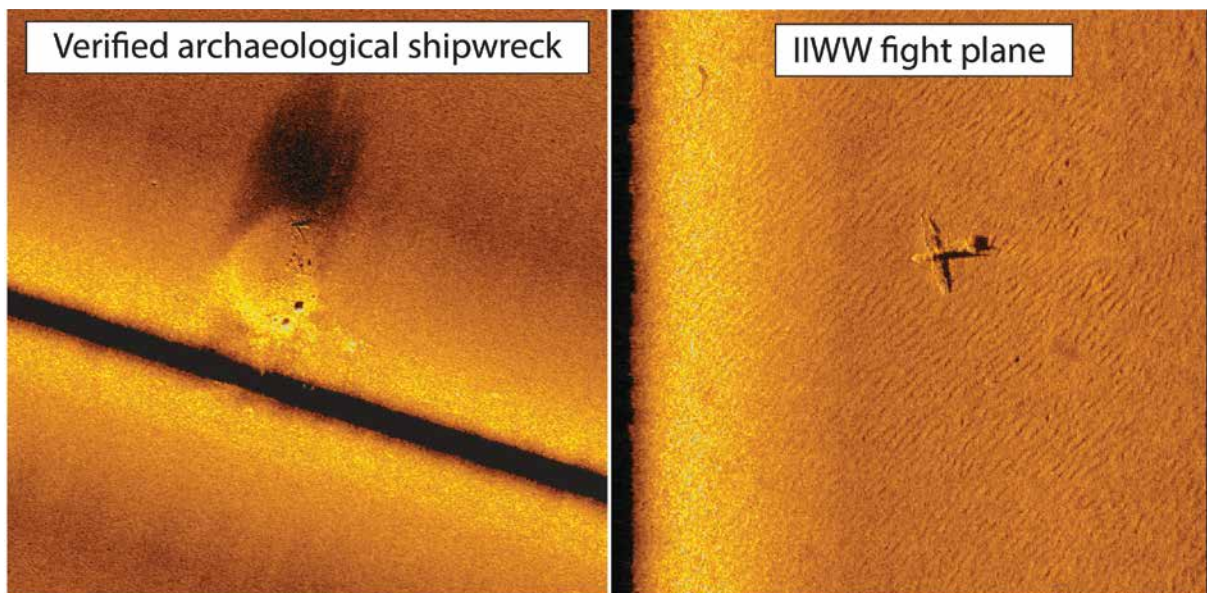


Fig. 2 Comparison between modern and ancient remains (Image: University of Malta)

¹ Operational Programme I - European Structural and Investment Funds 2014-2020 "Fostering a competitive and sustainable economy to meet our challenges" Project part-financed by the European Regional Development Fund - Co-financing rate: 80% European Union Funds, 20% National Funds.

The main payload is an Edgetech dual frequency (600/1600 kHz) side scan sonar, and a Blueview Multibeam MB2250 that is used for gap filling and backscatter.²

The autonomy of the AUV permits the team to plan missions of up to a maximum of eight hours, with surface management exclusively focused on tracking and being on standby in case of an emergency ascent and surfacing of the AUV. This differs substantially to surface tasks and responsibilities assigned whilst using a towed system.

The physical properties and capabilities of this particular AUV, which includes ease of operability, stability, and battery autonomy, has enabled the team to produce images that are of higher definition quality than traditional towed systems and in a shorter period of time. Therefore, the sonar imagery often permits the identification of targets without the necessity of deploying divers and/or remote operated vehicles (ROV), which is more common with modern wrecks, easily identifiable in comparison to ancient remains (Fig. 2).

This set-up allows the UM to survey an average of 5 km² on a typical working day. The number of days spent surveying depends mainly on budget, and on average the team achieves approximately 50 days at sea, surveying around 250 km² annually.

4. Using an AUV

An AUV is an autonomous robot that is used as a marine survey platform. For navigation purposes, the AUV integrates a Global Positioning System (GPS), navigation systems, and propulsion and direction modules, all of which are built into a robot vehicle. This is what enables the AUV to execute planned missions whilst simultaneously avoiding potential hazards and obstacles. A forward-looking sonar and a collision avoidance sonar ensure the AUV does not collide with submerged obstructions (cliffs, rocky outcrops, etc.). These systems allow the AUV to perform planned missions and to modify parameters when necessary. If the obstacle-avoidance is activated, the AUV is nevertheless able to return to its original survey mission after avoiding the obstacle.

Through the use of the dual frequency sonar integrated into the AUV, the UM is able to obtain geo-referenced 2D imagery of the seabed that provide highly accurate measurements of targets and features. The Blueview multibeam is used to capture data to fill the gap created by the nadir of the side scan sonar. The resulting 2D images allow for the extraction of information on aspects such as the geology of the area, the presence of cultural remains, or even fishing activities (Fig. 3).

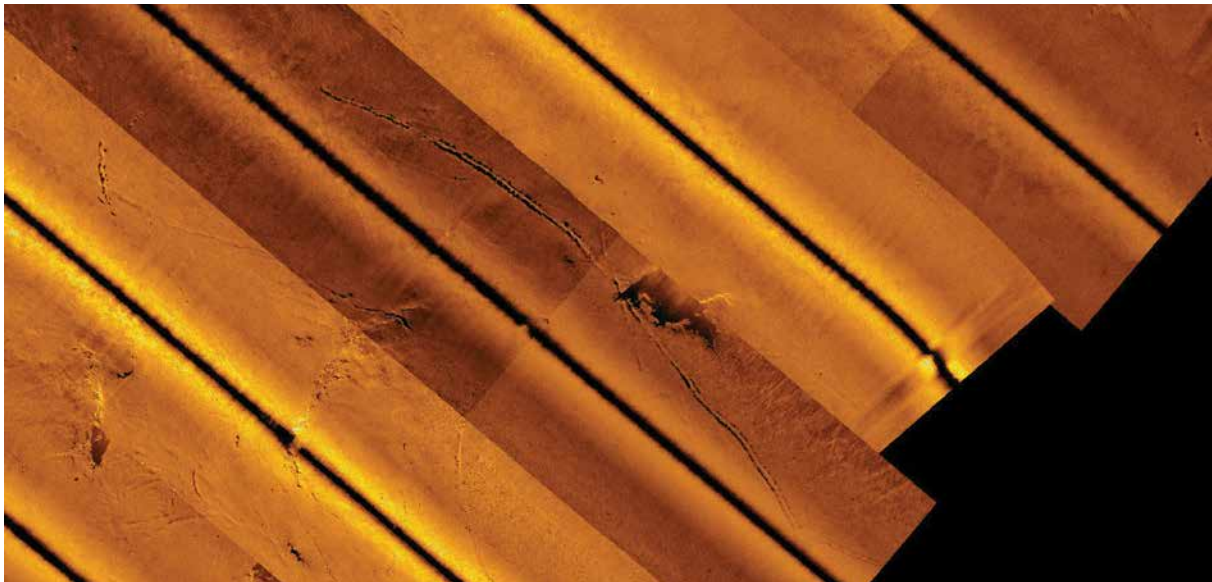


Fig. 3 Anchor marks over geology (image: University of Malta)

² <https://www.teledynemarine.com/en-us/products/Pages/gavia-mb-2250-gapfill-module.aspx> (accessed on April 7, 2022).

5. UM's methodology

The methodology employed by the UM follows a series of pre-defined steps that are aimed at locating, documenting, and identifying UCH with side scan sonar.

5.1. Selection of survey area

The selection of a survey area is based on work conducted in previous years, allowing the team to systematically continue its survey of Malta's territorial seabed. The location of potential areas of interest may, however, influence the choice of survey area.

5.2. Survey area

A 'blind survey' is a survey of a broad area of the seabed that is being captured for the first time. These surveys can be equated to field-walking techniques in terrestrial surveys. Data is captured systematically along pre-determined survey lines which result in the creation of a geo-referenced map revealing any potential cultural targets and anomalies for future research. The AUV is flown at a safe distance from the seabed in order to avoid any potential obstacles that may be unknown and unmarked on navigational charts. A height of between 10–13 m is maintained, allowing for safety considerations that do not interfere with the quality of data gathered (Fig. 4).

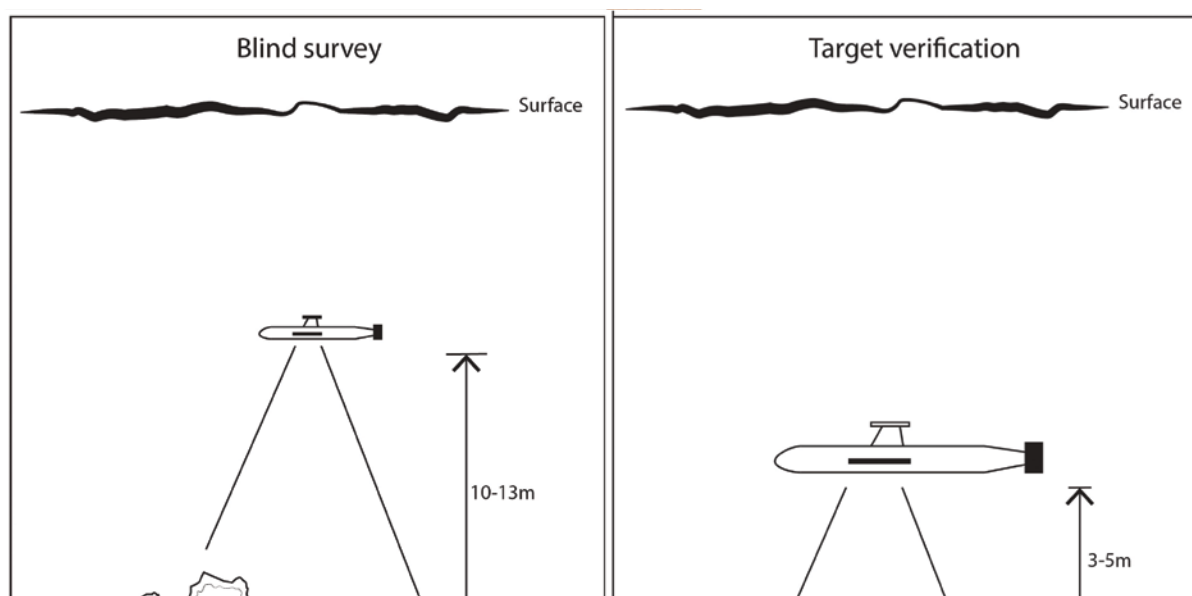


Fig. 4 Flying height of the AUV depending on the mission's configuration and objective (author: A. Bravo-Morata Rodríguez, University of Malta)

5.3. Data processing

Once the survey is complete, data processing commences. Whilst many software packages are available, the UM utilises Chesapeake SonarWiz. Using this software, data is displayed visually, geo-referenced, and able to provide measurements and other verifications.

Data processing involves the evaluation of all individual survey lines, where targets, or 'anomalies', such as intact aircrafts and modern shipwrecks are immediately recognizable. Other anomalies, such as ancient shipwrecks, may be unrecognizable or harder to interpret (Fig. 2). In these cases, it is often experience with interpreting sonar data that allows researchers to differentiate between archaeological potential and for instance modern structures or geological features. Elements that are evaluated include sudden changes in the topography of the sea or reflectivity of objects that differ from the natural environment. In those cases where anomalies are flagged as being potentially of interest, a second survey phase is considered and then planned.

5.4. Remote inspections of anomalies

The survey of specific targets in high definition involves the planning of survey lines using the low-resolution images of the target from the initial blind survey. Using this approach, the alignment or longitudinal axes of the target can be matched to the new survey, where the number of lines and height of the AUV depends on the size of the target. However, the primary aim is to acquire data from both sides as well as from various angles.

The AUV is flown at a closer level to the seabed since the composition of the seabed is no longer an unknown variable due to the previous blind survey data (Fig. 4). The UM team is now able to plan a more precise pattern to be followed by the AUV, including elements such as proximity of survey lines, how close the target is to the sonar transducer, and how much area needs to be covered. Using this set-up, high-resolution data can be captured (Fig 5).

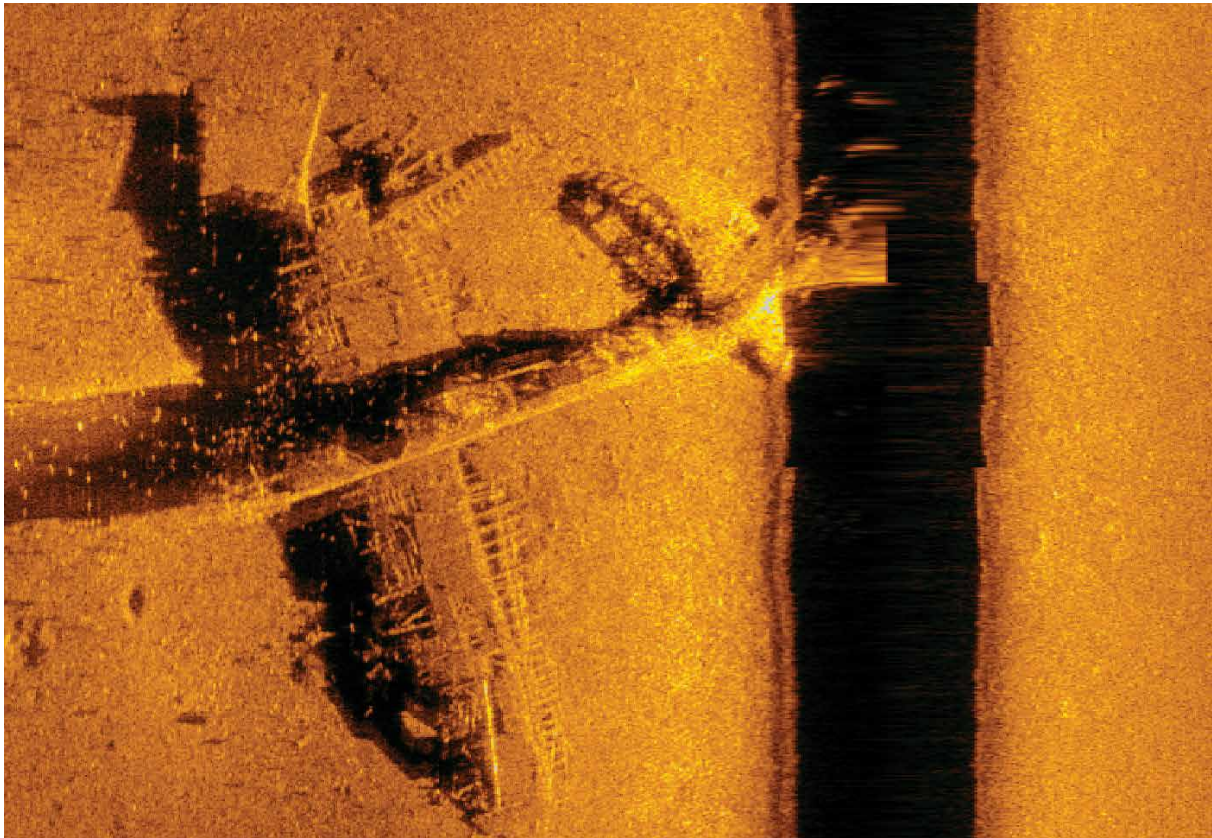


Fig. 5 Remains documented in high frequency (image: University of Malta)

5.5. Inspection of selected sites

Once these targeted surveys are carried out, a list of identifiable targets of potential archaeological interest is created. Depending on depth, size of target, budget, and equipment availability, decisions are made for further site inspection. For small sites up to a maximum depth of 120 m, the final inspection and documentation is carried out by technical divers (Fig. 6). This phase consists of gathering as much information as possible by documenting the site, confirming the importance of the target, and registering the site in the inventory of discovered sites.

Since 2015, the UM has been developing a 3D modelling process based on Structure from Motion (SfM) photogrammetry. Initially 4k video footage was used, however, today, full-frame mirrorless cameras that generate 24 megapixels still images are preferred. The cameras are coupled with powerful underwater lights that help balance colours in the images and provide light at depth. More recently, a diver propulsion vehicle (DPV) was adapted, where the lights and camera set-up are mounted onto the DPV. This configuration allows for the documentation of large and more complex wreck sites without compromising time spent at depth, often the most challenging and limiting factor. To-date the UM has recorded large wrecks up to a depth of 80 m. The resulting 3D models are used to study and identify wrecks, and are also used for public outreach purposes and publications.³

³ <https://underwatermalta.org/> (accessed on April 12, 2022).



Fig. 6 Diver documenting a site found with the AUV (photo: University of Malta)

6. Conclusion

Since 2005, the UM has surveyed approximately 30% of Malta's territorial seabed. Thousands of anthropic targets have been identified, a significant amount of which are of historic interest, including ancient wrecks, second world war ships, planes, submarines as well as conflict related items (UXO's). Of these, a considerable number have been documented in detail for further research and public outreach.

Utilising its current methodology, the UM is able to systematically survey approximately 150–250 km² annually. This approach will enable the entirety of Malta's seabed to be surveyed in a relatively short amount of time. The resulting geo-referenced data will enable the creation of dedicated database on Malta's UCH that informs on heritage management considerations.

The premise here is that effective management is based on knowledge-based decisions. Beyond the relevance to archaeological research and heritage management, is the relevance to other fields of research such as geology, oceanography, or fishing practices.

References

- Bowens, A. (ed.) 2009. *Underwater Archaeology: The NAS Guide to Principles and Practice*; Blackwell Publishing: Chichester, Archetype publications, London.
- Campbell, J. B. 2002. *Introduction to remote sensing*. New York, Guilford Press.
- Gambin, T., Hyttinen, K., Sausmekat, M., Wood, J. 2021. Making the Invisible Visible: Underwater Malta—A Virtual Museum for Submerged Cultural Heritage. *Remote Sensing* 13: 1558. <https://doi.org/10.3390/rs13081558>
- Gambin, T. 2014. Side Scan Sonar and the Management of Underwater Cultural Heritage. In *Future preparedness: thematic and spatial issues for the environment and sustainability*. Msida, Ed. University of Malta: 259–270.
- Gambin, T., Bravo-Morata Rodríguez, A., Sausmekat, M. 2021. From Discovery to Public Consumption: The process of Mapping and Evaluating Underwater Cultural Heritage in Malta. *Heritage* 4: 2732–2745.
- Kapetanović, N., Vasiljević, A., Nađ, Đ., Zubčić, K., Mišković, N. 2020. Marine Robots Mapping the Present and the Past: Unravelling the Secrets of the Deep. *Remote Sensing* 12, 3902. <https://doi.org/10.3390/rs12233902>
- Quinn, R. 2013. Acoustic Remote Sensing in Maritime Archaeology. In A. Catsambis, B. Ford, D. L. Hamilton (eds), *The Oxford Handbook of Maritime Archaeology*. New York, Oxford University Press: 68–89.
- Søreide, F. 2011. *Ships from the Depths: Deepwater Archaeology*. College Station, Texas A&M University Press.
- USGS. What is remote sensing and what is it used for? Available online: https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used?qt-news_science_products=0#qt-news_science_products (accessed on July 21, 2021).
- UNESCO 2001. *Convention on the Protection of the Underwater Cultural Heritage*, <https://unesdoc.unesco.org/ark:/48223/pf0000126065> (accessed on March 15, 2024).