



HM Submarine A7

An Archaeological Assessment

A report on the results of the A7 Project 2014

Peter Holt



Prepared by:
Peter Holt BEng., Project Manager, The SHIPS Project



Published by:
The SHIPS Project
c/o 3H Consulting Ltd., 6 Honcray, Plymouth, PL9 7RP, UK
pete@3HConsulting.com

Prepared for:
British Sub Aqua Club



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Cover image: Conning tower, periscope and foredeck of A7 in 2014 (Ships Project)

Title	HM Submarine A7 - An Archaeological Assessment
Author(s)	Peter Holt, Mike Williams, Mallory Haas, Robert Stone, Keith Hiscock
Origination Date	01 December 2014
Reviser(s)	Peter Holt, Julie Williams, Steve Fletcher, Peter Bernardes, Allen Murray
Version Date	11 December 2015
Version	1.0
Status	Release
Circulation	BSAC
Subject	Report on the archaeological assessment of HM Submarine A7 in 2014
Coverage	Country – UK, Period - 20 th C
Publisher	ProMare, The SHIPS Project
Copyright	ProMare
Language	English
Resource Type	Document
Format	MS Word, Portable Document Format (PDF)
File Name	A7_Project_Report.doc, .pdf

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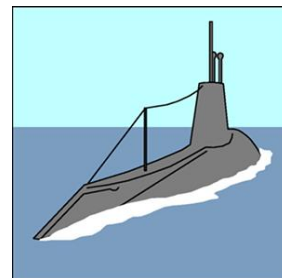
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1. Introduction

1.1. Summary

This is the report on the project to investigate the Royal Navy submarine HMS/M A7 lost in Whitsand Bay, Cornwall, in 1914. The project is a wide-ranging study into the development, the loss and the current condition of the submarine.



Prior to its designation in 2001 the A7 was rarely visited by sports divers due to the difficulty of locating the small submarine in deep water and the nearby presence of more accessible shipwrecks. Consequently little is known of the wreck site, its environment and how the submarine has deteriorated over time. Similarly the history of the vessel and its loss has received scant attention either in the historical or educational record, either locally or nationally. Since its designation as a Controlled Site no monitoring has been conducted on the site and since no baseline survey was ever conducted it is impossible to tell whether or at what time any unauthorised physical interference has occurred. There was much that could be learned so in 2013 the A7 Project was created by the SHIPS Project (Shipwrecks and History in Plymouth Sound) team, which comprises divers from several local BSAC dive clubs, and further afield, principally Pilgrims SAC, Plymouth Sound BSAC, Totnes SAC and Oxford University Underwater Explorer's Group (OUUEG), to coincide with the 100th anniversary of the A7's loss in 1914.

1.2. About the SHIPS Project

The study of HMS/M A7 forms part a larger maritime history and archaeology project that is already running in the Plymouth area. The SHIPS Project (Shipwrecks and History in Plymouth Sound) was started in 2009 and has been developed by the U.S. charity research foundation ProMare to promote and investigate the maritime history of Plymouth and its estuaries.



A number of projects have been started under the umbrella of the SHIPS Project. These smaller projects are diving projects where shipwreck sites are investigated by divers, they are recording projects that gather information, projects run by students at the University of Plymouth and research projects recording information in books and archives.

The projects are run by different people or groups and are co-ordinated by the SHIPS Project. The Project web site is used to publish the results of the smaller projects, to help exchange information between different groups and to help find resources to get each project completed.

Fieldwork Projects

- The [Jennycliff Wall Project](#): Survey, mapping and identification of the Jennycliff Wall
- The [Liberty70 Project](#) : Recording and mapping the [James Eagan Layne](#)
- Investigation of Royal Navy 36 gun frigate [Amethyst](#)
- Identifying geophysical targets in and around Plymouth Sound (with Plymouth University)
- Survey the remains of the [Poulmic](#) (for the NAS Adopt-a-Wreck scheme)
- Locating and recording heritage on the foreshore of Plymouth Sound and its Estuaries
- The Roman River Crossing Project, near Calstock, Cornwall [COMPLETED]

Fieldwork is undertaken with the help of volunteers from local BSAC dive clubs, in addition to those who are part of the SHIPS team, students from the universities at Plymouth, Bristol and Oxford and Nautical Archaeology Society members.

Collaboration Projects

- Geophysical survey of the [Coronation \(1691\)](#) off Penlee Point (with the Coronation Project team)
- Recording the [SS Rosehill](#) in Whitsand Bay (with Totnes BSAC for the NAS Adopt-a-Wreck scheme)
- Recording of the [Mewstone Cannon Site](#) (with Plymouth Diving Centre for NAS Adopt-a-Wreck scheme)
- Survey of the yacht [Glen Strathallan](#) (with [Aquanauts](#) for the NAS Adopt-a-Wreck scheme)

Recording Projects

- 'Stray Finds' - Recording, photographing and drawing objects recovered from Plymouth Sound, with the information published on the [Finds](#) pages
- Mount Edgcumbe House Museum - *Metta Catharina* Exhibit - Supporting the creation and development of a museum exhibition and archive for the [Metta Catharina](#) wreck
- The Guns of Plymouth - Recording the big guns and cannons in and around Plymouth Sound
- Anchors - Recording anchors for the [BigAnchorProject](#)
- Adopting Archives - Collecting unwanted research papers, documents and photographs about sites in Plymouth and elsewhere. The archives are scanned then the original documents and photographs are deposited with an appropriate museum or institution.

The SHIPS Project is also involved in various university research and technology projects with Plymouth University, the University of Birmingham and the University of Bristol

The SHIPS Project web site can be found at: www.promare.co.uk/ships.

1.3. Funding

The SHIPS Project was funded by ProMare, a US research foundation. Established in 2001 to promote marine research and exploration throughout the world, ProMare is a non-profit corporation and public charity. Their team of experienced archaeologists and marine professionals execute a variety of research projects all over the world, independently and with academic, corporate and governmental organizations that are designed to advance man's knowledge of history and science. ProMare UK is an affiliate member of the Council for British Archaeology (CBA) and a member of the Nautical Archaeology Society (NAS). The ProMare web site can be found at www.promare.org.

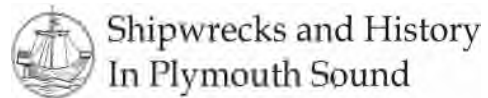


Additional support was provided by the various project partners listed in Sections 1.4 and 1.5, in the form of the loan or discounting of equipment, the provision of air fills and boat time for diving operations, of boat time and equipment for geophysical surveys, and of time and equipment involved in the preparation of the virtual reality modelling, together with untold hours of volunteer time by divers, researchers and various expert advisors.

1.4. A7 Project partners

Partners of the A7 Project include:

- Plymouth University, School of Marine Science and Engineering
- Plymouth University, School of Geography, Earth and Environmental Sciences
- University of Birmingham, School of Electronic, Electrical and Computer Engineering (Human Interface Technologies Team)
- Nautical Archaeology Society, 'Lost Beneath the Waves' Project
- Swathe Services Ltd., Truro
- MSubs Ltd., Plymouth
- 3H Consulting Ltd., Plymouth
- In Deep Dive Centre, Plymouth
- Orcalight Ltd.
- Cornwall and Isles of Scilly Maritime Archaeology Society
- Oxford University Underwater Explorers Group
- Pilgrims Sub-aqua Club
- Plymouth Sound British Sub-aqua Club
- Totnes Sub-aqua Club



1.5. The Dive Team

The Project involved a total of 14 divers and a further 20 or so for the background research, geophysics and management. As part of the build-up to the project dives, team members were given additional training as required, with BSAC Nitrox workshops, boathandling courses and diver coxswain assessments all being run.

The dive team for the A7 Project were:

Peter Bernardes, Kevin Camidge, April Cunningham, Steve Fletcher, Mallory Haas, Peter Holt, Ben Kellett, Innes McCartney, Jose Quijano, Allen Murray, David Pelly, Mark Pearce, Mark Prior, John Reynolds



Peter Holt is the leader of the A7 Project and also directs the SHIPS Project for US research foundation ProMare and he is also a visiting research fellow at Plymouth University. He has 20 years experience in the offshore industry as Systems Architect for Sonardyne International Ltd., designing underwater positioning systems for ROVs and divers. He is also runs 3H Consulting Ltd., a maritime archaeology consultancy company with particular expertise in surveying, shipwreck recording and geophysics, and developed the *Site Recorder* software used on maritime archaeology projects all over the world. Peter has managed a number of archaeology projects in the UK, was survey manager for the recent excavations on the *Mary Rose* and has participated in excavations and survey work on more than 30 sites in the UK, USA, Turkey, South Africa, the Caribbean, Mauritius and Oman. He has written a number of papers on surveying, geophysics and data management and has contributed to a number of books. He is a NAS Senior Tutor and regional co-ordinator for NAS South West and holds a BSAC Advanced Diver qualification. Peter is a member of Pilgrims SAC (BSAC branch 1854).

Peter Bernardes is a BSAC First Class Diver and National Instructor, with 45 years' experience instructing all levels of sports diving, 15 years instructing on BSAC instructor courses and 40 years skippering various small diving boats, RIBs etc. He is also a commercial diving instructor and an HSE First Aid Instructor/Examiner. Asked for his thoughts on the project peter commented that "it was very good to work on a worthwhile project, with the chance to see the complete process of the research, planning, mobilising, diving and an excellent report at the end" reflecting the fact that it is all too easy for fieldwork to be completed but the project report to remain unfinished. Peter is a member of Pilgrims SAC.

Stephen Fletcher is a BSAC Dive Leader who has completed about 600 dives. He is also a member of the Nautical Archaeology Society and has the NAS part1 qualification and undertaken a number of

part 3 courses. He has been a member of the Plymouth SHIPS project for the last 5 years searching for and surveying wrecks and artefacts in the Plymouth area. He has dived on wrecks all over the world.

Stephen's main role on the A7 project was to video the submarine on each dive so that we could carefully analyse the wreck after the dive, looking for areas we wanted to look at on further dives and enabling us to produce in depth drawings of the wreck. Stephen was particularly interested in looking into the possible causes of the sinking of HMS A7 and working with Peter Holt they were able to come to a reasonable scenario after looking into the events leading up to the sinking.

"It was a huge privilege to dive on this protected wreck and to look into the reasons why she sank. Luckily the viz was half decent and there was little or no current on most of the dives so we were able to perform our measuring and videoing without any real problems. At 40m you don't have a lot of time to hang around when you have a specific task to perform, in my case, providing decent videos of the wreck, but on every dive I couldn't stop thinking about the entombed crew, what they must have gone through, how they would of worked hard to release the boat from the silt she was stuck in before eventually running out of air, a sobering thought, god bless them. Hopefully people will respect the controlled status of this site and not dive on it without the permission of the MOD".

Stephen is a member of Oxford University Underwater Explorer's Group (BSAC branch 9205).

Mallory Haas began her career underwater 6 years ago by following archaeology in to the Great Lakes. She is an historical archaeologist working in the Great Lakes region for CLUE in Lake Erie, and for The SHIPS Project in the UK. She has been working in archaeology for 9 years, getting her feet dirty with prehistoric terrestrial archaeology in the mid-western states. Mallory has been working as the SHIPS archaeologist since 2013, conducting oral histories with early divers and researching early Royal Navy ceramics. Mallory has helped to coordinate awareness of shipwrecks in the Great Lakes as well as working with BSAC clubs and divers in Plymouth to better preserve their submerged history.

As SHIPS Project Archaeologist Mallory was involved with the A7 Project as a member of the main dive team, a safety diver, one of the Diver Coxswains, videographer of team's survey and detailed recording of A7's in situ. She coordinated the outreach with the family members of the lost crew of A7, and conducted interviews with the family members, as well with the first recreational divers that relocated A7, prior to its designation. She is also a co-author on the BAR academic publication of the archaeological assessment. Mallory is a PADI Rescue Diver and is a member of Pilgrims SAC.

David Pelly is a BSAC Advanced Diver and HSE Part 2 Commercial Diver and runs a local dive shop, Sandford and Down. David has been diving for 40 years and brought his experience with subsea NDT equipment to the project. David is a member of Plymouth Sound BSAC (BSAC branch 164).

April Cunningham is a marina manager when not part of the SHIPs Project, but spent the summer in Plymouth diving on the A7 and other sites when conditions didn't allow the A7 site to be visited. April was a member of the main dive team and assisted with the detailed recording of the site. April is currently a member of BSAC Direct.

Jose Quijano was another member of the SHIPs Project who spent the summer diving on the A7 and assisting with the detailed recording of the site. Jose is a PADI Rescue Diver and is also a member of OUUEG.

Allen Murray is a First Class Diver and Advanced Instructor with over 20 years experience of diving in and around Plymouth Sound. Allen brought technical diving expertise to the dive team and helped to develop the decompression schedules and diving protocols for the A7 Project. Allen is a Seasearch trained diver and a NAS Senior Tutor and undertook marine biological recording on the site as well as acting as a safety diver and diver coxswain.

“It wasn’t until I got involved with the A7 Project and started looking at the research that the team was pulling together that I realised that I might actually have a family connection to one of the crew who died on the boat. My grandmother on my mother’s side was a Venning and the family tree shows them as coming from South-east Cornwall, and the Engine Room Artificer on the A7 was a Richard Venning from Devonport. I’m still trying to establish a connection, but it certainly made the project much more personal for me.”

Allen is Diving Officer of Pilgrims SAC and is also a member of Totnes SAC (BSAC branch 598) and Wellington & Taunton SAC (BSAC branch 10).

1.6. Acknowledgements

The A7 Project dives would not have happened without the help and support of many other people, including:

- Dive support was courtesy of Jim Kellett and Sean McTierney at In Deep Dive Centre
- Dive planning was courtesy of Allen Murray
- Additional archival research was undertaken by Nicola Fyfe and Adam Bush
- The virtual reality model was developed by Prof. R. Stone, Dr R. Guest and Hossein Moghimi at the University of Birmingham
- Marine biology survey analysis was thanks to Dr Keith Hiscock
- Legal advice relating to permitting was provided by Dr Mike Williams
- The marine geophysical survey was completed by Mawgan Doble and Gwyn Jones at Plymouth University

Our thanks go to the many people who have provided information and supported the A7 Project, including:

Jenny Ashdown and the team at Cygnus Instruments, Adam Bush, Mark Beattie-Edwards at the Nautical Archaeology Society, Jeff Crawford, Mark Dunkley at English Heritage, Tony Hillgrove, Mavis Jones, Julie Lawrence, Andy Liddell at MOD Salvage & Marine Operations, Shane Newman at Orcalight Ltd., Tristan Nichols, Innes McCartney, Peter Mitchell, David Peake, Mark Prior, Laura Quigley, Bob Reid, Dominic Russell, Josie Scobling, Margaret Screech, John Shelley, Peter Sieniewicz, David Smith and Ken Snailham, Peter Washburn and James Williams at Swathe Services Ltd.

2. Executive summary

The A7 Project is an investigation of the early Royal Navy submarine HMS/M A7 lost with all hands during a training exercise in Whitsand Bay, Cornwall, on 16th January 1914. The project started in October 2013 with a proposal put to the UK Ministry of Defence (MoD) to undertake an archaeological investigation of the submarine. The A7 is a Controlled site under the Protection of Military Remains Act 1986 and access to the site is restricted. The project proposal was accepted by the MoD and a license to visit the site was issued for a two month fieldwork season in the summer of 2014.

The aims and objectives of the project have been completed. The historical research produced a detailed narrative on the origins and development of the A class submarines of which A7 is one of the thirteen that were built. The research also collated information about the last crew of the A7 as the submarine is their last resting place. The site was investigated by remote sensing then a detailed condition assessment of the outside of the submarine was completed by divers; this also included ultrasonic hull thickness measurements used to investigate corrosion. The documentary research and the results of the condition assessment were used to formulate a new theory about why the submarine was lost. The story of this forgotten submarine has been the subject of media attention, has been promoted locally and nationally, at international conferences, on social media and is the subject of a number of publications. A digital archive of material has been created about the life and loss of this submarine which can now be shared with a number of organisations and institutions.

The A7 submarine is the last complete example of the first type of submarine developed by the Royal Navy. The class were developed rapidly and in secret by a Royal Navy officer with no previous experience in submarines, yet what was produced was the forerunner of the British submarines that fought in WWI. As such this contribution should be recognised and the name of Reginald Bacon R.N. be added to the list of the great submarine designers.

The remains of the A7 submarine are still largely intact so the undocumented secrets of how this submarine was constructed and operated still remain a mystery. But the hull is corroding and this project suggests that a conservative estimate for the survival of the submarine to be between 40 to 50 years.

3. Glossary

Term	Description
Ballast tank	A steel tank in the submarine that can be filled with air or water and used to alter the buoyancy
Beam	The width of the submarine
Binnacle	A mounting for the compass used for steering
Bitt	A strong point on the hull used for attaching mooring ropes
Bow shutter	A curved steel fairing that covers the torpedo tube Cap
Cap	A waterproof hatch at the front of the torpedo tube
Casing	A thin metal structure fitted on top or around a Pressure Hull
CinC	Commander in Chief
Concretion	A hard mix of iron corrosion products, dead marine life and seabed material
Conning tower	A tall tower fitted on top of a submarine
Cowl	A curved funnel fitted to the top of a Ventilator
Cutwater	A hollow metal structure fitted on top of the bow of a submarine
Displacement	The mass of water displaced by the submarine in water
Dodger	A canvas sheet used to protect the crew from spray
Fin	The conning tower plus the thin steel fairing around it
GNSS	Global Navigation Satellite System, Global Positioning System, GPS
h.p.	Horsepower, a unit of power. 1 horsepower = 745.7 Watts
Hawser	A thick rope, in this case made of steel
Hydroplane	A horizontal rudder used to control the diving depth of the submarine
Hz	Hertz, a unit of frequency
Lap	The overlap between hull Strakes
Light ballast	With all ballast tanks empty of water and full of air
Lighter	A dumb barge that has no engine
MOD	Ministry of Defence
Mooring pipe	A reinforced pipe that is used to pass a mooring rope from inside to outside of the hull
Multibeam Echo Sounder (MBES)	A sonar instrument used to make very high resolution 3D images of the seabed
Pressure hull	The part of the submarine's hull containing the machinery and crew
Receiver of Wreck	The authority responsible for management of items recovered from shipwrecks
Samson post	A strong vertical pillar fitted to the hull and used for attaching towing lines
Scour	A depression in the seabed created by water currents around an object
Scuttle	A window
Silt	Light granular sediment less coarse than fine sand
Stanchion	A vertical post used to hold up a safety line or a Dodger
Strake	A strip of hull material, in this case a steel plate
Telegraph	A mechanical device for communicating over a distance or through a barrier
Trimmed down	Of a submarine; with all ballast tanks full of water
Universal joint	A mechanical joint for transferring rotation across an angle
UT	Ultrasonic Thickness
Ventilator	A pipe for allowing air into or out of a space
Wire sweep	A wire Hawser dragged across the seabed and used to snag wrecks

4. Aims and objectives

Aim 1 - Document the story of the loss of the submarine

The story of the loss of HM Submarine A7 will be researched and documented, including the production of a bibliography of historical and literature sources.

Aim 2 - Undertake a non-intrusive detailed site assessment

The current condition of the A7 is unknown as it has not been seen by divers since 2001. The area in which the submarine lies will be mapped in detail using marine geophysical survey methods to confirm the general condition of the wreck.

Aim 3 - Undertake a non-intrusive condition assessment of the wreck

To determine the current condition of the wreck the hull will be photographed and recorded in detail using divers. Ultrasonic thickness measurements will be made of the hull plates to determine the degree of corrosion.

Aim 4 - Raise public awareness about the submarine and its loss

The story of the sinking of submarine A7 was well known at the time of loss but it has been largely forgotten. The submarine can be used as a platform for raising awareness of its own story, the contribution made by such boats and their crews to the war effort and to maritime cultural heritage in general.

Aim 5 - Investigate the cause of the loss of the submarine

The project will collate all information relating to the sinking and may be able to help formulate a new hypothesis about how and why submarine A7 was lost.

Aim 6 - Create an archive of information about the submarine

A documentary archive about the submarine will be created and delivered to appropriate depositories, as advised by MOD and English Heritage.

5. Scope

This section describes the scope of the project, what will be included as well as what is potentially relevant but will not be included in the project.

- Document the story of the loss of submarine A7
- Includes a summary of the basic construction history
- Includes a narrative of the loss of the submarine and attempted salvage
- Includes events relating to the site from abandonment to the present day
- Does not include a service history for the submarine

- Undertake a detailed site investigation
- Includes the seabed in area 500m around the wreck
- Does not include a sub-seabed investigation

- Undertake a condition assessment of the wreck
- Includes a detailed investigation of the visible hull
- Includes an area of the seabed within 20m of the hull
- Does not include any part of the buried hull

- Does not include the inside of the hull
- Raise public awareness about the A7 and its loss
- Includes the story of the A7, her loss and her role as a memorial to her last crew and as part of the nation's maritime heritage
- Investigate the cause of the loss of the submarine
- Includes an analysis based on any information collected and collated during the project which may be relevant to the cause of the loss.



Figure 1: Submarines alongside deport ship HMS Forth in the Hamoaze, with A7 in the centre

6. Background

6.1. Location

HM Submarine A7 lies to the west of Plymouth; offshore from Whitsand Bay on the south Cornish coast (Fig. 2). The wreck is at position:

50° 18.527 N 004° 18.008 W (WGS84)

The site is 17km (9.2 nautical miles) from Sutton Harbour in Plymouth.

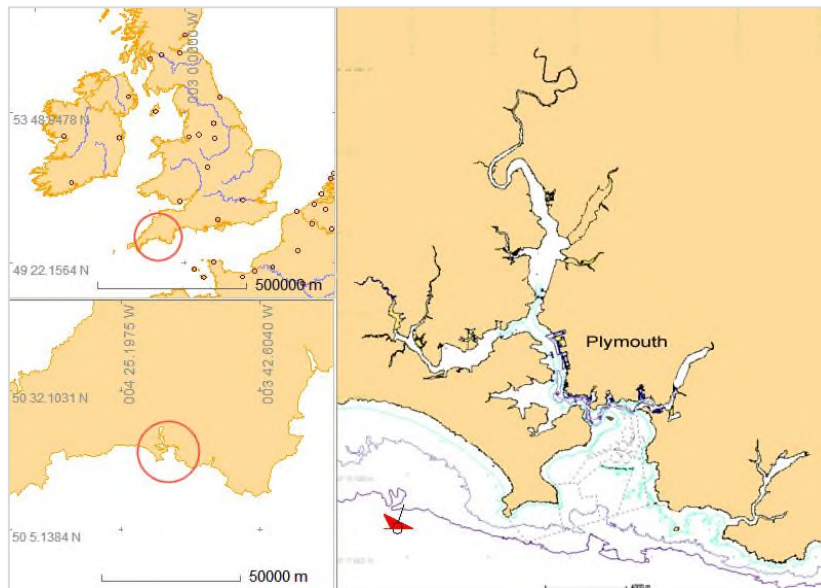


Figure 2: Site Location with A7 position shown in red

Whitsand Bay is an extensively used area including recreational diving, fisheries and shell-fisheries. Abandoned trawl nets may be present on the site.

Other wrecks in the area include the WW1 collier S.S. *Rosehill* 2.4km to the north, the frigate HMS *Scylla* and Liberty ship S.S. *James Eagan Layne* 4km to the north east and the 'Rame barge' 3.8km to the east (Fig. 3). These shipwrecks are also being investigated by the SHIPS Project.

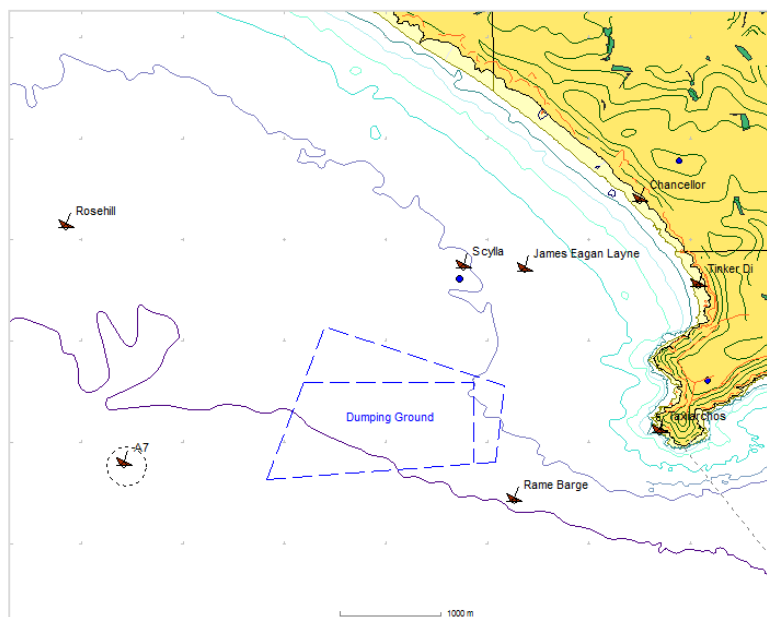


Figure 3: Location of A7 in Whitsand Bay, the dumping ground and nearby wrecks

6.2. Royal Navy submarine development

The A7 is a Royal Navy (RN) A-Class coastal submarine; her keel was laid down in September 1903 and the submarine was completed in April 1905 as part of the Group II programme that included submarines A5 to A13. Like all her class, she was built by Vickers, Sons & Maxim Ltd. in Barrow-In-Furness, England, as a joint development between the company and the Admiralty; the technology was new and the A class were the first British designed submarines in the Royal Navy¹.



Figure 4: A class submarines with A7 in the background (RNSM)

In December 1900 an agreement had been reached for Vickers to construct the first submarines for the Royal Navy²; five Holland class boats to be built under license from the Electric Boat Company in the USA. The new submarines were based on John Holland's successful design for the submarine Holland VI. One of the most significant events in the development of Royal Navy submarines occurred shortly after the Vickers contract was signed; the appointment of Captain Reginald Bacon to the newly-created post of Inspecting Captain of Submarine Boats. The development of submarines for the Royal Navy was a series of extremely rapid and overlapping design improvements which were both poorly documented and outside of mainstream development so the sequence of events is not entirely clear. But one of the opening gambits was Captain Bacon immediately recognising that the 63ft. long, 104 ton Holland submarines were too small and too unseaworthy to be useful in the open sea or in battle. Bacon attempted to get their construction stopped³ but failed; instead he somehow managed to convince the Admiralty to purchase an additional, larger vessel from Vickers that was based on his own design, this sixth boat was to become HMS/M A1.

For the sixth boat Bacon set about designing something that could be used in the open sea. A1 was built as a rapid proof-of-concept prototype to see if a boat 100ft long could be handled underwater, if the boat was seaworthy, if a suitable petrol engine could be constructed, and if the big engine could be operated in a confined space without suffocating the crew⁴. With A1 being very much a prototype, the first batch of true A class submarines A2-A4 were launched in June and July 1904;

these included a significant number of design improvements over the original A1 including a modified hull shape, a taller conning tower, twin torpedo tubes and an improved petrol engine⁵. The third batch of A class boats, known as Group II and including submarines A5 to A12, were launched between February and September 1905. This new batch contained yet more improvements, with a better engine, a new layout for the ballast tanks, a different arrangement for the engine exhaust and a taller conning tower. A7 was laid down at Vickers yard on 1st September 1903 as yard number 305, launched on 23 January 1905 and completed on 13th April that same year with pennant number I.17. The A7 was 30.2m (99ft) long with a beam of 3.9m (12ft 9in) and a depth of 3m (10ft) and displaced 190 tons on the surface and 205.5 tons submerged. On the surface she was powered by the latest version of the Wolseley petrol engine and submerged she was powered by a 150 h.p. electric motor fed by a large bank of batteries. The petrol engine could push her along at 12 knots (22.2 kmh⁻¹) on the surface and give her a range of 500 nautical miles but submerged she could only achieve 8 knots and a range of 30 miles. The A7 was armed with two 18in bow mounted torpedo tubes and she had a crew of 11. The last of the class was A13 launched in 1905 but not commissioned until 1908; A13 was notable as she was the first Royal Navy submarine to be fitted with a diesel engine.

This new design of A class submarine was a considerable improvement on the Holland boats, primarily because they could be kept at the correct depth even at moderate speeds, whereas the Hollands had to be trimmed very carefully and kept at full speed when manoeuvred under the water⁶. Yet the A class were still limited in endurance, space was limited and although better than the Hollands, they were not good sea boats.

Early in 1905, the A7 became the first Royal Navy submarine to be fitted with experimental hydroplanes on the forward side of her conning tower. Each plane was ten square feet in area actuated from the control room by a rod connected to gearing on the plane shaft. Initially this class of submarine was dived while stationary in the water but later it was found that they could submerge while underway and the conning tower hydroplanes were added to see if this would assist in diving. The experiments were not a success and the hydroplanes were later removed⁷.

By 1914 when the A7 was lost, the tiny A class submarines were obsolete and those that remained in service had been reduced to a training role. In September 1910 the Holland boats and A1 were taken out of service⁸ and the remainder of the first batch A2, A3 and A4 were taken out of service in March 1912. Submarines A5 and A6 were taken out of service in April 1916 while A8 to A13 survived in service until August that year; they were scrapped in 1920 with A2 surviving until 1925 before the same fate overtook her⁹.

The information available about early RN submarines is both scattered and patchy. Detailed information was not published at the time they were in service as the designs were kept secret¹⁰ and the significant features were covered by secret patents. The development of submarines was swift with subsequent designs overlapping so previous models were almost immediately made obsolete and thus not worthy of documenting further. The speed of development was phenomenal: there was a span of just 10 years between the launch of the first RN submarine *Holland No. 1* and the launch of *E1*, the first of the truly functional seagoing submarines that fought in WW1.

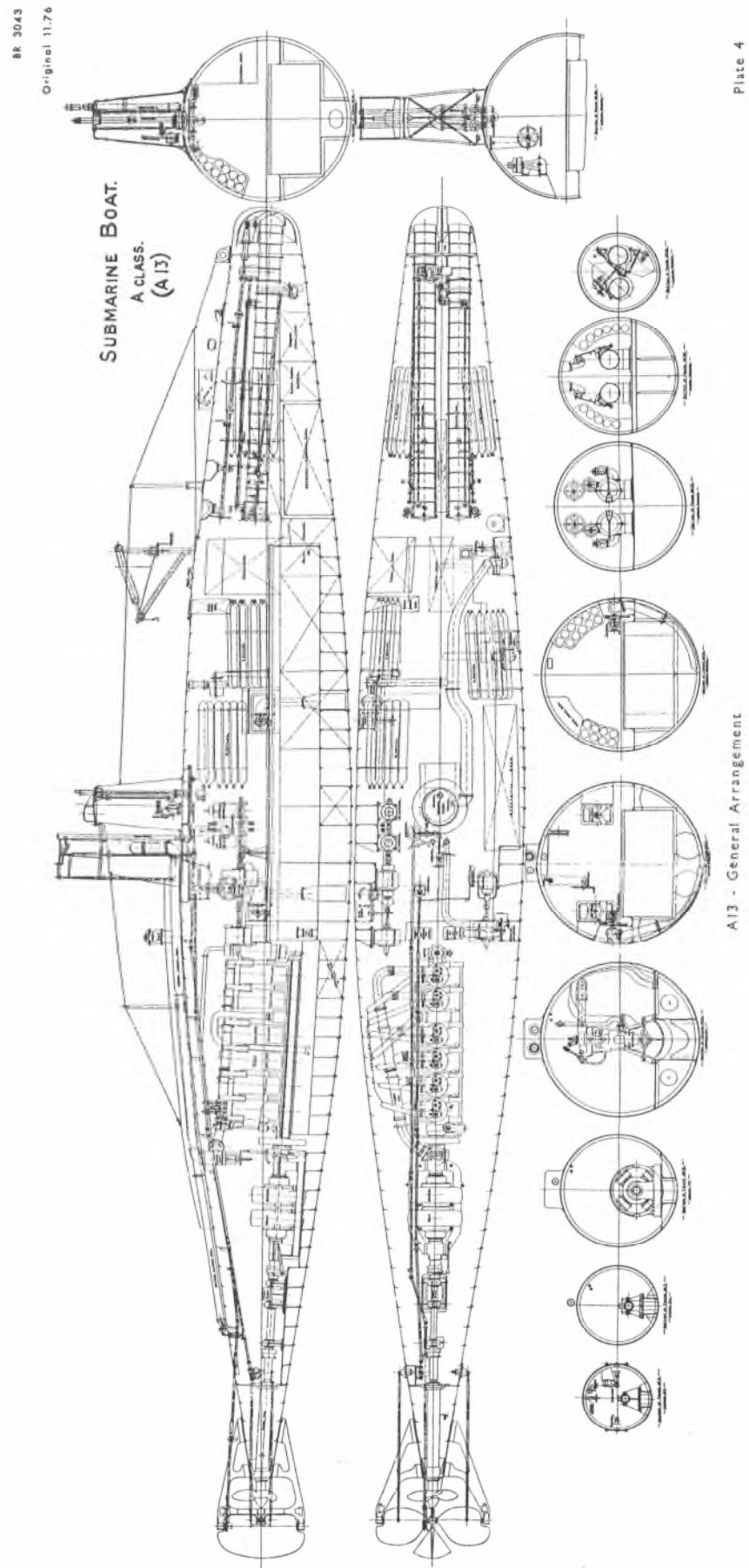


Figure 5: Internal general arrangement plan for submarine A13 with its experimental diesel engine (Harrison, 1979)

6.3. Submarine losses

The development of early submarines is as often marked by tragedy as by significant successes. Between the launch of *Holland No. 1* in 1901 and the start of World War 1 in August 1914 there were 68 serious accidents in submarines in various navies, including 23 collisions, 7 battery (hydrogen gas) explosions, 12 gasoline explosions and 13 sinkings due to improperly shut hull openings. Technical developments and improved training reduced the risks considerably but submarines at this time were anything but safe. The A Class boats suffered a number of catastrophes:

- The A1 was the first Royal Navy submarine to be lost in peace or war having been rammed and sunk by the SS *Berwick Castle* on 18 March 1904. She was salvaged and re-commissioned but sank again on trials in August 1911
- Submarine A2 foundered in 1920 after grounding in Portsmouth Harbour
- A3 sank off the Isle of Wight after colliding with HMS *Hazard* in 1912
- A4 sank after an explosion on board whilst under tow
- A petrol explosion on board A6 in 1905 killed six of her crew
- A8 sank in Plymouth Sound after water entered the main hatch whilst she was underway at speed in a swell
- A10 sank in 1917 alongside in Ardrossan but sustained no casualties

The list of incidents suggests that this class of submarine were particularly hazardous but this impression has to be tempered with the fact that the A class submarines were in use on average three times per week, so the number of incidents compared to the number of routine dives is very small. Up to the time of her loss, the sinking of A7 was the only accident to occur to an RN submarine while it was diving, other than due to a collision, in 12 years of submarine operations.

Submarine losses 1904-1914

1904	March 18, A1 sunk by a liner off the Isle of Wight, 11 lost
1904	June 20, Russian <i>Delphin</i> sunk at Cronstadt, 26 lost
1905	Feb 16, Gasoline explosion on the A5, 6 killed and 8 injured
1905	June 8, A8 sank in Plymouth Sound, 15 lost
1905	July 6, French <i>Farfadet</i> foundered, 14 lost
1905	Oct 16, A4 sunk in Portsmouth Harbour, no lives lost
1907	June 13, Explosion on the C8, officer killed and 2 injured
1909	April 16, Italian <i>Foca</i> sunk, 13 lost
1909	June 12, Russian <i>Kumbala</i> sunk, 20 lost
1909	July 14, C11 run down by a steamer in the North Sea, 13 lost
1910	April 15, Japanese <i>No. 6</i> disappeared, 6 lost
1910	May 26, French <i>Pluviôse</i> run down, 27 lost
1911	Jan 17, German <i>U3</i> sunk off Kiel, 3 lost, 25 rescued by crane
1912	Feb 2, A3 run down by HMS <i>Hazard</i> off the Isle of Wight, 13 lost
1912	June 8, French <i>Vendémiaire</i> sunk, 14 lost
1912	Oct 4, B2 cut in two by the liner <i>Amerika</i> off Dover, 15 lost
1913	June 7, E5 had an explosion in her engine room, one killed, four seriously injured
1913	Dec 10, C14 sunk in Plymouth Sound after collision, no lives lost
1914	Jan 16, A7 sunk in Whitsand Bay

7. The Loss of HM Submarine A7

Friday 16th January

On Friday 16th January 1914, the submarine A7 was due to undertake torpedo practice in Whitsand Bay, a fairly typical day in the routine of a submarine that spent an average of three days per week exercising at sea.

Submarine A7 left Devonport with the 25 year old Cornishman Lt. Gilbert Welman in command, in company with submarine A9, two B class and two C class submarines, the tender *Pigmy* and the torpedo boat destroyer *Griffon*. Welman had taken command of the A7 on 13th November 1913, his second in command was Sub Lt. Robert Morrison who had transferred to submarines in June 1913 then recently joined the Devonport depot ship *Forth* on 4th December. HMS *Forth* was the parent ship of the 3rd Submarine Flotilla in Devonport. The Coxswain in charge of the submarine was the 29 year old P.O. John Crowley; for him this was only his second time on the boat as he had joined *Forth* only two days beforehand. Of the other eight crew on board that day two were not 'regulars' as one was a replacement for a sick crewman and another had swapped jobs for the day with a friend.



Figure 6: Submarines A7 and A9 in the Hamoaze

Once in Whitsand Bay, the A7 and A9 were to run a series of dummy attacks against the gunboat *Pigmy*. The two B and C class boats are not mentioned in the reports about the loss of A7 so it is thought they were nearby undertaking their own attacks on the destroyer *Griffon*. Out at sea there was a strong breeze from the north-east and the water was a little choppy; there was also some mist reducing visibility¹¹.

Submarine A9, commanded by Lt. G.F. Bradshaw, was stationed at Position A 2.5 miles WNW (292°M, 274°T)¹² from Rame Head while A7 was to be stationed at Position B, 5 miles WNW from Rame Head (Fig. 11). There was some delay in her arrival as A9 had already carried out two attacks on *Pigmy* by the time A7 eventually arrived in the Bay. A7 was last seen about 2 miles south-east of position B, trimmed down with main ballast tank blown, waiting for *Pigmy* to start her run before

commencing the attack¹³. A7 was out of position, in a rush as she was late and in deeper water than she should have been.

A report by Commodore Keyes suggests that A7 was 2 miles away from her assigned position as '*she was late in leaving harbour, and in order to avoid an attack which A9 was delivering, approached her position from seaward. Finding that she had not time to reach this position, she apparently dived in order to cut off the target ship, approximately in the position in which she now lies.*'¹⁴

Having picked up A9's second torpedo, at 11:10 *Pigmy* started her next run and A7 was seen to dive to start her first attack on the ship. *Pigmy*, under the command of Lt. Cdr. T.K. Triggs, was at that time about 1.6 miles S74W (254°M, 236°T) from Rame Chapel headed north-west at approximately 4 knots; this course was held until 12:00 when Rame Chapel bore N64W (296°M, 278°T) 4.3 miles, see Fig. 11. The expected torpedo from A7 was not seen and the submarine had not reappeared so it became obvious that A7 had failed in her attack. A black ball was hoisted by *Pigmy* as a signal to tell A7 to come to the surface but this had no effect, raising concerns on board as A7 had not been seen for nearly an hour. *Pigmy* then headed S63E (117°M, 99°T) towards Rame Head to search for the now overdue A7, changing course at 12:08 to head S5W (175°M 157°T) towards where A7 had last been seen.

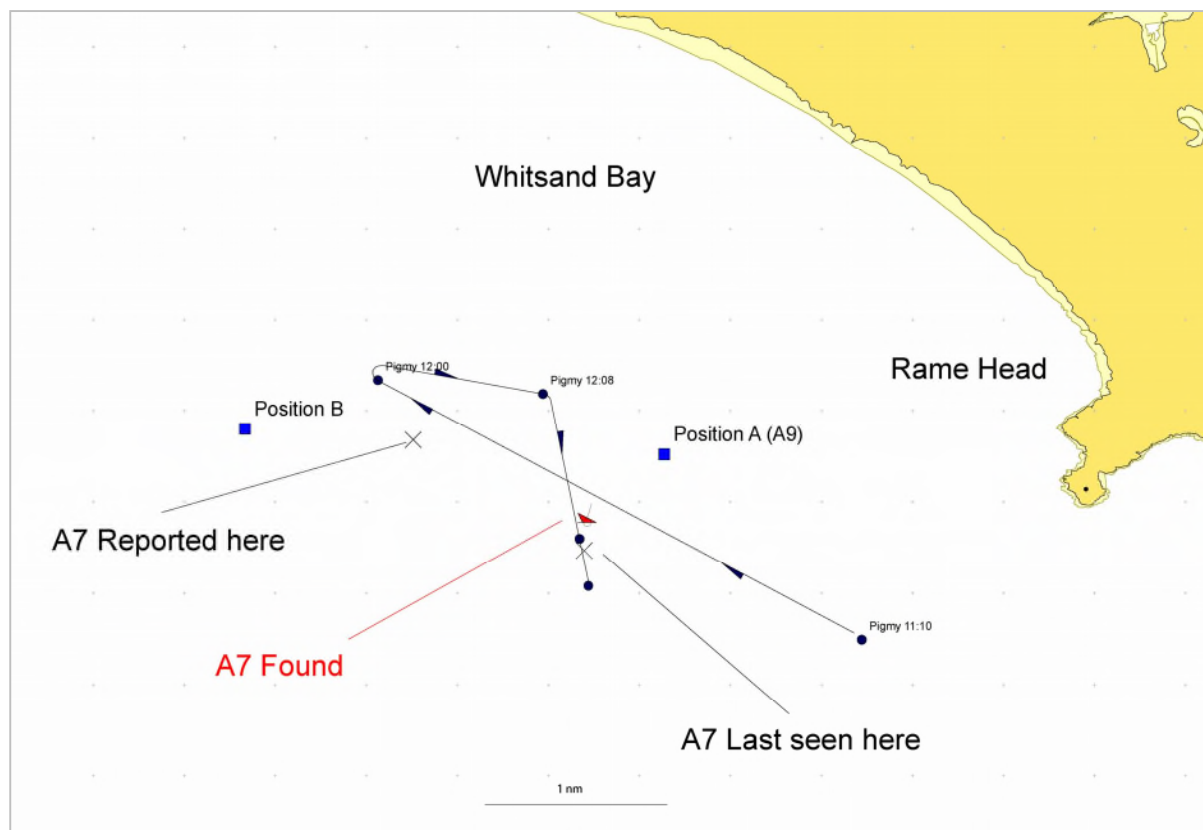


Figure 7: Chart showing *Pigmy's* track, the last known location of A7, the reported location of A7 and where she was eventually found

At 12:15, an hour after A7 had submerged, one of the crew of *Pigmy* saw a disturbance on the sea surface and at 12:18 a second disturbance was seen by the crew and the skipper approximately 3 miles West by North (281°M, 263°T) from Rame chapel. It was thought that the disturbance was caused by the crew of A7 attempting to blow water from her ballast tanks in a desperate attempt to reach the surface. No more bubbles were seen so *Pigmy* took cross bearings, marked the location with a buoy then returned to Plymouth Sound at full speed to alert Commander Tomkinson in HMS

Forth and the Commander in Chief (CinC) Devonport¹⁵. Meanwhile, *Griffon* escorted the other submarines back to Devonport. Once the depot ship *Forth* and the CinC Devonport had been informed a message was immediately sent to Sheerness requesting that the salvage vessel *Yard Craft No. 94* be sent to assist as she had been successful in raising the submarine *C14* from Plymouth Sound in the previous December¹⁶.

It had been estimated that the crew of the A7 only had enough air for six hours so time was short. Just after 15:00 *Pigmy* returned to Whitsand Bay along with dockyard tug *Escort* towing lighter *No. 23* carrying a large quantity of wire hawsers and other gear plus a crew of shipwrights and six divers. Unfortunately, by the time they arrived on site the waves had increased considerably in height and they failed to locate the buoy dropped to mark the last known position of A7. The ships had to return to base as darkness fell and at this point everyone realised that there was no hope of saving the crew of the submarine.

Saturday 17th

At 05:30 the next morning, the dockyard tug *Escort* was sent out with lighters *No. 21* and *No. 23*. *Escort* was followed by torpedo boats *105* and *107* along with *Bittern* and *Opossum*, with Rear Admiral Murray, Superintendent of the Dockyard, in charge of the salvage operation¹⁷. At 10:15 the destroyer *Griffon* relocated the buoy that had been laid by *Pigmy* the day before then proceeded to lay another buoy alongside it in case the first one carried away. The position of *Pigmy's* buoy was noted as being 3 miles West by North (281°M, 263°T) from Rame Head which is the same position in which it was dropped, so the reports that the buoy had drifted off site are incorrect¹⁸.

Note: Where was A7 found?

There is some confusion regarding the position of the sunken submarine. The position of the A7 reported to the Admiralty and to the press on the day she was lost was 4 miles WNW (292°M, 274°T) from Rame Head in about 36m depth. The position where she was last seen, where the buoy was dropped and relocated the following morning was 3 miles West by North (281°M, 263°T) from Rame Head; this is 1.2 miles south east of the position that had been reported. A newspaper interview with one of the salvage team includes a discussion about why the buoy was found in the wrong place, with the salvor offering up reasons why the buoy could have dragged from its position, despite the fact that the buoy was found where it was dropped. So it is possible that the ships were searching in the wrong place when *Pigmy* and the other vessels returned to Whitsand Bay on the afternoon she was lost, perhaps one reason why *Pigmy's* buoy could not be relocated.

By this time there was no possibility of saving the crew but it was essential that the A7 was salvaged to see what went wrong. Twelve ships, a mix of torpedo boats and destroyers, began searching for the submarine by dragging wire sweeps across the seabed, with divers ready to be deployed on any obstruction that was snagged. Two days after the sinking the ships were reported to be searching in 40m to 48m water depth, deeper than naval divers were expected to work at that time and although they did not know it, a long way to the south of the location where she was finally to be found¹⁹.

Tuesday 20th

By Tuesday 20th there were sixteen ships working in pairs, sweeping the seabed with heavy wire hawsers in an attempt to snag the submarine, but they were hampered by fog, bitterly cold winds and rising seas. Each snag caught on the wire had to be investigated by a diver and so far the only thing they had caught were large rocks²⁰. By now, *Yard Craft No. 94* had arrived in Plymouth from Sheerness with the Rover class tug *Alliance* (W.77) but she could do nothing to help until the submarine had been found. On Wednesday 21st the commander of the torpedo boat flotilla searching for the A7, Cdr. D.W. Gordon-Hamilton, was found dead in his bunk on board the destroyer *Thrasher*. It was thought that his death was brought on by standing on the open bridge of

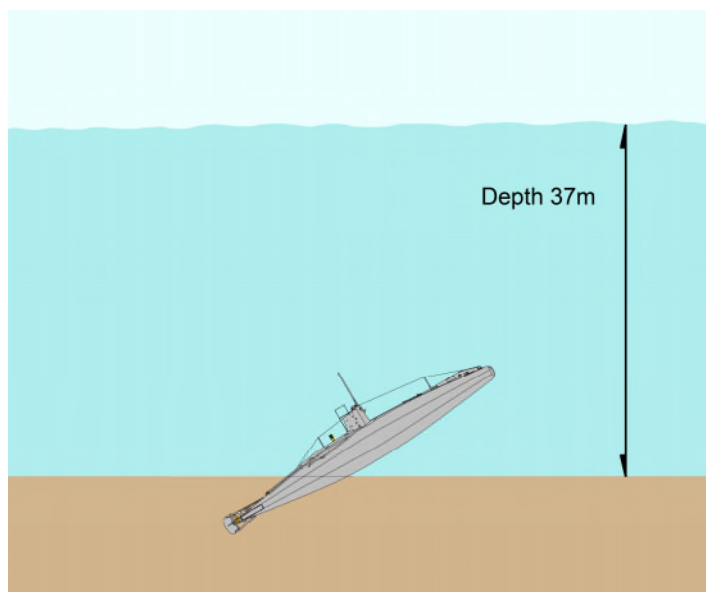


Figure 8: The A7 as found by divers in 1914 with her stern buried in the seabed and bow 10m above

his ship during search operations most of the previous day in the bitterly cold weather. Two more snags had been found the evening before, but as it was too late for divers to venture underwater the two snags were marked with buoys and destroyers were anchored close by to guard them. Diving operations resumed in the morning but to everyone's disappointment the snags were both found to be rocks.

One of the ideas proposed for the loss was that the crew had been disabled and the submarine had continued heading seaward until she ran out of battery power, so the Admiralty made a statement that 'if need be they would sweep the entire bay from Rame Head to Looe Island²¹'.

Wednesday 21st

Finally, the missing submarine was found five days after she was lost, but only by a lucky accident. The crew of the *Pigmy*, the vessel involved in the original training exercise, spotted a large quantity of oil floating on the sea in Whitsand Bay close the last known position for the submarine. With daylight fading they sent down experienced diver William Garland who after a short dive confirmed that they had located the A7. A second dive was made soon after where Garland attached a 2 inch rope to the submarine - quite a feat in zero visibility in the dark on a second dive to 40m depth - and not surprisingly Garland is reported to have '*felt the after effects for several hours*'²². The missing submarine was found just 300m from the location where *Pigmy* had seen her dive on her last practice torpedo run.

The wreck was found in 37m depth with between six and seven metres of the submarine's stern buried in the muddy seabed and the bow 10m off the bottom²³, raised at an angle of 30° to 40° (Fig. 12). Most of the submarine was below the maximum operating depth of 30m and the deepest part of the hull was at a depth of 40m.

Thursday 22nd

Attempts were made to move the submarine but bad weather and a heavy swell hampered operations causing the wire hawsers passed under the hull to slip.

Friday 23rd

By Friday, Lighters No. 21 and No. 23 as well as the salvage lighter Y.C. 94 were working on the wreck. A wire hawser was placed around the hull and the tug *Alliance* attempted to tow the submarine free of the seabed using all of her 1400 horsepower. Unfortunately the stern of

Note: A7 Location

To add to the confusion about the submarine's position noted earlier, a telegram from Devonport to the Admiralty about the finding stated that the position in which the submarine was found was approximately that given in the telegram of 16th January, a position now known to be incorrect. The Western Morning News of 22nd also states she was found 4 miles WNW of Rame Head, a location 1.2 miles from where the wreck actually lies.

A7 was firmly embedded in the seabed and *Alliance's* efforts had no effect at all.

Saturday 24th

With a conventional tug unable to move the A7 at all, the Navy then decided to use the 14,000 ton, 18,000 horsepower battleship *Exmouth* to pull the submarine free after having divers attach a steel hawser of sufficient strength to the hull. Confident of success in this next attempt, No. 10 dock in Devonport's North Yard was prepared to receive the A7 once she had been recovered.

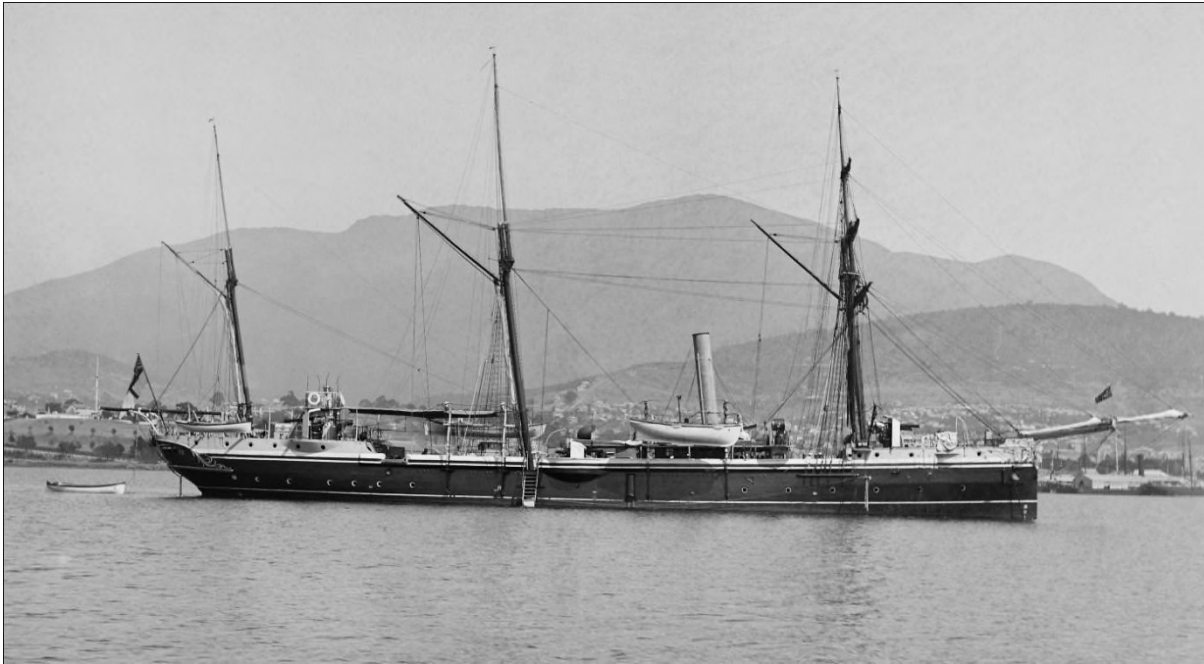


Figure 9: HMS Pigmy

Sunday 25th - Monday 26th

The weather from 24th to 26th was not favourable with too much ground swell for the divers to be able to attach a hawser to the stricken submarine. On Monday 26th the weather was not calm enough for diving but submarine exercises were resumed in Whitsand Bay, with A8, A9 and B3 going to sea with *Pigmy* acting as their tender²⁴.

Tuesday 27th

On Tuesday the tugs *Alliance* and *Firm* were given the task of sweeping a 5in. steel hawser under the wreck. With this done, a team of divers went down with the intention of securing the hawser around the hull but only succeeded in wrapping it around the forward part of the submarine, not far enough aft for it to be used to pull the wreck free. In the afternoon an attempt was made to sweep a thicker 5½ in. hawser under the hull but this proved unsuccessful²⁵.

Wednesday 28th

On the morning of 28th, the tugs *Firm* and *Alliance* attempted to use the 5in. hawser rigged the day before to pull A7 free from the seabed. The two tugs, '*were able without very great difficulty to take the strain. The hawser had only been taut a few minutes so far as could be seen on the surface, when it 'kinked' and the jerk caused the hawser to flip off the body of the submarine*'. A diver was sent down to see if the pulling had any effect but as before the submarine had not moved at all²⁶.

With the two tugs having failed in their attempt it was the turn of Duncan class battleship HMS *Exmouth*. Divers from the salvage vessel *Y. C. 94* managed to attach a 5½ in. hawser to the towing eye fitted on the bow of the sunken submarine. Shortly before 15:00 the steel hawser attached to the submarine was taken to the quarterdeck of the HMS *Exmouth* and shackled around her after gun turret. Keeping tension on the hawser to prevent it from slipping under the bow of the submarine, the *Exmouth* was gently pulled into position by the tug *Alliance*. When the *Exmouth* was in line with the submarine and the slack had been taken out of the hawser, the *Exmouth* started her engines and slowly began to increase the power. After about 40 minutes of continuous pulling the towing eye on the submarine broke apart and the tow cable came free.



Figure 10: HMS Russell, sister ship to HMS *Exmouth*

Divers were immediately sent down only to find that the immense power of the battleship had not managed to move the submarine at all, but the eye plate on the bow had ‘started’, or pulled loose, raising concerns that the submarine had now flooded making the salvage more difficult²⁷.

Thursday 29th January to Tuesday 17th February

A succession of gales stopped any diving on the site until 17th February. Divers attempted to get a wire hawser around the hull but it slipped from under submarine before it could be attached, so diving operations were abandoned for the day.

Wednesday 18th to Tuesday 24th

Bad weather again delayed any further operations until 24th February when the salvage team awoke to a fine day with light northerly winds. With the aid of the tugs *Alliance* and *Escort*, a 6½ inch hawser was swept under the hull, divers were sent down and they succeeded in getting it around the hull ‘between the periscope and conning tower’, which is not possible as the periscope is mounted on the conning tower, so it is more likely that they got the cable between the binnacle and the conning tower²⁸.

Wednesday 25th

The morning of 25th brought light northerly winds, calm seas and thick fog. Divers were dispatched to try to move the hawser farther aft around the widest part of the hull but they were unable to move it as the cable had tightened around the hull overnight²⁹.

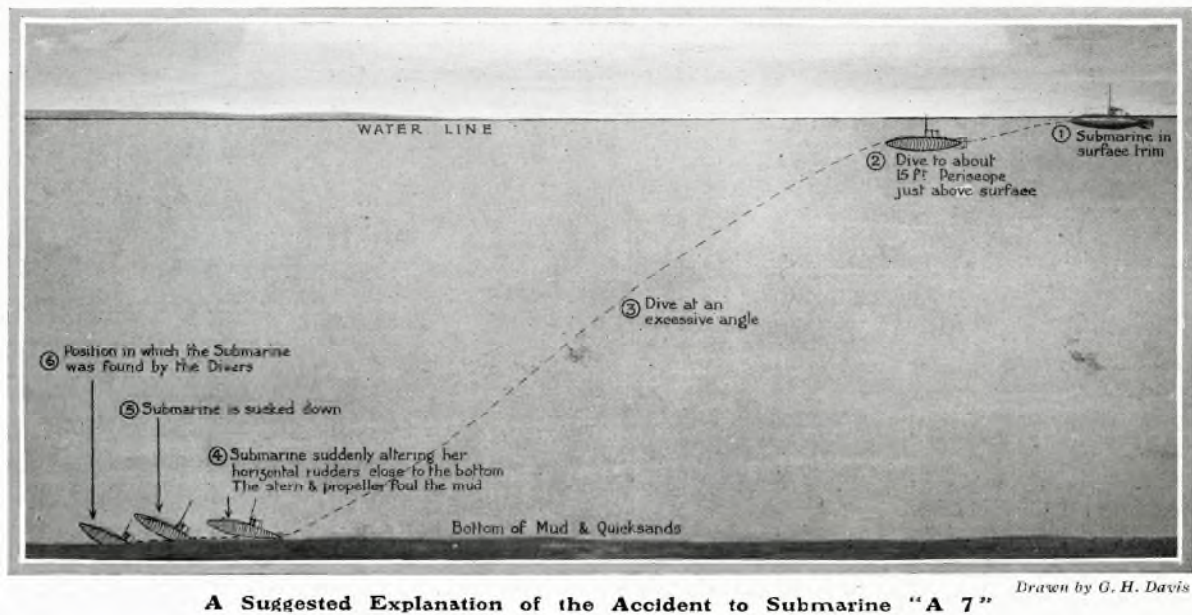


Figure 11: The press were keen to offer suggestions about how the A7 sank as shown in the *Sphere* magazine on 31st Jan. Note the huge depth of water compared to the scale of the submarine (courtesy of the Mary Evans Picture Library)

Thursday 26th

On 26th the heavy steel hawser round the submarine was loosened so the divers could move it aft along the hull, finally managing to get a complete round turn around the hull behind the conning tower. After hooking up the hawser from the seabed the tugs took up the slack in the wire so it would not foul the submarine. Both ends of the hawser were transferred to the battleship *Exmouth* and attached with two turns around her aft gun mounting. A straight pull from the seabed had not worked so this time a sideways pull would have any effect. *Exmouth* drifted with the tide until the hawser was tight then steadily increased power until she was pulling with revolutions for 11 knots at right angles to the keel of submarine. The *Exmouth* pulled steadily for 40 minutes but the enormous strain placed on A7 appeared to have no effect and the boat remained resolutely secure in the seabed³⁰. Running short of options, a more violent method was attempted; the *Exmouth* shut off engine power, the towing hawser was allowed to go slack then the engines of the battleship were put full ahead. The result was that the hawser parted under the strain with a report that sounded like gunfire³¹. It is a testament to the skill of the submarine designers and builders that the A7 remained in one piece after being pulled around by a huge battleship 80 times her size.

Friday 27th to Saturday 28th February

Poor weather conditions stopped any diving operations.

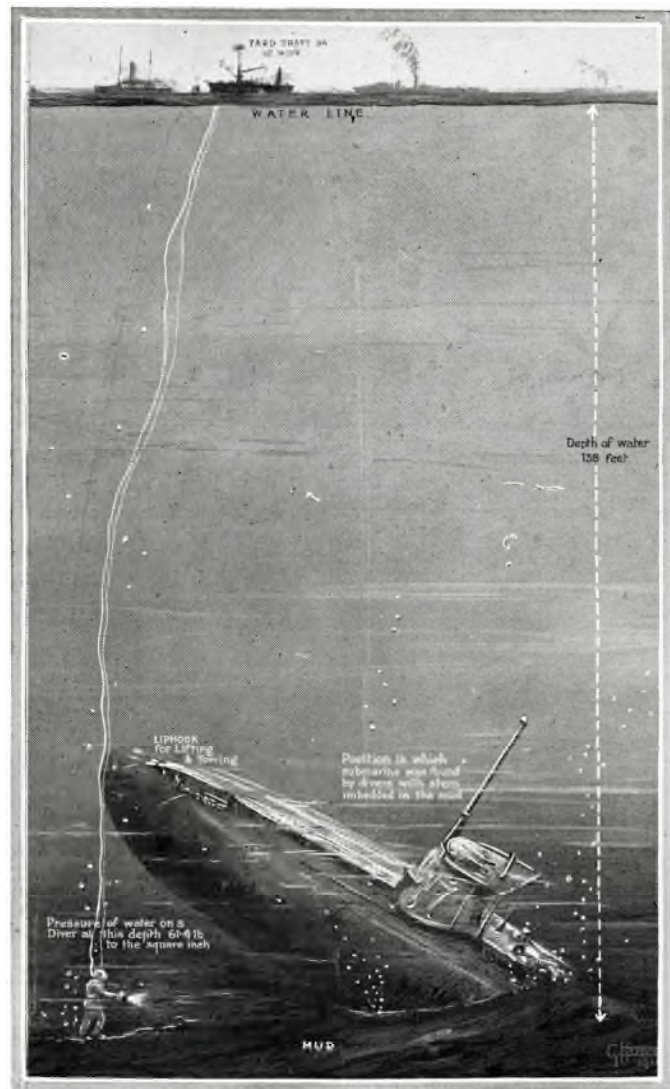
Sunday 1st March

On 1st March divers were sent back to the wreck and 'to their surprise found it comparatively light down there'. Having bright sunshine and clear visibility, the divers examined the wreck and found that despite *Exmouth's* best efforts the submarine had not moved at all, the hull was undamaged and the hawser around the aft end was still in place³². The divers also noted that on the starboard side of the craft, stretching away inshore and out of sight, was the rest of the hawser which broke during the last pull. The divers got a rope on to the hawser so they could recover it to the surface but were unable to do any more³³.

Tuesday 3rd March

By the end of February the six weeks of salvage attempts had failed to move the submarine at all. A report by the salvage officer Lt. Highfield after the inspection by divers on 1st March noted that the best efforts of one of the Navy's battleships had failed to have any effect so the likelihood of a successful recovery of the submarine was very small. On 2nd March the Commander in Chief Devonport informed the Admiralty that the recovery operation had been abandoned³⁴. The tug *Alliance* and the salvage vessel Y.C. 94 left Plymouth for their home port of Sheerness as plans were being made in Devonport for a funeral service to be held over the submarine³⁵.

This was the latest in the long line of A-Class submarines sunk in peacetime during the previous decade and this, combined with the unsuccessful attempts at salvage, exposed the Navy to widespread criticism. Questions in the House of Commons suggested that this class of submarines was obsolete as well as dangerous, as did a letter in the *Times* newspaper from the father of Sub Lt. Morrison who lost his life in the accident³⁶.



Drawn by G. H. Davis
The Accident to "A 7" I

The position of the submarine as found by the divers

Figure 12: Another illustration of the trapped submarine, again showing the greatly exaggerated depth of water (Mary Evans Picture Library)

Diving operations on the A7

Diving operations during salvage attempts on the A7 were undertaken by Royal Navy divers. The equipment they used was known as 'standard dress'; a design dating back to the 1830s that includes a waterproof suit, brass helmet and corselet, lead weighted boots with lead weights hung front and back on the chest. Air is provided to the diver down a heavy hose that has a strong rope lifeline attached, the air being fed from a hand cranked pump on the surface.

At 37m or 121ft, the diving operations on the submarine were at the limit of what was expected from a Royal Navy diver. Mixed breathing gases were not available at that time so the divers were breathing air which has a significant narcotic effect at that depth and only allows dives of between 10 and 15 minutes in duration. The pumps used to provide the air to the divers were hand cranked and not very efficient so two had to be used to provide air for just one diver.

On the bottom, the divers would have found it hard to move around because of the heavy diving equipment they wore. Doing any kind of work would have been difficult as the water in January would be very cold making the diver's hands numb. The stiff umbilical hose and rope that attached the diver to the boat was difficult to manage, it would have snagged on the submarine and would have acted like a sail dragging the diver in any current. It was usually very dark at that depth with little natural light; the underwater visibility was just a few metres at best and further restricted by the small viewing ports in the helmet. Unlike modern sports divers who can swim over the seabed, the standard dress diver would have to walk around, stirring up silt on the seabed and reducing the visibility still further.

The submarine would have provided yet more challenges with the stern buried and the bows 10m off the bottom. The smooth sides of the rounded hull provided few footholds for any diver to climb about on and falling 10m from the bows to the seabed would have been hazardous because of the rapid pressure change over that distance. But the biggest challenge of all was manhandling the 6½ in. circumference (2 in. diameter) steel cable that had to be looped all the way around the hull aft of the conning tower.



British Navy Series. Divers about to descend.

Figure 13: Contemporary postcard showing Royal Navy divers about to descend

8. Early submarine crews and the last crew of the A7

8.1. Early submarine crews

Obtaining crews for the early RN submarines was never easy. The secrecy under which the Navy kept the first Holland submarines meant that knowledge about them was not widespread, and for those that did know about the boats they were seen as being experimental and thus dangerous. It was also known that conditions within the hull were cramped, hazardous and unhealthy, often tainted with gasoline fumes and carbon monoxide gas from the engine or poisonous chlorine and explosive hydrogen gases from the huge bank of batteries³⁷. Hall describes the situation in a 1910 report on pay and conditions for submarine personnel:

*'The discomforts in submarines cannot be exaggerated...clothes cannot be dried, fires are not permissible, in cold weather it is difficult to keep reasonably warm, the amount of fresh water precludes any attempt at personal cleanliness and the roar of the engines is all over the boat and although the officers and men are nominally working watch on watch there is no certainty in the watch off. To many, the smell inside a submarine after she has been a short time at sea, which is absolutely peculiar to itself, is most revolting, all food tastes of it, all clothes reek of it, it is quite impossible to wear any clothes again after they have been used in it.'*³⁸

To encourage recruitment to the fledgling Submarine Service it became necessary to offer a financial incentive in the form of 'hard lying' money in recognition of the poor conditions in which the submariners had to work. The early submarines were dangerous, fickle contraptions that needed a steady hand to control them and it was soon recognised that training was one means of reducing the risks. Those in charge of submarines trained their crews to a high level of expertise so it was in their interest to try to keep the crews together. This led to further friction between the Submarine Service and the old guard battleship Admirals as this

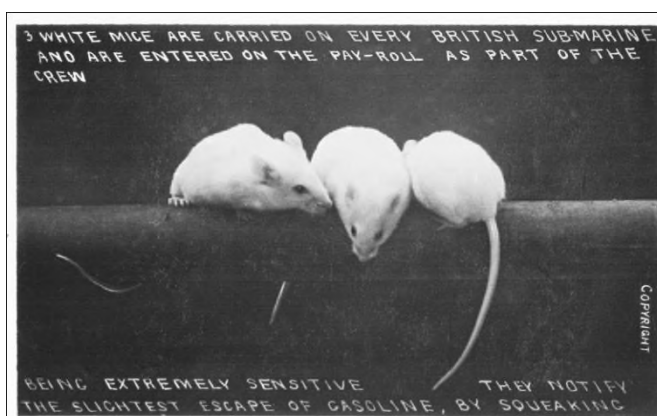


Figure 14: White mice were used on board the boats to detect carbon monoxide, not gasoline, keeling over when levels got too high for their small bodies. As Holland trials captain Frank Cable is quoted as saying: 'When the mice died it was time to go ashore' (Morris 1998)

'service within a service' was soon seen as being elitist and this policy became a problem for the crews themselves as promotion was dependant on time spent on surface ships. The Submarine Service also fostered a deliberately less formal working environment to help retain the experienced men, with relaxed dress codes and an early finish to the working day. There was an informal interaction between officers and men who were literally 'in the same boat'; this was a unique relationship within an Edwardian Navy still very clearly split along class lines where officers and men did not mix. The end result was that there was a minimal turnover of people with the Service so submarine crews could end up working together for years.

'Shortly before Christmas he came home and said the noise in the submarine had been enough to kill anyone. His head was very bad, apparently from the gasoline' - Widow of Ldg. Stoker Northam³⁹

8.2. The last crew of the A7

The last crew of the A7 were a mix of her regular crew, some new on board the submarine and two particularly unlucky ones who had exchanged jobs for the day.



Figure 15: Postcard commemorating the last crew of the A7 (RNSM Collection)

The last crew of the A7 were:

- Petty Officer John Francis Crowley
- Able Seaman Ernest Frederick Dyer
- Able Seaman Frank Charles Harris
- Able Seaman Frederick Jewell
- Sub. Lt. Robert Herman Grant Morrison
- ERA 2nd Class Robert William Nagle
- Acting Leading Stoker John Northam
- Able Seaman Charles Edward James Russell
- ERA 1st Class Richard Venning
- Acting Leading Stoker Lancelot Wagstaff
- Lt. Gilbert Molesworth Welman

After the news of the loss of A7 was announced in the press, the King and Queen, the German Kaiser and Admiral Tirpitz, the kings of Spain and Norway and the French president all sent their condolences for the loss of the crew. On the 5th March, a flotilla of three battleships, three destroyers and 13 submarines left Devonport led by the cruiser HMS *Forth*, the parent ship for Devonport submarines. The colours on all the ships in the harbour were all at half mast as the ships

passed by, heading towards Rame Head for a memorial service in the Bay for the lost crew of the A7. A salute was fired, the last post played and when the *Forth* passed over the place where A7 lay trapped on the seabed the orphaned son of Engineer Artificer Nagle dropped a wreath of flowers on to the sea⁴⁰. Many of the crew left wives, children and mothers as dependants so a memorial fund was set up that obtained donations from all over the world.

In 2014, on the 100th anniversary of the loss of A7, an Act of Remembrance was held for the captain and crew of the A7⁴¹ on Rame Head, the closest point of land to the submarine. Great-nieces and nephews of Gilbert Welman were joined by representatives of the RN Submarine School⁴².

Lt. Gilbert Molesworth Welman

The Commanding Officer of the A7 was Gilbert Welman, known as 'Gibby' to his family. Born on 16 September 1888 in Newquay as the eldest of eight children, Welman joined the Navy at the end of 1903 and became one of the last cadets to train in the wooden wall warship *Britannia*. Welman was made a midshipman by February 1905 and an acting Sub-Lieutenant in April 1908. That year he applied to join the Submarine Service and was accepted. His service record notes that Welman was '*a good practical officer; a good hardworking and zealous officer*'. Submarine training started in January 1910 with a promotion to Lieutenant in December that year. Welman was assigned to HMS *Forth* in July 1913 and was made commander of A7 on 13th November 1913⁴³.



Welman (26) was described by his sister as a great charmer, lively, amusing, talkative and a favourite with everyone⁴⁴; he had recently become engaged to Enid Russell Brown and they were soon to be married.

Sub. Lt. Robert Herman Grant Morrison

Sub Lieutenant Robert Morrison was the second captain, 1st Lieutenant and executive officer on A7. Morrison was the second son of Lt. Col. R.H. Morrison and his wife Louise of Johnstown House, Cabinteely, Dublin, born on 11th May 1891. Morrison joined the Navy on 15th May 1904 and was made acting Sub-Lieutenant in May 1912, but a failed navigation certificate in January 1912 delayed promotion for four months. Morrison also failed Engine Room training in June 1913 and was noted on record that he was not capable of performing duties as an Junior Engineering Officer, but no further training was necessary as he was to be sent to submarines. A transfer to *Dolphin* in June 1913 started his submarine training with a move to *Forth* and the depot ship *Onyx* in Devonport on 4th December 1913⁴⁵.



Morrison (23) was a keen rugby player and was due to play as full back for the Devonport United Services in a match the day after the A7 was lost. Morrison's father wrote an impassioned letter to the press⁴⁶ about the dangers of this 'worn out class of submarines' which included a story his son had told him about A7 being stuck on the seabed for an hour before Christmas, a story denied in parliament by Churchill⁴⁷. There is a memorial in the Kill o' the Grange Church in Dublin to Morrison and his brother, Acting Major Richard Fielding Morrison, lost in action in Belgium in 1918.

P. O. John Francis Crowley

ON 210582

The coxswain and chief non-commissioned officer on board A7 was Petty Officer John Crowley. The coxswain held the most responsible job on board as he was tasked with steering the submarine.

Crowley was born on 8th April 1884 in Ballyheigue, County Kerry, in Ireland, joining the Navy in April 1902. In December 1906 he was transferred to *Forth* for submarine service where he stayed until June 1911 when he moved between other vessels and establishments including *Vivid*, *Crescent*, *Flora*, *Tamar*, *Defence* and *Alacrity*. In June 1913 he was stationed at the Devonport training establishment *Impregnable* and from there he moved back to *Forth* on 14th January 1914. The 29 year old Crowley joined *Forth* just two days before the A7 was lost and it was only his second time on board the boat⁴⁸.



E.R.A. 1st Class Richard Venning

ON 269321

Engine Room Artificer Richard Venning was one of the replacement crew on board on the day A7 was lost. Born 16 April 1870 in Devonport, Venning was an engine smith before joining the navy on 21st March 1898. Venning joined *Forth* and the submarine service in July 1913 after fifteen years in surface ships including *Royal Oak* and the *Empress of India*. Venning was a crewman assigned to the smithy aboard the *Onyx* but joined the crew of the A7 as illness cover for another seaman⁴⁹. The 45 year old Venning lived with his parents in Trelawney Terrace, Torpoint, along with his wife and four children aged between 4 and 17.

E.R.A. 2nd Class Robert William Nagle

ON 270745

Born in March 1879 in New South Wales, Australia, Robert Nagle came to England with his parents at the age of 13. Nagle was apprenticed in the engineering department at Lairds in Birkenhead as an engine fitter, and after completing his apprenticeship he joined the Navy in August 1902. After spending time in surface ships including the *Royal Oak* and *Cornwall* he volunteered for submarine service in 1911, joining *Forth* from *Vivid* on 17 June⁵⁰.

The 35 year old Nagle lived with his wife in Onslow Terrace, Plymouth⁵¹

Acting Ldg. Stoker John Northam

ON 304857

John Northam was born on 22nd January 1882 in Stonehouse, Plymouth. Joining the Navy in August 1903 he served in surface ships until transferred to *Forth* in October 1910, staying there for 10 months. By August 1912 Northam was on the *Cormorant* before transferring back to *Forth* on 17th September 1913⁵².

Northam (32) lived in Stonehouse and was married with two children, one 3 years old and the other 8 months. In an interview with the press, John Northam's widow confirmed the statement made by Morrison's father that the A7 had been stuck on the seabed for an hour one day before Christmas⁵³.



Acting Ldg. Stoker Lancelot Wagstaff

ON K13882 [SS107841, K13856]

The fabulously named Lancelot Wagstaff was born in Manchester on 24th October 1889 and was employed as a carter on leaving school. Wagstaff joined the Navy as a Stoker 2nd Class at *Vivid II* (Devonport) on a short service engagement on 31st July 1908. Transferred to submarines in January 1911, Wagstaff joined *Forth* in Devonport and was rated Acting Leading Stoker on 15th October 1913⁵⁴.

Wagstaff (25) was married to Florence Langdon, living in James St., Plymouth. They had one child aged 14 months and at the time he was lost she was pregnant with her second. Reports in the press noted that Wagstaff was a fair boxer known as the 'Lancashire Lad' and only a fortnight before had taken on 'Black Bob' of Stonehouse. The press interviewed his widow who said that Wagstaff had joined the submarine service for the better rate of pay. Florence also mentioned that the A7 had previously been stuck on the seabed; *'Some time before Christmas when the submarine was exercising in Cawsand Bay the vessel took a dive and could not be brought to the surface for over an hour owing to a failure of the apparatus'*, adding *'On another occasion he was 'gasolined' and Wagstaff was brought home in a cab in an unconscious condition'*⁵⁵.

AB Ernest Frederick Dyer

ON 239725

Able Seaman Earnest Dyer was born in Bedford on 26th June 1891 joining the Navy at the Chatham Division in June 1909, initially to serve in surface ships. Transferring to submarine depot ships *Thames* in April 1912 and *Bonaventure* in October 1912, Dyer was moved to *Cormorant* in November 1912 before going back to *Bonaventure* in September 1913. By 22nd October 1913 he was allocated to *Forth* in Devonport⁵⁶. Single and aged 23 his address was given as Ware in Hertfordshire.



AB Frank Charles Harris

ON 234433

Able Seaman Charles Harris was from Leeds; born in December 1888 he joined the Navy at the age of 18. Harris was in surface ships until January 1911 transferring to the submarine depot ship *Forth* for seven months, then to *Egmont* and *Eclipse* before returning to *Forth* on 5th November 1914⁵⁷. Harris lodged with a Mrs. Atkins of Coombe St. in Exeter, who is quoted as saying, *'should the bodies of the crew be recovered, it is Mrs. Atkins' intention to have her adopted son buried in Exeter'*.

AB Frederick Jewell

ON 238164

Able Seaman Frederick 'Nat' Jewell was another of the crew on Friday 16th who was not a 'regular' as on that day he had taken the place of his friend Leonard Lutley⁵⁸. Jewell was born in Clovelly, North Devon, on 10th December 1890, joined *Impregnable* as a Boy, 2nd Class, in February 1907 having previously been a fisherman. On 2nd February 1912 Jewell transferred to *Forth* from *Blake*⁵⁹. The 24 year old Nat Jewell was single.



AB Charles Edward James Russell

ON 233337

Able Seaman Charles Russell was from Cheltenham, born on 16th June 1887. Russell joined the Navy in June 1905 after previously being a golf ball maker. Russell had between four and five years in submarines, joining *Forth* in December 1908 to January 1910 then back to *Forth* in April 1912⁶⁰ with time on Dundee depot ship *Vulcan* and tender *Hebe* in between. Russell lived with his wife and family at 11 King St., Devonport.



Figure 16: Small card printed in 1914 as a memorial to the crew of A7 lost in the disaster

8.3. Other stories

Harry Cotterill

ON Unknown

In the February 2000 edition of the Navy News was an article by P. Taylor which he had been inspired to write by the articles published previously about thefts of items from the A7 submarine. The article briefly recounts the story of a chap called Harry Cotterill who is described as the signalman on the A7. On the day of her loss, Cotterill headed off to the dockside toilet before boarding the boat; whilst there the Flotilla Commanding Officer (CO) arrived at the boat demanding to know why the A7 was late in leaving. When told she was waiting for her signalman, the CO told Lt. Welman to leave at once and the signalman would

be brought out to her by the next boat. Cotterill arrived back at the dock, got a dressing down from the CO and was shipped out on the next submarine to leave; this lost sight of A7 so he never made it on board.

No Harry Cotterill, or variations of that name, has yet been traced.

Leonard Lutley

ON 233528

Leonard Lutley should have been on board A7 on the day she was lost, but he had swapped jobs with his friend Fred 'Nat' Jewell. Lutley was born on 25th September 1889 in Plymouth, joining the Navy in June 1907 transferring to the submarine service and *Forth* in January 1912. The A7 having been lost in January 1914, the 25 year old Lutley soon transferred to surface ships moving to *Vivid* in August then to *Devonshire* in November that same year⁶¹.

In an interview with Lutley's daughter Margaret Screech⁶², she said:

'He never spoke very much about this submarine, but when January came around he use to sometimes think about 'Nat' down at the bottom of the sea.'

'He joined at 15 or 16, quite young, so they had to put his age back, his birthday was in September, but the recruiting officer said we'll put it for June. So his Naval birthday was always the 25th of June, where his proper birthday was the 25th of September 1889.'

The most interesting comment was about a potential cause for the loss of A7:

'On the day of the fatal dive he always said that his chum Fred "Nat" Jewell asked to swap duties and so he sailed and not my father. Dad always said that the helm was reversed so that when the boat got into difficulties instead of forward she buried herself rearwards into the sand. Father always said the steering gear, not the coxswain, he never said anyone else... or that they all knew... it was wired backwards, but I think that in those days when there was so few of them they all mucked in and did various jobs. But he always said that why she buried herself in so much was because it was the wrong way round.

It is not clear if this refers to the mechanical linkage to the rudder or hydroplanes that is reversed or the electrical control for the electric motor.

Note - Submarine Accidents in Plymouth

Plymouth has seen more than its fair share of submarine accidents:

- The first was the sinking of the 'submarine' *Maria* in 1774, a 50 ton sloop that had been modified by the addition of an air-tight compartment. Mr John Day intended to descend in this contraption to 30m depth in Plymouth Sound hoping to benefit from wagers that he could stay underwater for 24 hours. When the attempt was made Mr Day lost his bet and became the first ever submarine fatality. This also initiated the first recorded submarine salvage attempt

[Falck 1775]

- The second occurred in 1905 when the A class submarine A8 sank in Plymouth Sound after driving herself under at speed in rough seas.

- Submarine A9 was rammed by the Little Western Steam Ship Company steamer *Coath* off Plymouth in February 1906. The submarine was doing a dummy attack on the cruiser *Theseus* when she was struck a glancing blow by the steamship which damaged the conning tower and fairing as well as bending the periscope. Fortunately the watertight shutter at the base of the conning tower was closed, a modification added after the loss of submarine A1 during an exercise, and A9 managed to surface with a conning tower full of water

[Sueter, 1907, p158].

- On 10th December 1913 the submarine C14 sank in Plymouth Sound after a collision with a hopper barge; the crew escaped, no lives lost and the boat was salvaged shortly after

[Evans, 2010].

- The most recent was in January 1914 when the A7 was lost in Whitsand Bay.

9. Site history

The Royal Navy divers who last visited the A7 in 1914 would have seen the hull angled up approximately 30°, bows 10m off the seabed, 7m of the stern buried in the seabed, the towing eye broken, some probable damage to the cutwater and a 6 ½ in. steel hawser left wrapped around the hull aft of the conning tower. After the funeral service over the wreck of the submarine in March 1914 the site was abandoned.

The A7 was then forgotten until 1972 when a Mr Calkin reported to the UK Hydrographic Office that there was a trawl fastener in that area. The submarine was subsequently relocated in 1972 by the RN hydrographic survey vessel HMS *Woodlark* ⁶³

Sports divers first visited the wreck of the A7 on 13 August 1981 after locating her with an echo sounder. The underwater visibility on the first dive was from 5 to 7m, the submarine was reported as being upright, partially buried in a thick blue clay seabed, with the periscope bent slightly aft, and a number of conger eels were noted inside the hull aft of the conning tower. When first found the compass binnacle was not attached to the submarine but was found lying on the seabed on the starboard side. The binnacle was recovered intact by the divers, with both iron compensating balls attached, compass still working and light bulbs inside the waterproof housing still intact⁶⁴.

Fortunately, the binnacle was cleaned and restored rather than being sent to the scrapyard to be exchanged for money, a fate which has occurred to many interesting and historical objects recovered from shipwrecks around Plymouth.

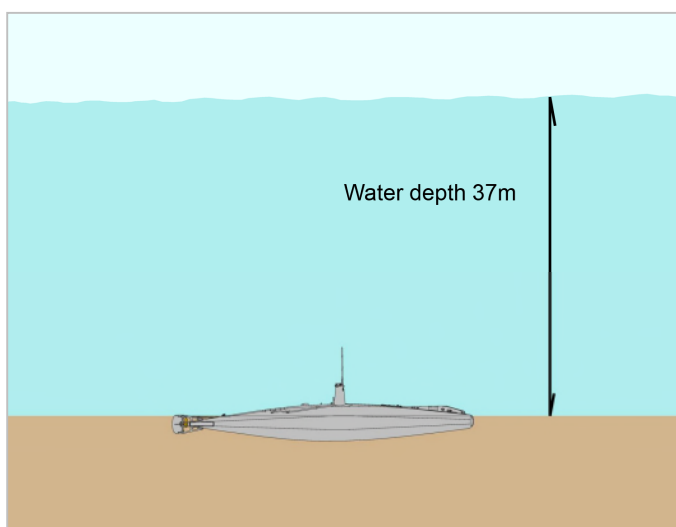


Figure 17: A7 as she lies today in 37m water depth, partially buried in the seabed

The first officially recorded dive on the A7 was in September 1985 by the Royal Navy clearance diving team from Plymouth and they confirmed that the wreck was the A7. The submarine was described as being in good condition, lying upright but partly buried up to the waterline with the top of the hull just 1m clear of the seabed (Fig. 17). The conning tower was intact, the periscope was intact and both the torpedo loading hatch and conning tower hatch were closed⁶⁵. At this time the wreck was occasionally visited by sports divers but it was not a popular site, being small there was little to see and in the days before GPS it was hard to find. The submarine was of interest to divers who recovered metal from shipwrecks for scrap, as at that time the A7 was rumoured to have a conning tower made of gunmetal and mercury for ballast, both valuable if they could be recovered and sold. In 1994 divers reported that the portholes and conning tower hatch were still in place. In 1998, divers noted a small hole on her starboard side large enough to shine a torch into. On the 50th anniversary of D-Day in 1995 a white ensign was attached to the periscope as a memorial to the crew of the A7.

Plymouth diver Peter Washburn had seen that a hole had been made in the hull that appeared to have been systematically enlarged to allow access to the interior, so this prompted the writing of a newspaper article to warn divers that the submarine was a war grave and should not be touched⁶⁶. In September, the Ministry of Defence (MoD) warned divers about theft of items from the

submarine⁶⁷ and the police started making enquiries about what had already been taken. In December 1999 the police arrested local dive boat skipper Roger Webber in connection with the recovery of the binnacle from the submarine⁶⁸. Although the binnacle had been saved from the scrapyard by Mr Webber, he had not been declared to the Receiver of Wreck when it was recovered in 1981 as required by law. At that time local divers were under the false impression that the Receiver of Wreck only dealt with salvaged cargoes; Mr Webber was quoted as saying *'In those days it was perceived that the Receiver of Wreck was only interested in commercial salvage. I believe that the new Receiver of Wreck agency (Maritime and Coastguard Agency) have fully acknowledged this by announcing their intention to have an amnesty.'* In May 2000, the MOD dropped its proposed court case against Mr Webber after he agreed to accept a police caution for the offence of theft by finding. The binnacle was then handed to the RN Submarine Museum in Gosport where it is now on display⁶⁹.

The A7 was designated under the Protection of Military Remains Act (Designation of Vessels and Controlled Sites) Order 2002, Statutory Instrument No.1761 which came into force on 30th September 2002. Once in force all divers were banned from visiting the site without permission.

The last report from visiting divers was from August 2002, just before the site was designated. The report said that there was a considerable amount of trawl net draped over the port side, the navigation lights had been removed from the conning tower and it was possible to see into the hull through holes in the hull. The hawsers used to try and raise the hull were also noted⁷⁰. A small dedication plaque was left on the top of the conning tower on the last day that diving was allowed on the site⁷¹, a plaque that is unfortunately no longer on the submarine.

Small inflatable dive boats have been seen in the area since the site was designated in 2001 but it is not possible to confirm that they were conducting diving operations within the restricted area of the designation⁷². During the A7 Project fieldwork some members of the project team met a diver who told them that he still visited the A7; the diver was aware that the A7 was a Controlled site but thought diving was allowed.



Figure 18: A diver on the A7 circa 1990, the view aft of the conning tower looking forward

10. Site investigation

10.1. Initial estimate of condition

Prior to the start of this project, the existing condition of the A7 was unknown as it had not been seen by divers since 2001 and the last RN hydrographic survey over the site was by HMS *Echo* in 2006.

When the wreck of the submarine was first found in 1914, between six and seven metres of the submarine's stern was buried in the seabed and the bow was 10m off the bottom, raised at an angle of 30° to 40°. All contemporary salvage attempts failed and the submarine was abandoned on the seabed. Sports divers first visited the site in 1981 and found that the submarine was now on an even keel, she was largely intact but buried right up to what would be her waterline when afloat and in light ballast. The last sports divers to legally visit the site in August 2002 reported that the submarine was essentially in the same condition as it was found in 1981 (Fig. 19).

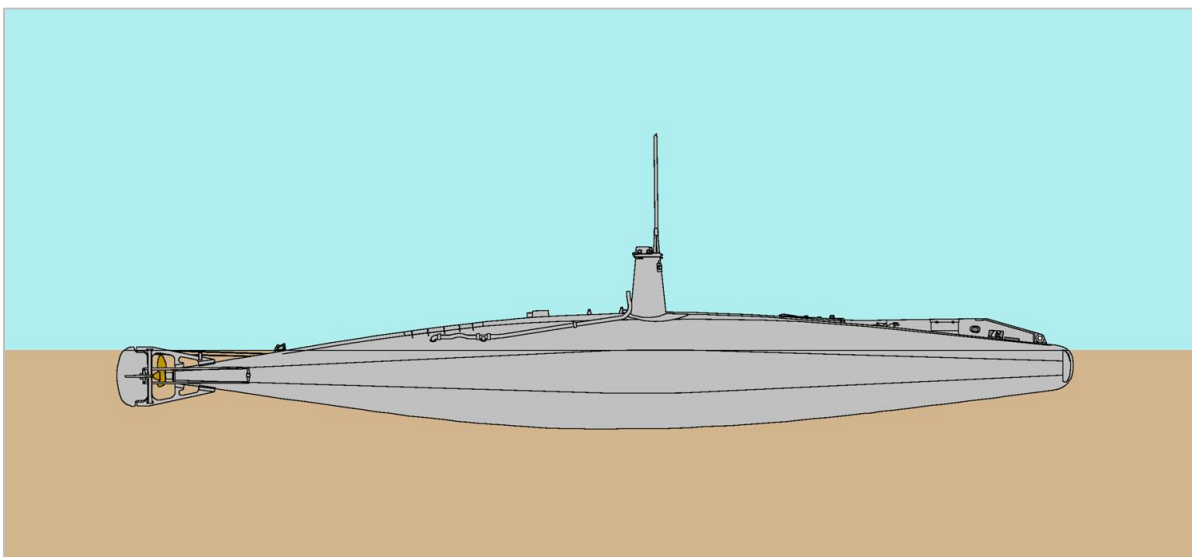


Figure 19: Estimate of hull attitude and burial depth based on divers' reports

10.2. Previous geophysical surveys

The wreck was first investigated in September 1972 during a Royal Navy hydrographic survey, with the submarine showing as a 3m high target in 37m depth. The wreck was resurveyed by the Navy in 1980, the estimated height of the wreck was reduced to 2.7m and a scour 1m deep was noted on the hull lying 080°/260° on grey clay⁷³.

A side scan sonar survey of the site was planned as a first step in the investigation of the submarine for the A7 Project; this would provide information about the position, attitude and condition of the boat as well as information about the seabed around it. On the 4th December 2013 a side scan sonar survey of the wreck was completed by Plymouth University and the SHIPS Project team using a GeoAcoustics SS981 side scan sonar transmitting at 410kHz. The sonar trace showed the wreck to be lying partially buried in a flat and featureless seabed, the visible part of the rounded hull 25m long and 3m wide, with the top of the hull 1.25m above the seabed and the top of conning tower 3.5m proud.

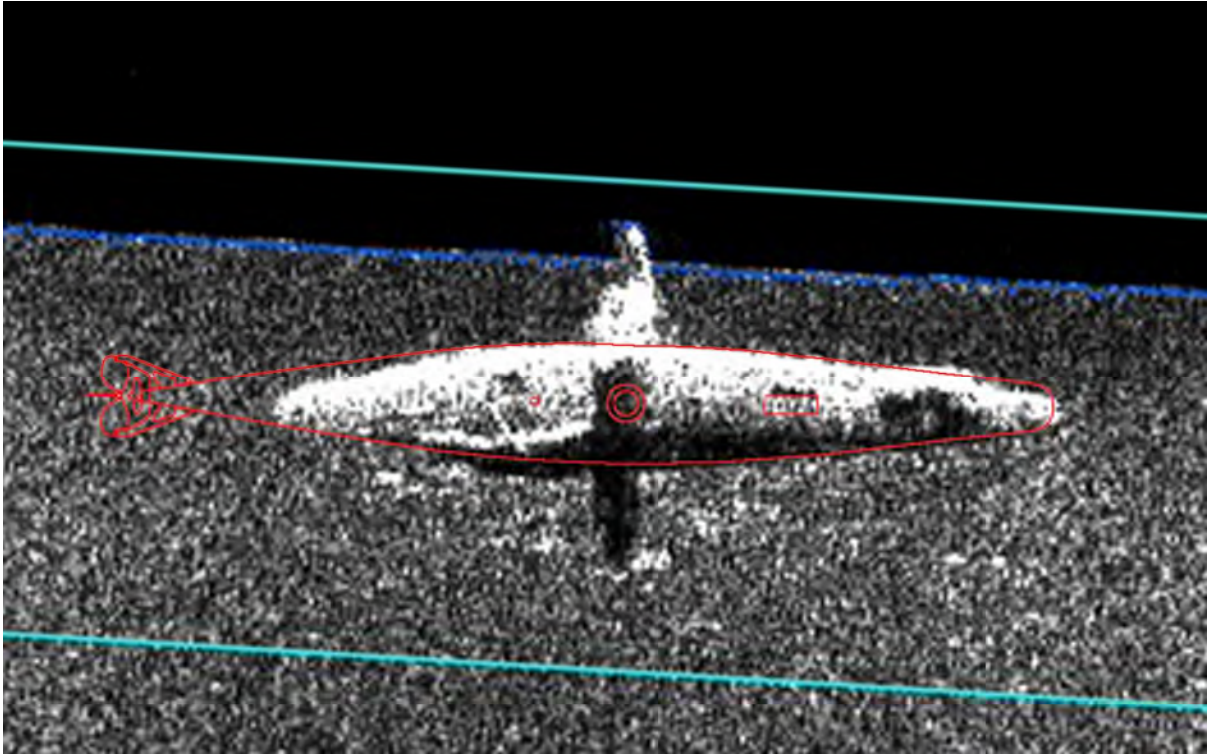


Figure 20: 2013 side scan sonar image overlaid with the outline of the hull

The bow of the submarine points to the north west and the aft four metres of the submarine hull, propeller, hydroplanes and rudder appeared to be buried (Fig. 20). The sonar image showed a 1.4m long dark feature on the hull 4m forward of the conning tower which corresponds with the torpedo loading hatch (red rectangle). This initially suggested that the hatch was open so the MOD was alerted to the possibility. It was subsequently found that the hatch was shut and this was simply a sonar artefact caused by the hatch itself.

Scars on the seabed were noted on the sonar record which are thought to be made by fishing trawls. The original sandy seabed around the submarine has been covered in a thick layer of fine silt deposited during recent dumping operations on the disposal site to the east so the seabed seen today is recent. The trawl scars suggest that fishermen are trawling within 20m of the hull and as they can still be seen this activity is likely to have happened recently (Fig. 21).

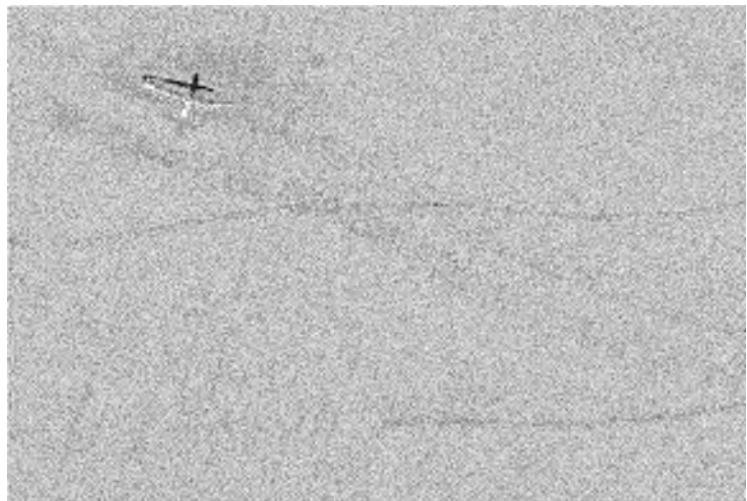


Figure 21: The two dark lines south and east of A7 are scars on the seabed made recently by trawl fishing

10.3. Marine geophysical survey

Before undertaking any investigation of the site by divers, the remains of submarine A7 were mapped using current marine geophysical survey techniques, including side scan sonar and multibeam sonar with the assistance of Plymouth University School of Marine Science and Engineering. This work formed the subject of a Plymouth University MSc Hydrography dissertation by student Mawgan Doble; the project was well executed and the dissertation achieved a distinction mark⁷⁴.

In this survey an area 500m x 500m was mapped, with the centre of the area on the known position of the submarine. The geophysical survey did not include any investigations below seabed level.



Figure 22: Plymouth University student Mawgan Doble mapping the A7 using multibeam sonar

On 5th June 2014, a bathymetric survey was undertaken using the Plymouth University's R2Sonic SONIC 2024 multibeam echo sounder (MBES) system from the University's survey vessel *Falcon Spirit*. For wide area mapping the R2Sonic 2024 MBES was set to transmit at 400kHz while for detail recording the same instrument was used at 700kHz. GNSS augmented positioning was provided by the Fugro Marinestar XP service, which claims 10cm horizontal and 15cm vertical accuracy, and vessel attitude was measured using an Applanix POS MV Wavemaster integrated in to the R2Sonic system.

Full details of the survey methodology and results can be found in Doble, 2014, *A Site Investigation of HM Submarine A7*.

10.4. Position and orientation of the hull

A precise position and orientation of the hull was determined using results from the vessel-mounted multibeam echo sounder survey as this provides more precise information than had been previously obtained using the towed side scan sonar.

The position and attitude of the centre of the conning tower is:

Position:	50° 18.5257 N	004° 18.0062 W	(WGS84)
Heading	284° True		
Roll	5° degrees to port		
Pitch	Even keel		

The position of the centre of designation for the site is 50° 18.518 N 004° 17.984 W⁷⁵.

The designation position is 30m from the actual position of the submarine on a bearing of 120° T.

10.5. Site charts

The bathymetric survey showed that the seabed around the submarine is largely flat and featureless with a gentle slope in depth to the south from 35m to 37m. In Fig. 23 below the submarine can be seen in the centre of the picture as the only feature within the survey area.

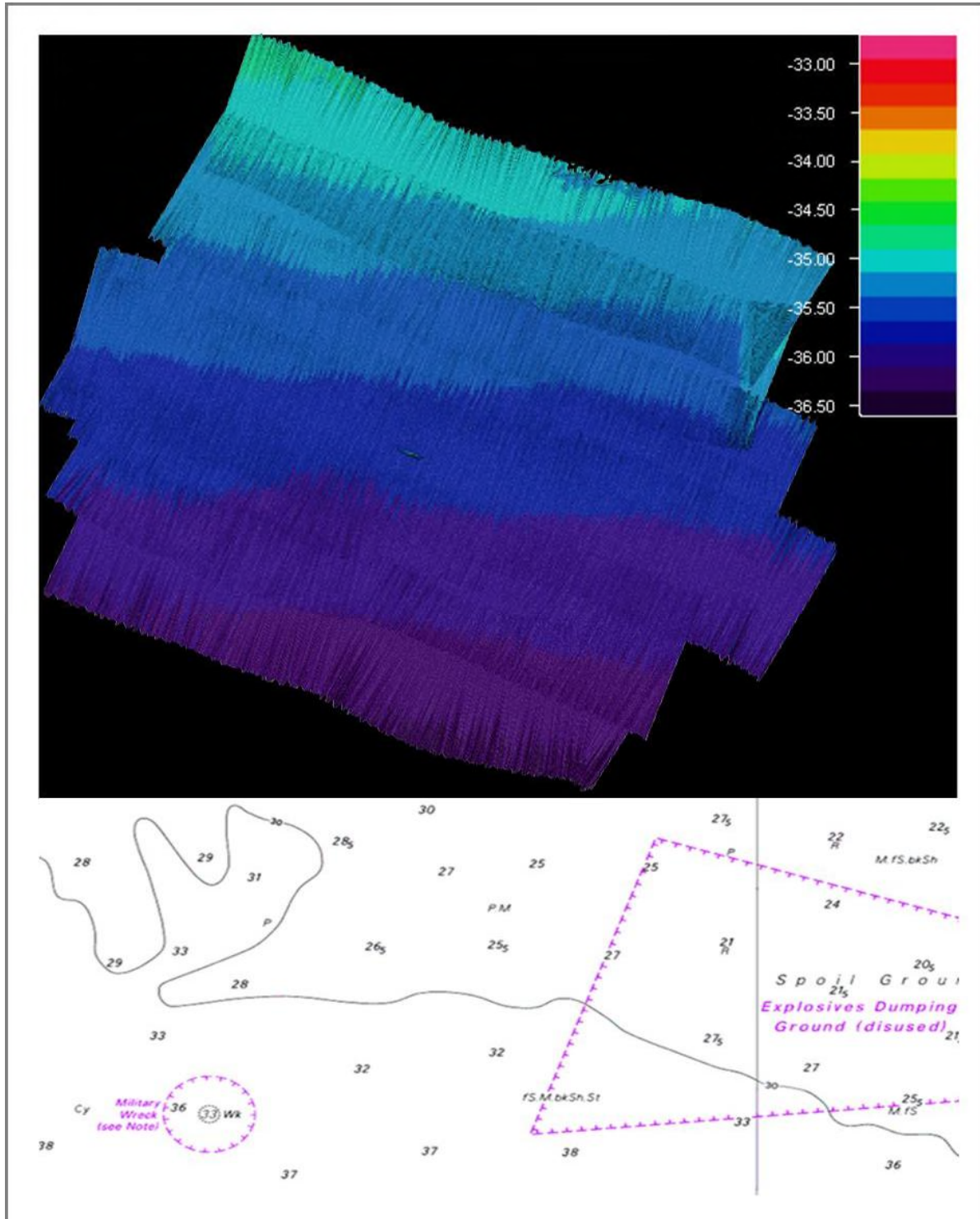


Figure 23: An overview of wreck site at 400 kHz with extract of Admiralty Chart 1900-0_w inserted below (Doble 2014)

10.6. 3D model

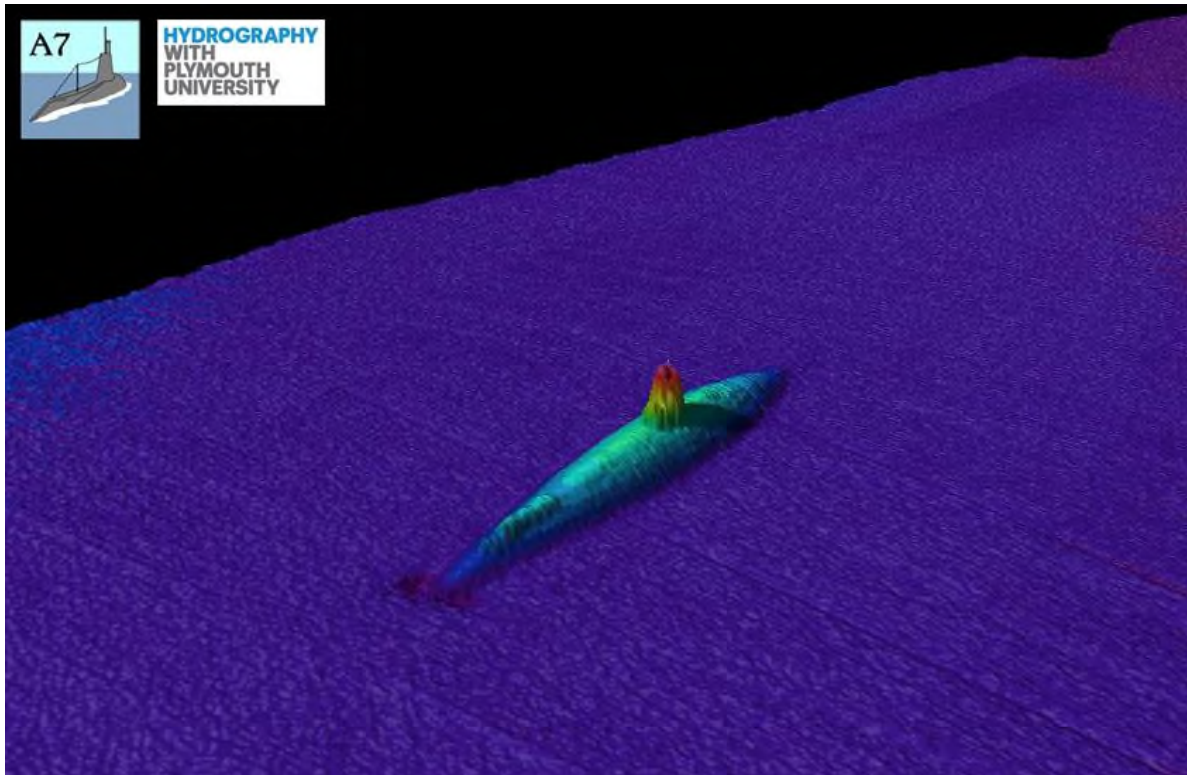


Figure 24: Three-dimensional model of the A7 submarine created from the multibeam sonar data, showing the submarine partially buried in the flat seabed and the small scour round the bow.

The results of the high resolution (700kHz) multibeam echo sounder (MBES) survey were used to create a detailed three-dimensional model of the wreck and seabed around it (Fig. 25, 25). The sonar showed the submarine to be as estimated from the previous side scan survey: largely intact, upright, with bows to the north-west and buried up to her waterline. The conning tower is shown along with the remains of the cutwater on the bow and the binnacle mounting aft.

Of the 30.2m length of A7 just 25.4m is visible on the surface. The deck is 1.1m proud of the seabed at the highest point near the conning tower and the tower itself extends a further 2.2m above the seabed. At the widest point on the hull the visible part of the submarine is 3.97m wide.

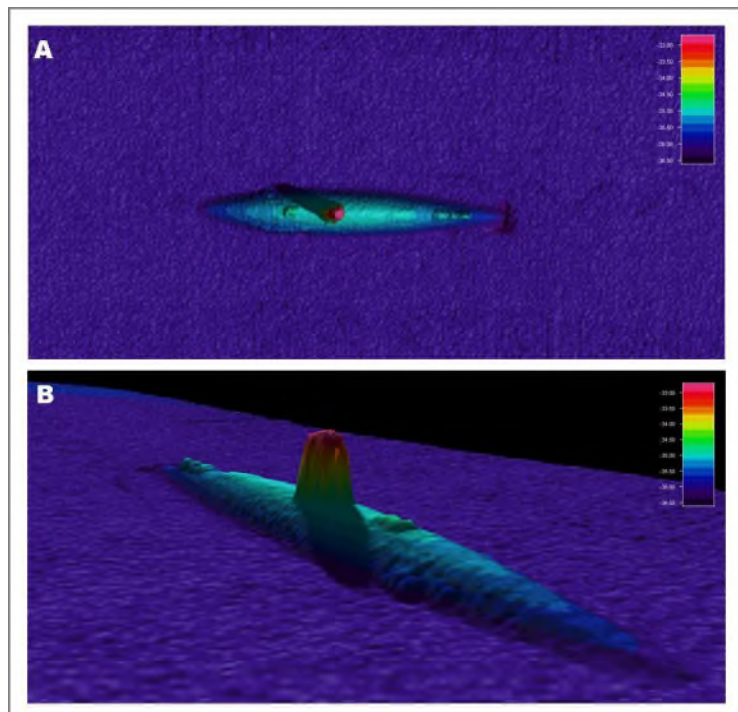


Figure 25: Two views of the 3D model from above and from the port side stern looking forward

10.7. Objects on the seabed around the submarine

The side scan sonar and the multibeam sonar were used to search for any objects on the seabed that lie close to the submarine.

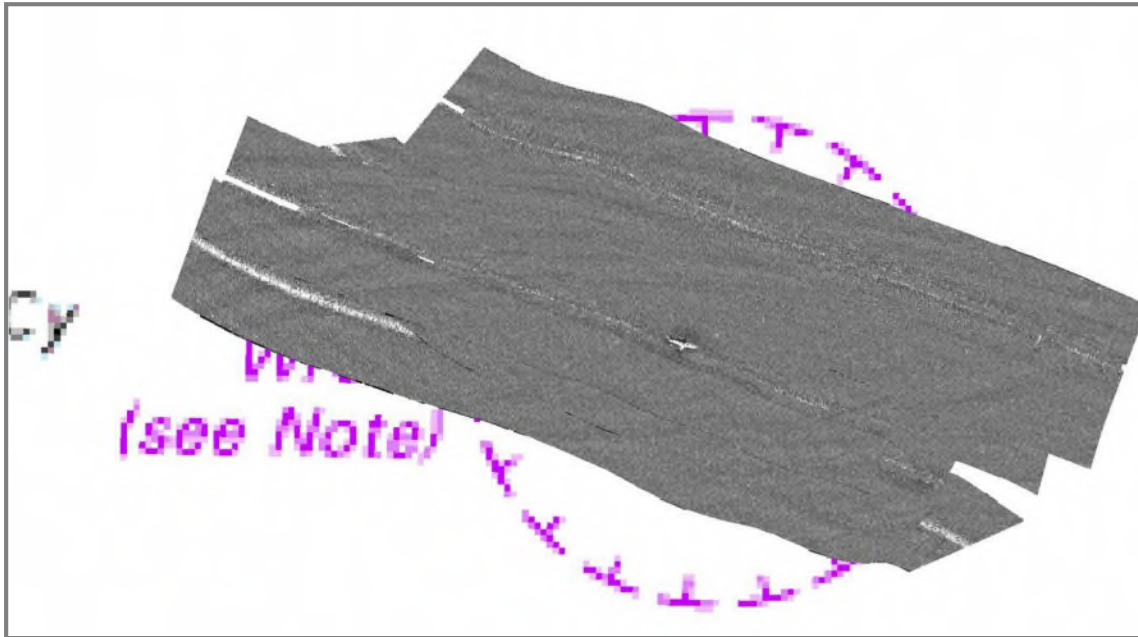


Figure 26: Mosaic of the GeoAcoustics side-scan sonar survey at 410kHz (Doble 2014)

Only one target (GS6) was detected near the submarine at 50° 18.510 N 004° 18.075 W; the object was 1.8m long and proud of the seabed. This target was not considered significant as it was 85m from the hull so was unlikely to be associated with it (Fig. 27). The recently deposited soft sediment covering the seabed in the area is likely to have buried any small objects from the submarine that were lying close to it, so they would not be detected with the side scan sonar.

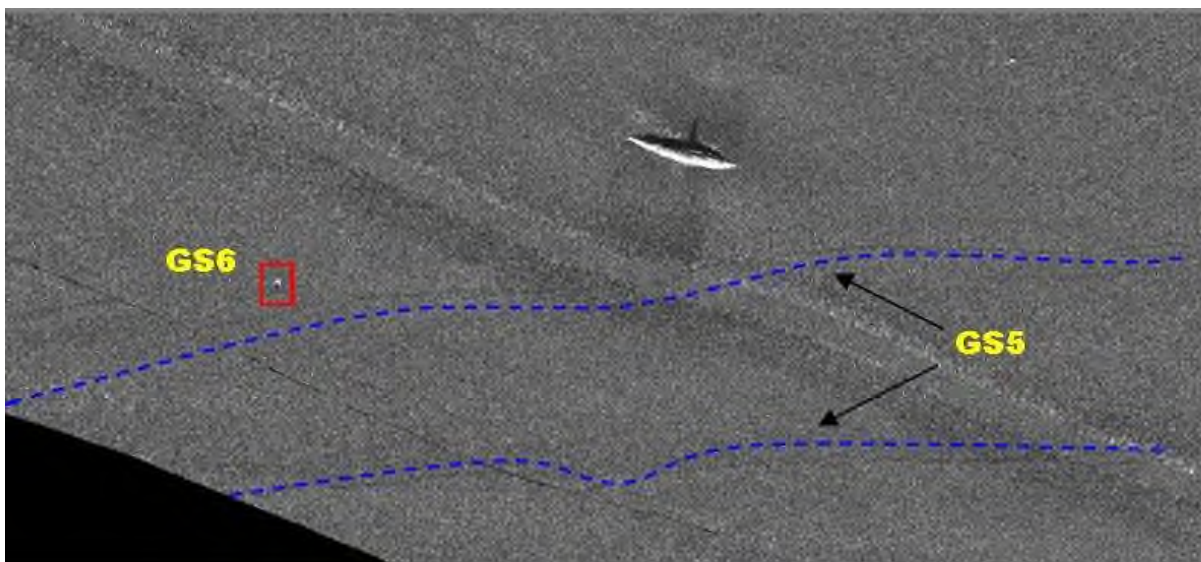


Figure 27: Mosaic of the GeoAcoustics side-scan sonar survey at 410kHz (Doble 2014)

The feature GS5 in Fig. 27 are scars on the seabed made by a fishing trawl net.

10.8. Bow Scour

The 3D model of the submarine and seabed recorded by the multibeam sonar clearly shows a scour pit formed around the bow, the pit is 0.3m in depth and approximately 3m wide (Fig. 28). The scour has been formed by tidal currents flowing around the submarine and is a common feature of shipwrecks buried in soft sediments. The scour around the bow allows more of the torpedo tube shutters to be seen than would otherwise occur.

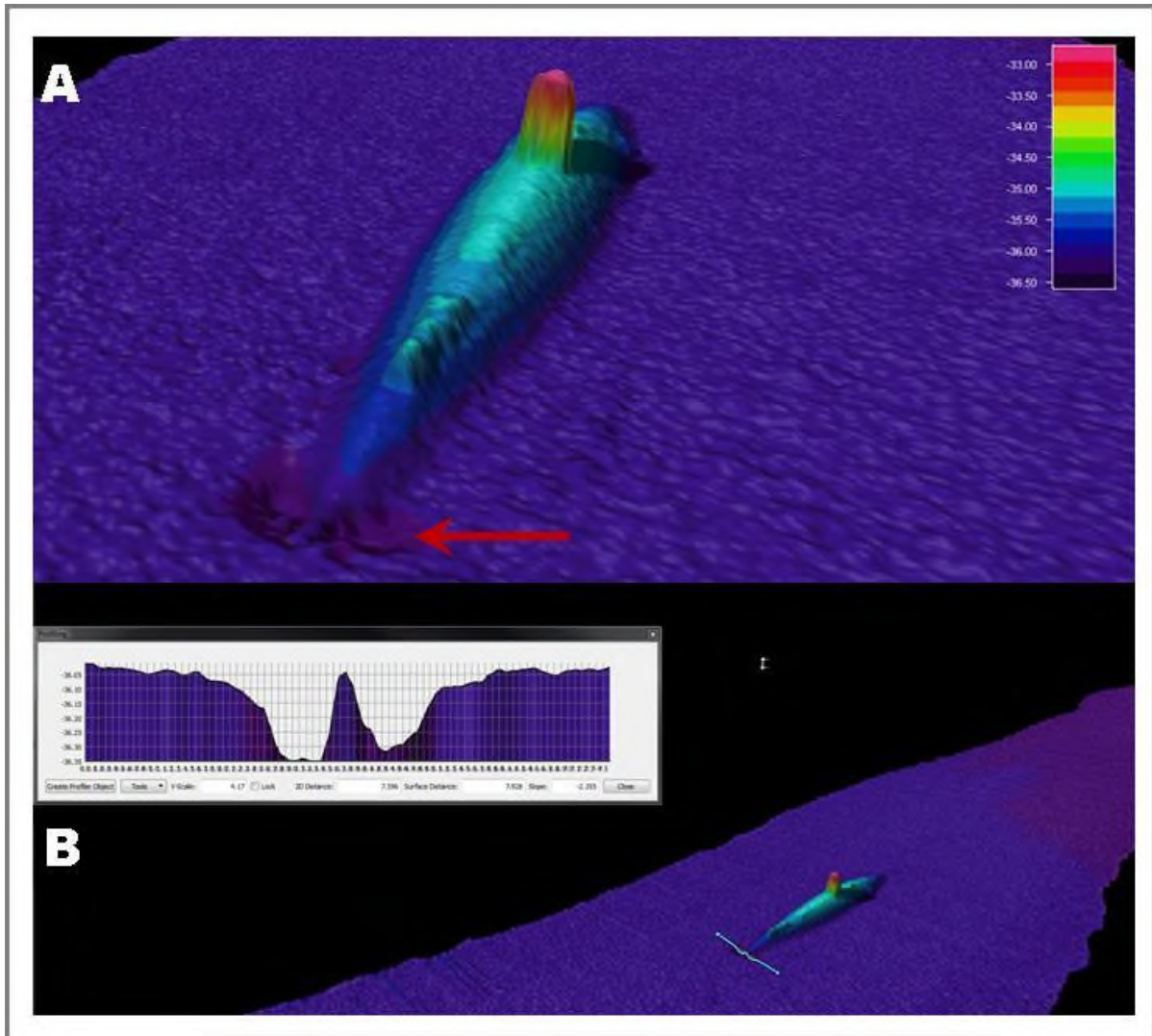


Figure 28: Bow view of the 3D sonar model (A) and a cross section through the bow scour (B)

11. Condition Assessment

11.1. Introduction and Method

Introduction

The hull of the A7 has been modified by a variety of sources, some natural, some during contemporary salvage attempts and some by sports divers in recent years. By investigating how the wreck of the A7 has achieved its current state we may learn more about how similar submarine wreck sites degrade over time and perhaps make better predictions of how they are likely to degrade in the future.

No detailed survey or recording work had been undertaken on this submarine prior to the A7 Project. Very few photographs of her prior to designation have been found during research and no film or video has been located. Some information about the site was made available to the project by sports divers who had visited A7 prior to designation but the quality of that information was variable. The divers were often not familiar with the features of the submarine, it was usually dark with poor visibility making interpretation difficult and the divers' ability to remember features on the site will have been adversely affected by nitrogen narcosis.

The three-dimensional model of the submarine created by the multibeam sonar data was used as the starting point for the detailed recording. From the sonar survey we knew that A7 was largely intact, upright, with bows to the west, the periscope was bent backwards and the hull was partially buried in the seabed, as shown in Fig. 29.

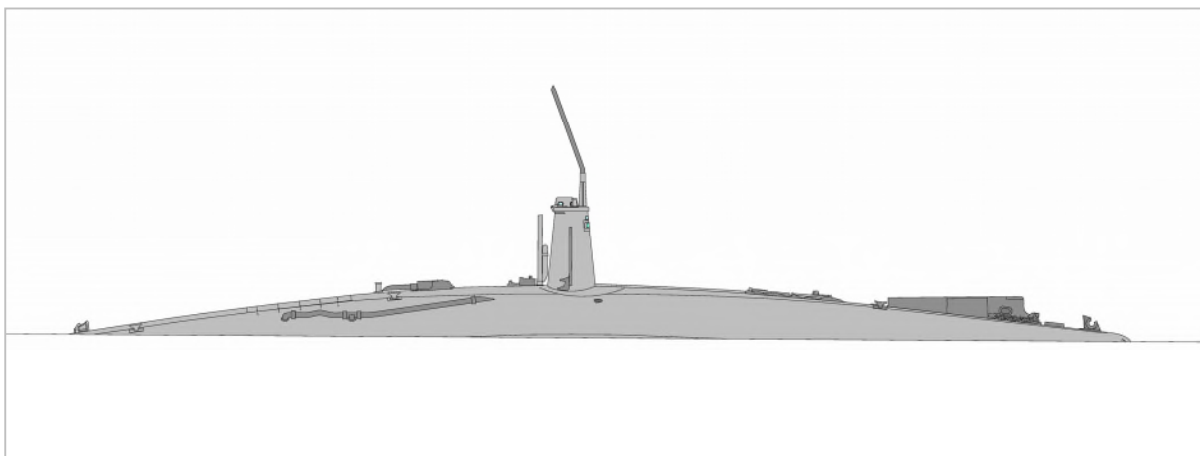


Figure 29: Starboard side elevation of the visible part of the submarine as seen in 2014, created using the Project survey results

Method

The condition assessment tasks were started once the wreck had been checked for hazards by the first dive team on site. Visibility on site was limited to a few metres so photography and video were usually restricted to small areas of the hull. The seabed around the hull is covered in a very fine, light sediment that was easily disturbed and did not fall out of suspension easily. Even the normal activity of the fish that inhabit the site stirred up enough sediment to adversely affect photography. Daily dive tasks were planned so that any tasks likely to disturb sediment were scheduled to happen after tasks needing good visibility.

The record of the marine life that inhabits the submarine was completed before the site was disturbed by other recording work. Fortunately, the submarine's steel pressure hull and conning

tower were largely free of encrusting marine life so the hull could be recorded without cleaning. This allowed the recording work to be completed as the pink sea fans that were growing on the hull are a protected species and were not to be disturbed.

When the submarine was first seen in 2014 the conning tower top and periscope were covered in a thick layer of plumose anemones and abandoned trawl net. The net and anemones obscured the details of the conning tower top so the net was cut away with shears and the anemones carefully removed using plastic scrapers and a plastic deck brush that would not damage the underlying metal. Removing the net also reduced the weight suspended on top of the conning tower leaving less to be supported by the rapidly thinning steel that forms the conning tower.

The entire hull was recorded on video using GoPro HERO3+ Black Edition cameras and video lights with detailed areas recorded as required. Before each dive the divers were briefed and provided with a plan of the hull showing the video images that were needed. Video taken on the site was used on subsequent days to help plan the tasks to be completed and brief the dive teams.



Figure 30: Photomosaic of the bow of A7 showing the torpedo loading hatches, hole H3 and the remains of the cutwater

Still photographs were taken using a Nikon D5200 digital camera fitted with an 11mm rectilinear lens in an Ikelite housing and custom dome port. Natural light was used for wide angle photographs on the rare occasions when visibility was good and two Ikelite DS160 strobe lights were used for detail photographs. An Orcalight Seawolf 2260 canister dive light⁷⁶ was loaned to the project for evaluation and this was used to provide wide area floodlighting at a distance from the camera (Fig. 31).

Trials during work-up dives on other wreck sites showed that the 22000 lumen light could be used to produce better results on deep, dark wrecks than could be achieved using the more usual strobe lights. Unfortunately, the times when the Orcalight was available to be taken onto the A7 site the weather was too poor to allow diving or the visibility on site was too low to be able to use the light effectively.

The short time available on site, poor visibility and potential for narcosis meant that survey work on site had to be as simple as possible. Positioning along the hull was controlled by a simple fibreglass tape baseline fixed between two control points so the tape ran along the top of the hull on the port side. The control points were 10mm stainless steel rods that were pushed into the soft seabed with one on the centreline of the submarine just forward of the bow and one on the centreline aft close to the upper rudder bracket.



Figure 31: Team diver April Cunningham carrying the Orcalight 2260 canister light

Errors in the measurements along the tape caused by the change in height of the tape along the hull were corrected during post-processing.

Detailed measurements and sketches were made of particular features on the hull and conning tower and any areas of damage. Some very limited seabed probing was done at the bow to confirm that both torpedo tube doors were closed and at the stern to check if the rudder and hydroplanes were still in place.

Diving operations were run safely with no accidents occurring during the 2 month fieldwork season. Dives were undertaken on the site from 7 August to 29 September 2014. Thirteen divers completed 24 dives with a total of more than 500 minutes on site.

Human Remains

No human remains were seen during the survey operations.

As A7 constitutes the last known resting place of the crew who were lost with the vessel the team implemented the following protocol for human remains:

1. No intrusive activity was undertaken on the vessel. No attempt was made to enter the hull or to record the interior of the vessel. All photographs and video were taken from outside of the hull.
2. Had any images taken from outside the hull inadvertently recorded any human remains these images were not be put into the public domain and would be restricted in circulation to MOD and English Heritage.
3. If, in the unlikely event, that human remains were encountered outside the hull the composition and location would be recorded and the matter referred immediately to MOD for further direction. The team would then implement the further directions received from MOD at no cost to MOD.

Note that the Burial Act 1867 does not apply to human remains on wrecks since these are not deliberate internments.

Unexploded ordnance and environmental hazards

No unexploded ordnance or environmental hazards were seen during the survey operations.

The protocol for unexploded ordnance and environmental hazards was:

- Since A7 was not equipped with a deck gun it was not anticipated that ordnance would be found. It was assumed that the torpedoes present on site would be practice torpedoes which remain within the hull. If any torpedoes were encountered outside the hull they would be recorded but, in accordance with the Project's 'no recoveries' policy, no intrusive activity would be directed at them.
- Since no intrusive activity would be undertaken no environmental risks to divers, beyond the normal diving risks, were envisaged. The existence of any environmental risks encountered e.g. leaking oil, lubricants etc. would be recorded and reported in the Project Report.

11.2. Permissions

Protection of Military Remains Act 1986

The site was designated in 2002 under the Protection of Military Remains Act 1986 as a 'Controlled Site' (see now Protection of Military Remains Act 1986 (Designation of Vessels & Controlled Sites) Order 2008: SI 2008/950)).

Controlled Sites are designated areas of seabed comprising the remains of a military aircraft or a vessel sunk or stranded in military service less than two hundred years ago (s.1). It is an offence within a Controlled Site to tamper with, damage, move or unearth any remains, enter any hatch or opening or conduct diving, salvage or excavation operations for the purposes of investigating or recording the remains, unless authorised by licence (s.2(3)(a)). Since unauthorised investigation is prohibited, it is accepted that any unlicensed diving is prohibited on these sites⁷⁷.

Application was made to MOD for a licence under the 1986 Act and the license was granted for a 2 month period of diving fieldwork on the site. All project personnel were made aware of the restrictions imposed by this Act and any specific licence conditions and were required to abide by them at all times as a condition of their continued participation on the project.

Merchant Shipping Act 1995

As no recoveries of wreck were contemplated by this project proposal no implications arise under this legislation.

Marine & Coastal Access Act 2009

No activity undertaken on the site had a requirement for a marine licence under s.65. A mooring buoy was laid, the Marine Management Organisation was notified and it did not remain in place beyond 28 days so it was exempted under Article 4, para. 22 Marine Licensing (Exempted Activities) Order 2011 (as amended)(S.I. 2011/409).

Since, with the exception of anchors and shot weights, no objects were to be deposited on the seabed by a vessel or recovered from the seabed using lift bags or a vessel, no licence requirement was triggered. The deposition of anchors and shot weights is an exempted activity (Article 4, para. 26A 2011 Order).

12. Significance

The remains of submarine A7 are significant for a number of reasons, primarily as the last resting place for her crew who died during a training exercise in 1914 but also because the submarine is of historical and technological importance.

Since the A7 sank in January 1914 and was a vessel being used for training submariners for the widely anticipated forthcoming hostilities, its loss can legitimately be placed within the historical context of WW1 military casualties. This is especially true since the RN was coming to a higher state of readiness in early 1914, reflecting the view in both the military and political establishment that war with Germany was a very real possibility at that time. The RN was experimenting with the development of tactics for operational deployment of new submarine maritime technology and the A7 appears to have been a casualty of this development as part of preparations for war. Its loss therefore had a developmental connection with WW1 and culturally should be seen as such.

The A7 is of importance for a number of historical and technological reasons:

- A7 is one of only three A class submarines that still survive today: A1, A3 and A7
- A7 is the last surviving member of the Group II A class submarines A5-A12
- The Group II boats were the end result of the development of the unique prototype vessel A1 and the experimental Group I vessels A2 - A4, and as such the Group II boats are the culmination of this particular design
- In service for approximately 11 years⁷⁸, the Group II boats can be considered to be the first practical and useful submarines in the Royal Navy, and thus an icon for the RN Submarine Service.
- Unlike her sister boats A1⁷⁹ and A3⁸⁰, submarine A7 is almost entirely complete
- The A7 is the result of an unusual and very rapid design process involving Vickers and Capt. Bacon that was untroubled by the constraints of the Director of Naval Construction⁸¹
- No external general arrangement drawings have been located for any of the A class boats so the surviving hulls are the only record of the external fittings
- No internal general arrangement engineering drawings have been located for the Group II submarines. Internal general arrangement drawings have been found for the Group I boats and A1 but the layout and fittings are different.
- Documents have not yet been located that describe the operating procedures for the A class boats so we do not know how their systems worked
- The petrol engine in A7 is the last example of the final Wolseley design for an engine that was far ahead of its time when it was developed⁸²

Were this vessel not designated as a Controlled site under the Protection of Military Remains Act there would be a good case for designation under the Protection of Wrecks Act (1973).

13. Condition Assessment - Features

13.1. Introduction

The condition of the features of the submarine are described in order from forward to aft, including:

- Torpedo tubes
- Cutwater, towing eye and Samson posts
- Foredeck
- Conning tower forward
- Conning tower aft
- Conning tower top
- Periscope
- Flying bridge
- Compass binnacle
- Aft deck and stern gear
- Exhaust system
- Pressure hull

The location of each feature on the hull is shown in Fig. 33.

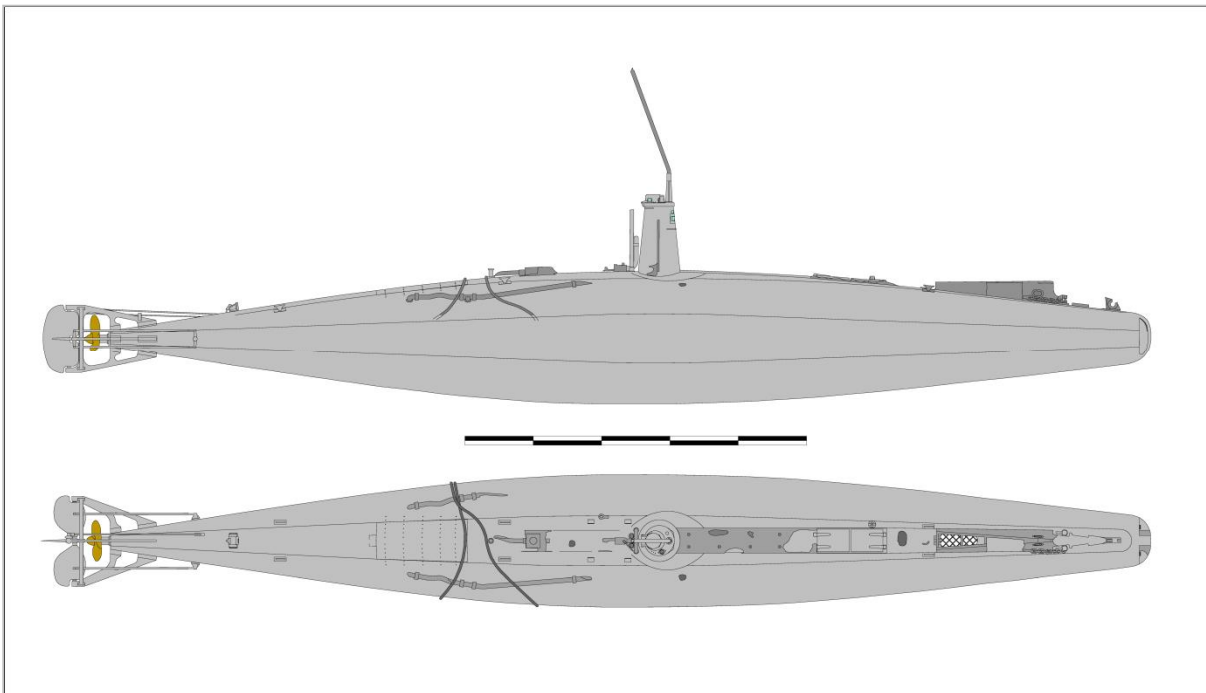


Figure 32: General arrangement plan and elevation drawing of A7 as seen in 2014

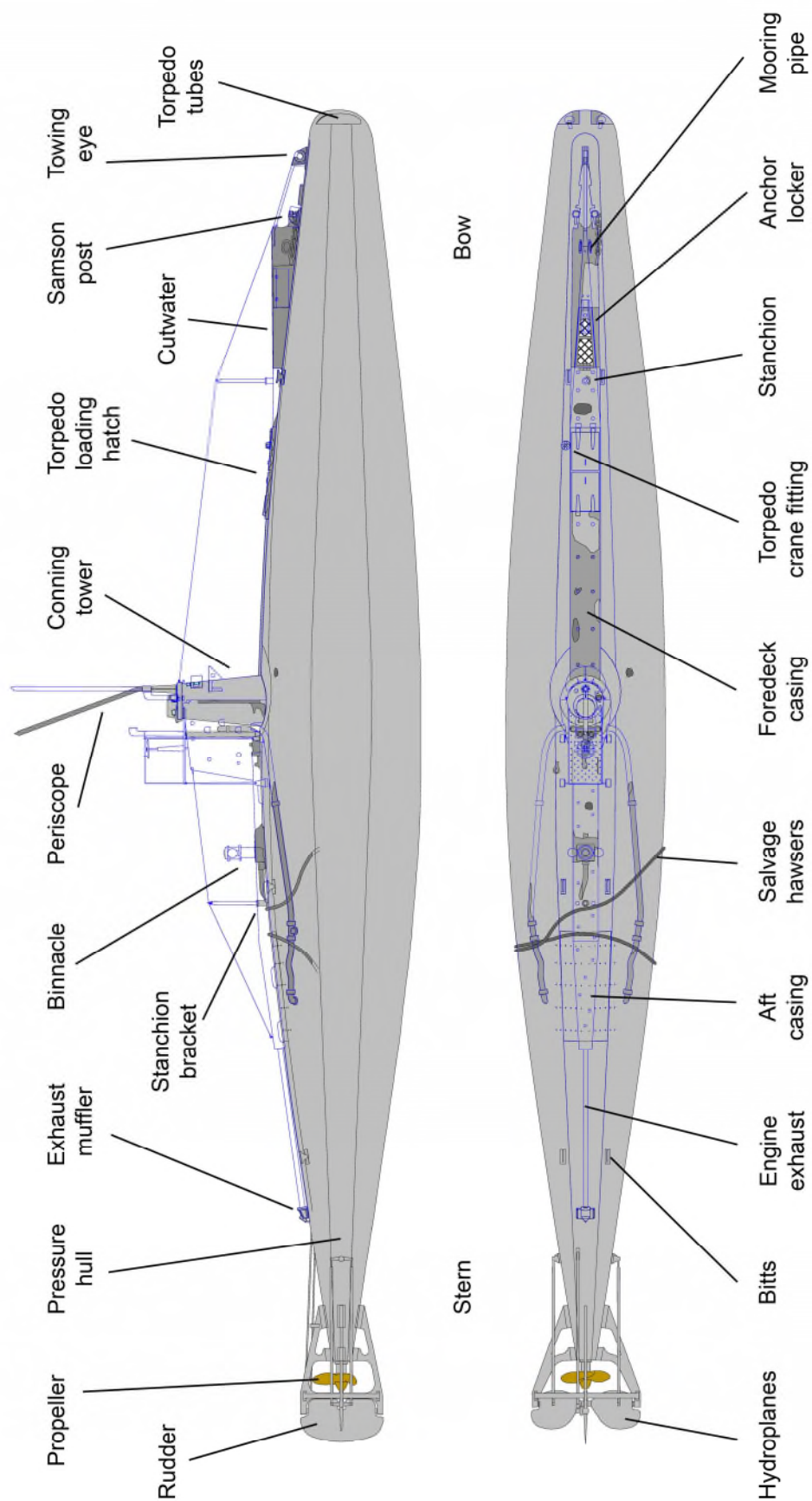


Figure 33: Diagram showing the names of features on the hull

13.2. Torpedo Tubes

The A7 is fitted with two 18 in. forward firing torpedo tubes mounted side by side in the bows of the boat. The outboard end of each tube is closed with a waterproof cap; this is opened and closed using a large hand wheel mounted on the inboard end of the tube. On the outside of each cap is a curved shutter made of thin steel plate so when the cap is closed the shutter improves the hydrodynamic form of the submarine's bow. The shutter is attached to the cap so when the cap opens the shutter slides upwards and backwards in to the casing. There is a hole in the shutter on its upper edge to allow access to the cap opening mechanism when the cap is closed and the shutter is down. Photographs of similar submarines show that an access panel hinged on the outside of the pressure hull covers the hole in the shutter when the shutter is in the closed position, with a chain attached to the shutter to hold down the access panel when the shutter is closed (Fig. 35).



Figure 34: Starboard bow looking aft, showing remains of the torpedo tube shutter and worm drive for opening the tube bow cap



Figure 35: The same design of torpedo tube, bow cap, shutter and inspection panel on submarine C1

On the A7 submarine both torpedo tube caps are closed and the shutters are down but both access panels and chains are missing. Photographs of A class submarines in service show them fitted both with and without these panels so they may not have been fitted to the boat when A7 sank. At the current burial depth of the hull the torpedo tube caps and opening mechanism should not be as exposed; however the shallow scour pit formed around the bow of the submarine allows more of the bow features to be seen (Fig. 34).

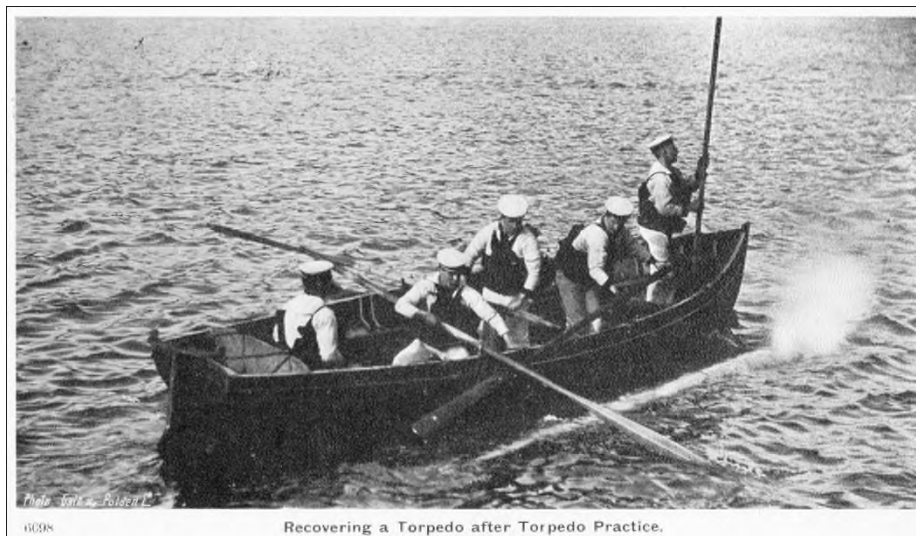


Figure 36: Postcard showing how practice torpedoes were recovered (Lawrence Collection)

13.3. Cutwater, towing eye and Samson posts

All A class submarines except for A1 had a raised cutwater fitted to the bows which would improve the boat's sea keeping capability when underway on the surface (Fig. 37). Water forced over the bows at speed could push down the nose of the boat and make her dive when least expected. The cutwater reduced the effect of the bow wave in A class boats but in the later B class this was improved by fitting a larger raised superstructure on the bow as a free flooding casing. The cutwater on A7 is constructed of thin steel plate over a steel frame built on top of the pressure hull. The hollow cutwater also contained the locker for stowing the small anchor and chain.

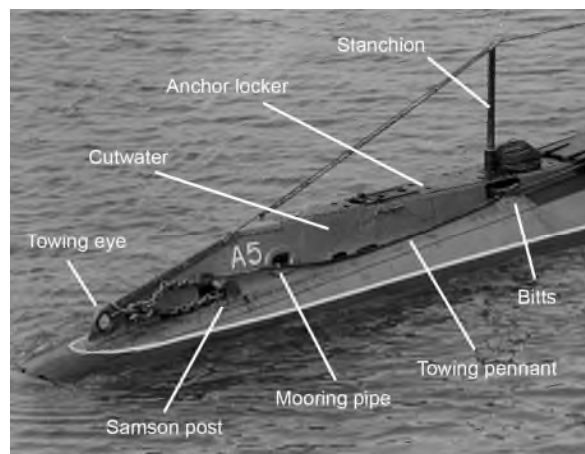


Figure 37: The names of features on the bow

A large reinforced steel towing eye was fitted to the forward end of the cutwater which could be used to attach a towing line to the bow and would be used when mooring the boat alongside (Fig. 38).

The towing eye on A7 is still in place and still firmly attached to the hull despite the reports that it had 'started'⁸³. The upper quarter of the ring is missing as it was broken during contemporary salvage attempts.



Figure 38: The remains of the towing eye from the starboard side, showing the missing upper quarter

The forward part of the cutwater is also completely missing, from the aft end of the towing eye to just aft of the two Samson posts mounted on the pressure hull forward of the mooring pipes. The remainder of the cutwater frame is still in place and in good condition. The missing forward section of the Cutwater may have been damaged during salvage work as parts of the structure were reported to have been recovered back to the surface⁸⁴.

The two Samson posts are still securely attached to the hull (Fig. 39). The remains of a towing pennant is attached to each of the Samson posts with a short length of chain that were used to reduce the effects of chafing on the cable when towing. The eye of the pennant wire is in place but the wire itself has corroded away on both sides, but on the port side the eye at the other end of the towing pennant can still be seen aft of the conning tower.

Aft of the Samson posts are two mooring pipes fitted flush to the sides of the cutwater. In contemporary photographs in the project archive the starboard side pipe is used as a hawse pipe for the anchor and the port side pipe is unused. A contemporary photograph of an A class in dry dock shows a pair of horizontally mounted rollers fitted to the hull within the cutwater alongside the mooring pipes. The anchor was stowed in the anchor locker on the starboard side with its chain led in through the starboard mooring pipe, around the rollers and in to the chain locker at the aft end of the cutwater where it attached to a strongpoint fitted to the top of the pressure hull.

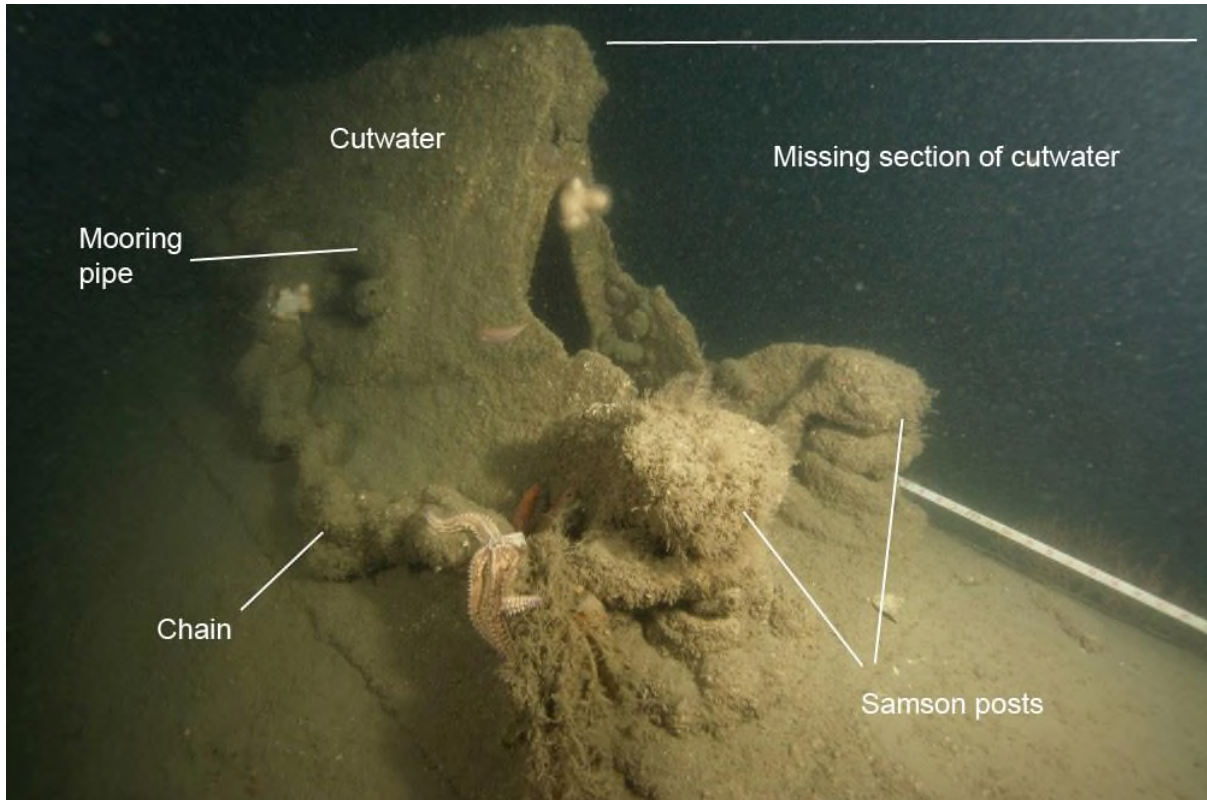


Figure 39: Cutwater and fittings on A7 from the starboard side looking aft

The thin steel casing is missing on the sides and top of much of the cutwater. The hatch over the anchor locker on the starboard side is missing as is part of the steel frame. An old trawl net is embedded within the anchor locker suggesting that some of this damage was caused by a trawler (Fig. 40).

The small anchor and chain can still be seen in the aft section of the cutwater, with the remains of the anchor strong point underneath still firmly fixed to the hull (Fig. 41).



Figure 40: The remains of the chain locker in the cutwater from the starboard side

13.4. Foredeck and Torpedo Loading Hatch

Aft of the cutwater are the eroded remains of two bitts fitted to pads on the pressure hull, one on each side.

The bracket that mounted the forward stanchion has been broken so only a small part of the circular base plate remains.

The casing between the cutwater and the torpedo loading hatch is missing. Here there is an oval shaped hole in the main pressure hull. The hole (H3) is on the highest point of the hull and sits across the centreline. This hole is discussed further in section 13.13 Pressure Hull.



Figure 41: Aft end of the cutwater looking forward, showing the two bitts, the remains of the stanchion bracket and the anchor strong point

The two rectangular torpedo loading hatch doors are firmly closed (Fig. 42). It is not clear if the hatches cover two separate rectangular holes in the hull or the two cover one larger hole. One larger hole would be more useful but there would be difficulty sealing it against the water pressure in the middle where the hatches meet. Contemporary photographs suggest that there are two separate rectangular holes.



Figure 42: The aft torpedo loading hatch

The port side of the aft door appears to have been levered up slightly, damage thought to have been done by visiting divers attempting to gain entry to the submarine⁸⁵.

At the forward end of the hatch on the port side is the vertical circular webbed bracket for mounting the removable davit that could be fitted to assist loading torpedoes through the hatch (Fig. 43).

The narrow casing that formed a walkway along the top of the hull is missing in many places and what remains is very thin and friable.

Just in front of the conning tower on the starboard side and 1m off the centreline is a small hole in the hull (H1), see section 13.13 Pressure Hull.



Figure 43: Torpedo loading davit bracket

13.5. Conning Tower - Forward

The fin of the submarine includes the conning tower which was part of the pressure hull plus a thin steel fairing that was intended to reduce drag through the water. The fin fairing contained two vertical ventilator tubes, the exhaust loop, exhaust pipe and the steering control shaft.

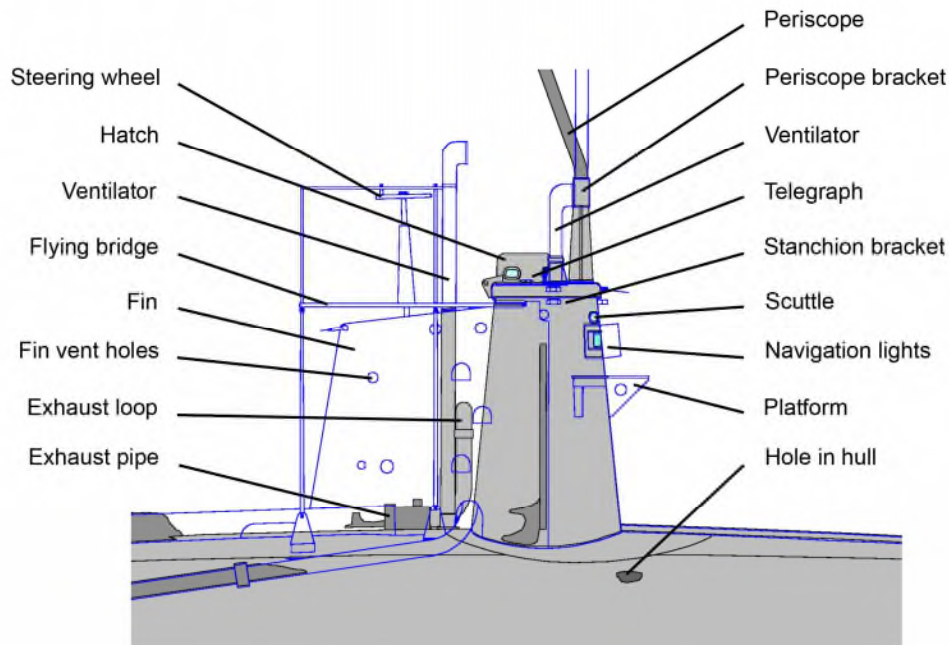


Figure 44: The names of features around the conning tower

The conning tower is still intact: this forms part of the pressure hull. The free flooding fairing was made of thin steel plate and has either been removed during contemporary salvage attempts or has simply eroded away.

The entire fairing is missing apart from one small fragment each attached to the conning tower at deck level on both sides, as well as a thin strip down each side of the conning tower where the forward end of the fairing was attached (Fig. 45).

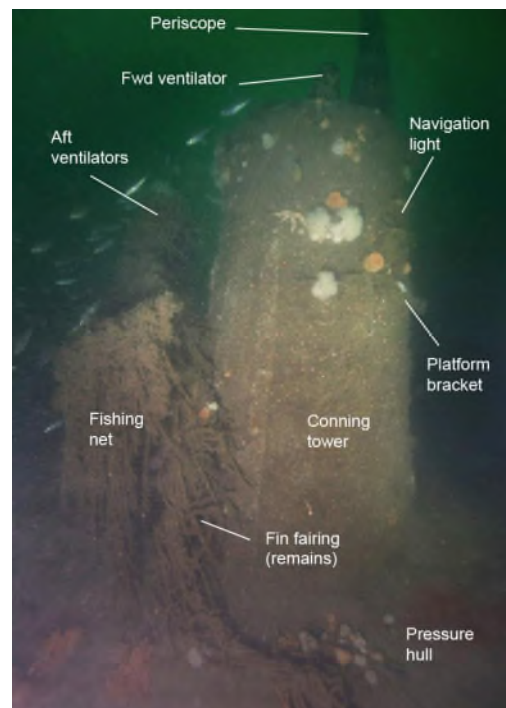


Figure 45: The conning tower from the starboard side

There are two small rectangular scuttles (windows) mounted on the front of the conning tower just above the navigation lights. The scuttles would allow some light in to the conning tower and would allow a limited view forward. The glass in both scuttles is still intact (Fig. 46).



Figure 46: Intact scuttle on the port side

Two navigation lights were mounted on the front of the conning tower above the platform, one on the port side and one on the starboard, with blinkers on the inboard side to restrict the angle over which each light could be seen. It had been reported that by August 2001 the navigation lights had been removed from the conning tower⁸⁶ but the port light is still in place and just the starboard one has been removed. The port light is in good condition with the glass lens intact (Fig. 47).



Figure 47: Intact navigation light on the port side

A small platform was fitted to the front of the conning tower about half way up. When underway on the surface it was likely that water would have been pushed up the front of the conning tower, so the platform may have been fitted to protect against water entering the submarine if the main hatch was open. Contemporary photographs also show this platform being used as an additional place for the crew to stand when the boat was on the surface (Fig. 48).



Figure 48: Conning tower looking aft; the remains of the horizontal platform bracket can be seen half way down

The remains of the bracket that attached the platform to the conning tower can still be seen.

Three stanchions could be fitted around the top of the conning tower that were used to hold up a canvas spray dodger; the dodger would provide some protection for the crew on the flying bridge when the submarine was underway on the surface. The three brackets for the stanchions are still in place on the top of the tower.

13.6. Conning tower aft

Aft of the conning tower and within the fin fairing are two 3½ inch (89mm) vertical ventilator tubes that were used as the exhaust for the forced ventilation of the battery compartment when the submarine was on the surface⁸⁷. The tops of the tubes could be fitted with removable cowls which were removed before the submarine dived; the cowls were made of brass and polished to a high sheen. Both ventilator tubes are in place and still exist to their full length.

When on the surface the submarine could be steered by the coxswain while he was standing on the flying bridge. A steering column topped with a removable brass hand wheel led down from the bridge to a universal joint at deck level, through the exhaust pipe on the centreline of the submarine then into the pressure hull where it connected with the rudder controls. The remains of the steering column now lie across the hull, still connected at the universal joint to a fitting through the remains of the exhaust pipe (Fig. 49).

Between the conning tower and the ventilators is the exhaust loop, see Exhaust System below.

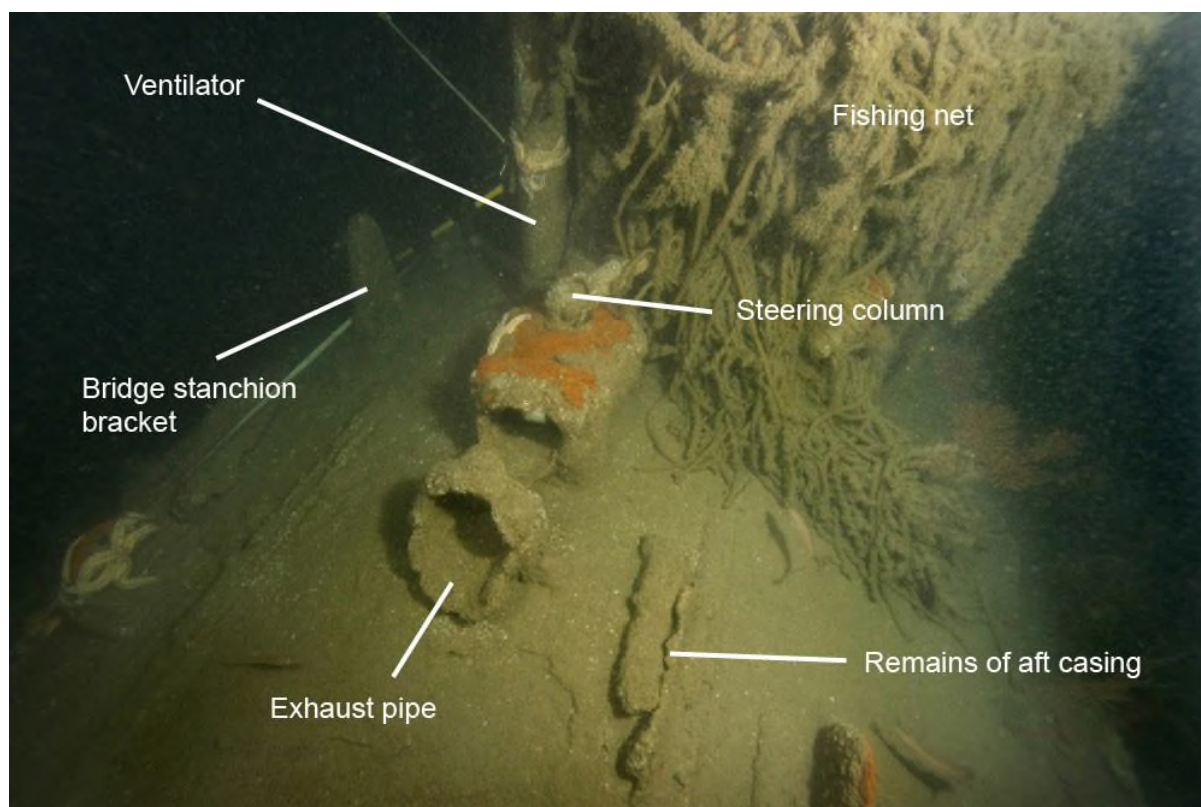


Figure 49: View of the aft of the conning tower looking forward

When the submarine was first found by sports divers the conning tower was heavily draped with old fishing net. The first divers on site removed some of the net to uncover the features on the top of the tower. At the start of the project fieldwork there was still a considerable amount of old trawl net and rope on the conning tower, particularly over the ventilator tubes to aft. The project team removed the rope and netting from around the periscope and from the conning tower top so the details could be recorded. The team intended to remove the remaining net wrapped around the ventilator tubes but this task was not completed due to lack of available time on site.

Between the steering column and the binnacle mounting on the upper centreline of the boat is a hole in the pressure hull (H2), see section 13.13 Pressure Hull below.

13.7. Conning tower top

On the flat top of the conning tower are mounted the main hatch, a ventilator tube, the periscope and a strainer (Fig. 50). A small steering telegraph was once also fitted to the top but this has now been removed. The top of the conning tower appears to be made from a large copper alloy casting.

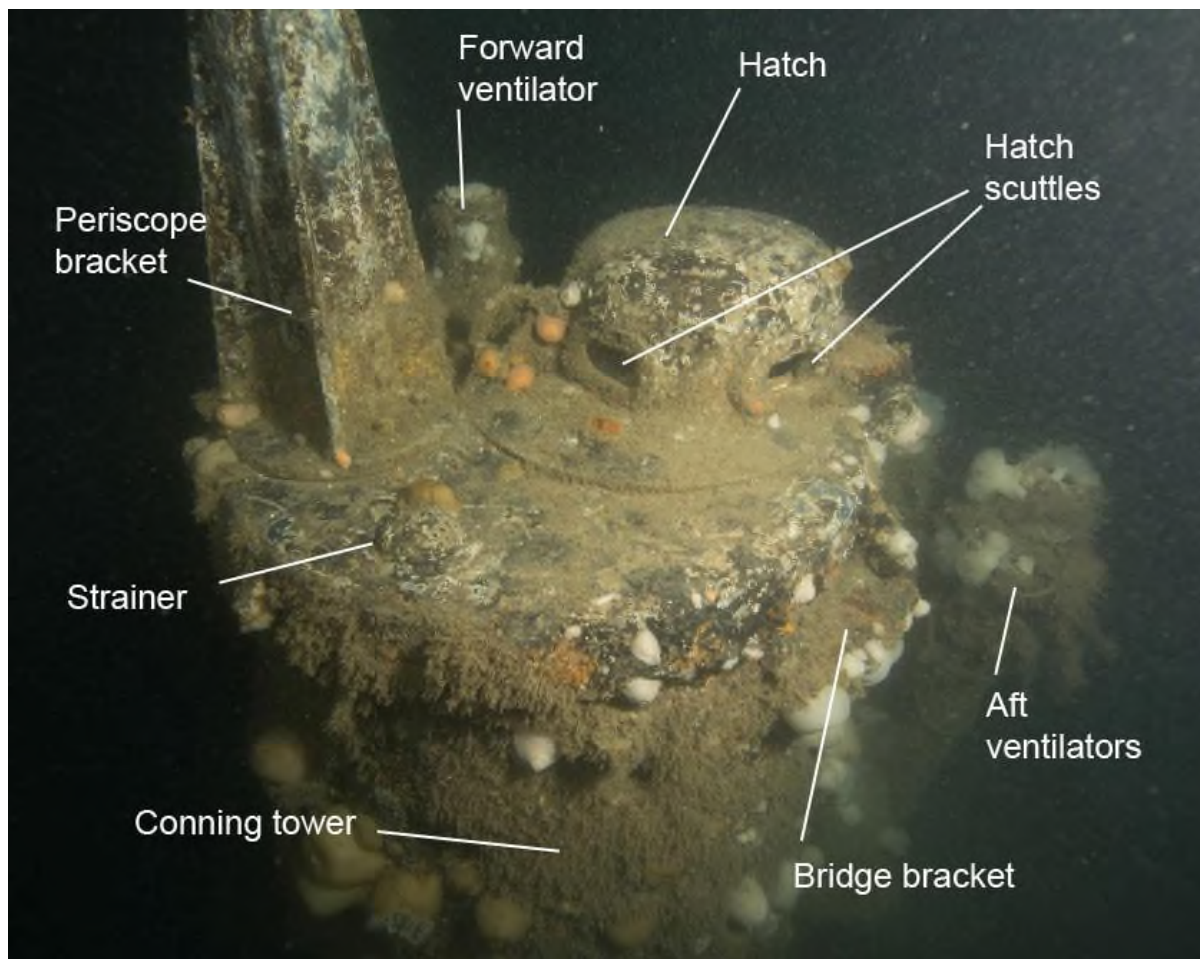


Figure 50: Conning tower top port side looking aft

The flat, circular main hatch is just large enough for a man to pass through, although it was noted that the crew had to take their waterproofs off first before they would fit through it. The hatch is attached to the tower by a horizontal hinge at the back so opens upwards and backwards towards the stern. A small hood or dome is mounted on the top of the hatch that has four glass scuttles around its edge and an opening handle fitted to the forward side. The glass in the forward and aft scuttles is still intact but it is broken in the scuttles on port and starboard sides.

In 1985 the main conning tower hatch was reported to be closed⁸⁸. Divers then reported that the conning tower hatch was loose as sports divers had tried to open it, but this was later secured shut by another team of sports divers to prevent any further intrusion. If there has been some attempt to secure the main hatch then the evidence for this is missing as the hatch is still held firmly closed by the two 'dogs' or clips on the inside and the hinges are still in place. It is likely that the two scuttles were broken by sports divers as no other cause is apparent. It is not known if the lower conning tower shutter is open or closed. Submarines A5-A13 were built with a sliding shutter worked by handwheel through a rack and pinion to cover the hull access opening⁸⁹.

The 3½ inch (89mm) forward ventilator for the main ballast tank is mounted on the top of the conning tower on the starboard side. The long brass cowl would have been removed before the

submarine dived but the short, fixed section of the ventilator tube and its supporting collar is still in place.

A small circular telegraph would have been fitted on the starboard side of the conning tower top but now it is missing. The telegraph was connected to a dial inside the conning tower and was used for the commander on the bridge to send commands to the crew on the inside of the submarine when the main hatch was closed. The telegraph was approximately 180mm diameter and 75mm high; one setting was 'Open Door' and another was 'Secure Hatch' but the other options are unknown. Visiting divers removed the telegraph leaving two mounting studs and the sheared off remains of the control rod through the conning tower top.

On the top of the conning tower on the port side forward is a small, domed strainer whose function is unknown.

13.8. Periscope

The periscope is mounted on the flat top of the conning tower on the forward side⁹⁰.

The periscope is rotated approximately 30° to port. It appears to be intact but has been bent aft by approximately 30° at a point just above the supporting collar (Fig. 51). The periscope was in this condition when first seen by sports divers in 1981, so the damage occurred during contemporary salvage attempts or at some time after the wreck was abandoned in 1914.

The upper glass prism on the periscope is still in place. There are saw marks all the way around the base of the periscope just above the top of the periscope bracket; these were made by sports divers attempting to salvage the periscope. The flat base plate of the webbed collar is attached to the top with four studs but the nuts used to hold down the base plate have been removed.



Figure 51: Conning tower top and periscope from the port side looking aft. The bend in the periscope can be seen just above the supporting collar

13.9. Flying Bridge

The flying bridge on the A class submarines was a light steel structure on which the crew could stand while the vessel was underway on the surface. The coxswain could 'con' the ship from the bridge using a large brass wheel to steer and the crew could also come up for air in ones or twos as a respite from the noise and foul atmosphere in the submarine. The original design for the bridge on A2-A4 allowed it to be folded away before the submarine dived. The bridge folded downwards and backwards so it would lie flat on the back deck casing between the conning tower and the compass binnacle. The later design of bridge as fitted to A7 was taller with the platform almost at the same level as the top of the conning tower which meant that this bridge was then too tall to be folded down.

Four stanchions supported the thin steel platform and were extended upwards to support a rope railing at waist height (Fig. 52). The two forward stanchions could also be used to support a canvas spray dodger that wrapped around the front of the conning tower top. The forward edge of the platform was also supported by two small semicircular brackets mounted on the back of the conning tower at the top.



Figure 52: The flying bridge on A7 from aft. The two ventilator tubes and cowls can be seen aft of the open main hatch

The four stanchions are attached to the submarine using four brackets attached to the pressure hull.

On the A7, the flying bridge structure appears to be completely missing. However a small part may remain under the trawl net that is draped over the aft ventilators. The four brackets are still in place on the hull as are the two brackets on the back of the conning tower.

13.10. Binnacle and Binnacle mounting

The main compass for the submarine would not work correctly if fitted inside the steel hull so instead it was mounted in a waterproof binnacle fitted to the back deck of the submarine (Fig. 53). The binnacle was made of copper alloy as it was non-magnetic so would not affect the compass. Two soft iron spheres were fitted on brackets on the sides of the binnacle and were used to compensate for the effect of the steel hull on the compass. The compass was read from inside the submarine using a small periscope that passed up through the base of the binnacle that was fitted with electric bulbs to provide light on the inside.

The remains can be seen of the mounting where the compass binnacle was fitted on the hull between the conning tower and the aft stanchion. The mounting is all that remains of the casing that ran along the centreline of the back deck of the submarine. When the submarine was found in 1981 the binnacle was not attached to the submarine and was found lying alongside the conning tower on the starboard side⁹¹. A cracked dent in the lower part of the binnacle stand suggests it may have been pulled off the submarine during the initial salvage attempts, although it has been suggested that the binnacle was torn from the wreck by a scallop dredger.



Figure 53: The compass binnacle from A7 on display at the RN Submarine Museum

The binnacle mounting also includes the remains of the exhaust pipe that ran along the back deck, see Exhaust System below.

13.11. Aft deck and Stern

Along the aft deck centreline was a free-flooding thin (1/8in. 3.2mm) steel casing that acted as a walkway when the submarine was on the surface and also as a conduit for the engine exhaust pipe. Only the outline of the aft deck casing still survives aft of the binnacle mounting. The exhaust pipe that ran along the back deck is also missing.

The bracket for the aft stanchion is still in place. The stanchion was used to hold up a safety line that ran from the back of the fin fairing, along the back deck and down to the hull casing right aft.

Aft of the bracket is the 6½ in. circumference (2 in., 51mm diameter) steel hawser wrapped twice around the hull by divers during contemporary salvage attempts. This is the hawser that was attached to the battleship HMS *Exmouth* for the final attempt at pulling the submarine from the seabed. No damage to the plating can be seen where the hawser is wrapped around the stern, so the tremendous pull of the 14,000 ton battleship during the salvage attempts had no discernable effect at all ⁹².

A section of heavily riveted steel plate 2.5m x 1.5m over the upper hull strake forms part of the pressure hull behind the stanchion bracket. This appears to be a section of the pressure hull that could be removed to allow large components of the engine to be replaced (Fig. 54).

At the end of the exhaust pipe was a muffler box which can still be seen on the hull.

The aft four metres of the submarine hull, the propeller, hydroplanes⁹³ and rudder are buried in the seabed. Two sports divers reported to the Project that they had seen the hydroplanes and rudder still in place on the submarine. Probing the seabed along the centreline of the hull aft of the exhaust muffler was a difficult task because the seabed was so easily stirred up reducing visibility to nil, but the stern gear does appear to be still in place and buried just below the seabed.

In service, a short flagstaff with bunting attached was mounted on the rudder and was used to mark the furthest end of the boat that was hidden under water. Remains of this flagstaff were not seen on the site.

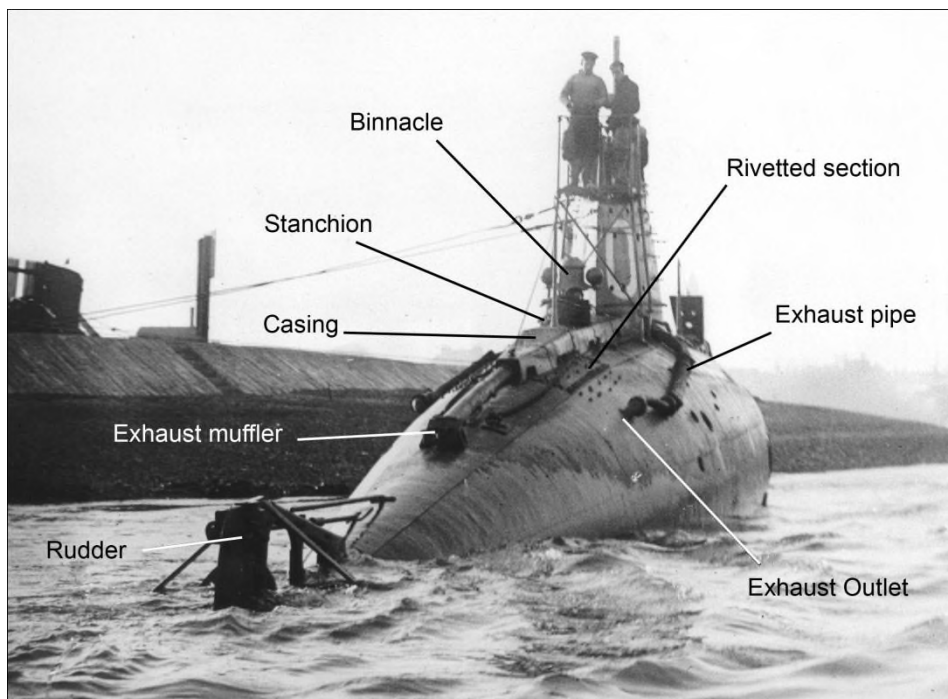


Figure 54: View of A12 ashore from aft showing features on the stern

13.12. Engine exhaust system

The first use of an internal combustion engine in a submarine was in 1897 by Simon Lake in his submarine *Argonaut*⁹⁴. The Wolseley company had built the 160 h.p. Otto engines under license for the RN Holland boats using drawings supplied to Vickers, so the same company was asked to produce the much larger petrol engines for the A class submarines. The massive 16 cylinder horizontally opposed design with a design output of 600 h.p. was based on racing car engine practice so had the advantage of low overall height and compact dimensions. The types of engines were different in the three distinct A class designs A1, A2-A4 and A5-A12. The third engine variant fitted in A7 had a bore of 11¼ in. (286mm) with 312 litres capacity, was 18ft 10in (5.74m) long and weighed 16.2 tons⁹⁵.

As there are no plans for the external fittings on submarines A5-12, so the remains of the engine exhaust system on A7 is the only known record of how this system was constructed (Fig. 59).

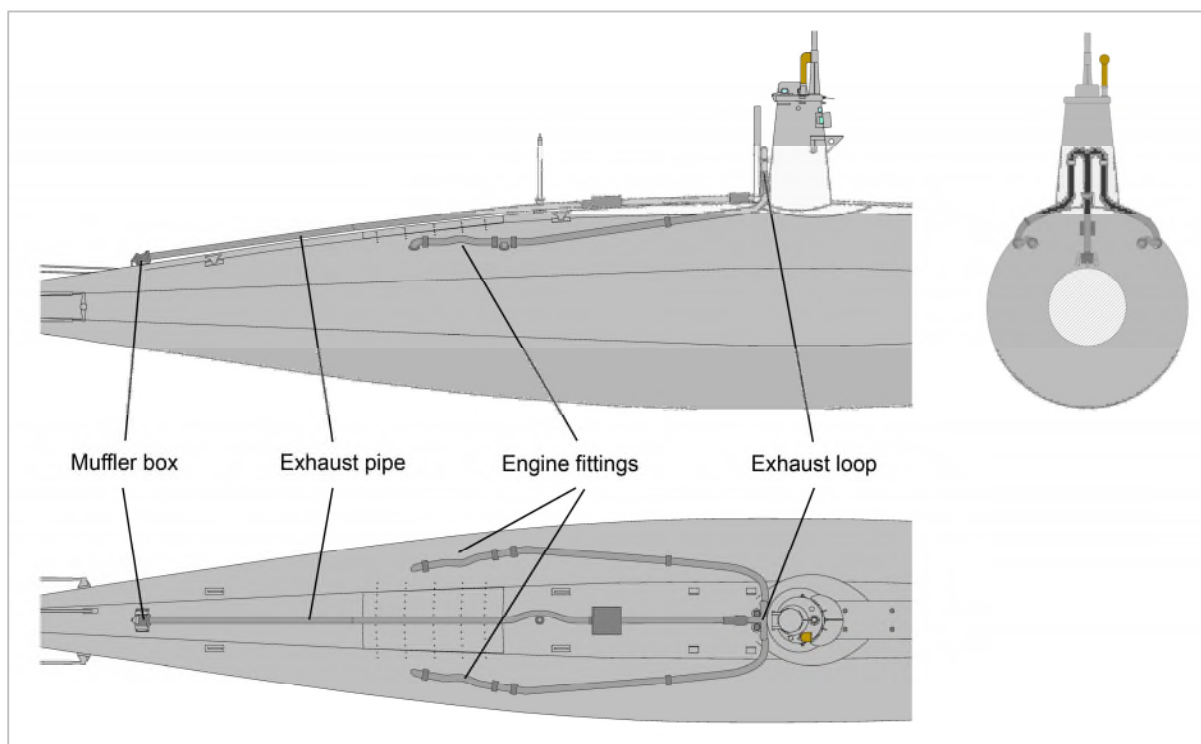


Figure 55: Drawing of the engine exhaust arrangement on the Group II boats

The petrol engine took the air for combustion from inside the submarine, which was refreshed with air from outside the hull pulled down the two ventilator tubes mounted aft of the conning tower.

The engine was arranged with two groups of four cylinders per side with the exhaust outlet for each group of four cylinders passing through a separate Kingston valve to the outside of the pressure hull. The two exhaust outlets each side joined in a manifold to a single pipe which led forward and upward to a point just aft of the conning tower. Here the pipes from each side of the hull joined in a manifold shaped in a vertical loop; this acted as a siphon trap stopping water from passing back down the exhaust pipes to the engine. The combined exhaust then passed down a single pipe along the centreline of the back deck to a muffler box on the stern where the exhaust was released to the sea. The muffler box would be below water level when the boat was running on the surface using her petrol engine so the noise from the exhaust would be dampened.

Remains of the exhaust pipes can still be seen on the A7. The pipes are connected to the Kingston valves by the engine but are damaged further forward so the section joining to the loop manifold behind the conning tower is missing. The loop manifold is still in place as is a short length of the single downstream pipe heading aft along the back deck. There is a break in the pipe to the short section that lies under the binnacle mounting to the aft stanchion bracket, and the section between this and the muffler box is missing. The muffler box is still in place as is the control rod that allowed the box to be opened and closed from within the submarine.

13.13. Pressure hull

Two-thirds of the hull of the submarine is buried in the seabed so the amount visible to divers is similar to the amount that would be visible from a ship if the submarine were afloat and in light ballast. The visible part of the pressure hull is intact and undamaged with the exception of three small holes on her upper side. Before visiting the site we had been informed that there were some holes in the pressure hull that allowed the inside to be seen by divers. In 1998, divers noted a small hole on her starboard side large enough to shine a torch into⁹⁶ and in 2000 divers reported that there were holes in the hull and the inside was now full of mud.

Just in front of the conning tower on the starboard side and 1m off the centreline is a small irregular shaped hole 250mm x 250mm (H1). This hole was noted by divers in 1998 (Fig. 56).



Figure 56: Hole H1 on the starboard side

Between the steering column and the binnacle mounting on the upper centreline of the boat is a hole (H2) in the pressure hull, which is approximately 200mm x 200mm in size. This hole was noted by the first sports divers to see the submarine in 1981 (Fig. 57).



Figure 57: Hole H2 in the stern

At the forward end of the submarine the casing between the cutwater and the torpedo loading hatch is missing.

Here there is an oval shaped hole in the main pressure hull 530mm x 300mm in size. The hole (H3) is on the highest point of the hull and sits across the centreline. Through the hole a high pressure air pipe that is fitted to the deckhead can be seen (Fig. 58).



Figure 58: Hole H3 in the bow

The cause of the three holes is unknown:

- The hull at each of the three holes H1 - H3 is in good condition and does not show any signs of damage or localised thinning of the plates.

- None of the holes show any signs of sports divers attempting to make the holes larger to allow access to the submarine.
- Two of the holes are at the highest point on the hull in that location so the hole may possibly be local corrosion caused by a pocket of air gathering at that point.
- The holes may be caused by electrolytic action around an internal hull fitting. Mixed metals in seawater in contact at that point may cause preferential corrosion of the hull, followed by the collapse of the fitting once sufficient metal had eroded that the hull could no longer support it.

The scope of work for the project specifically excluded investigating the inside of the hull. However the hole H3 in the pressure hull is large and it was visibly apparent that the hull is not heavily silted inside, and the silt only just covers the top of the floor plates over the batteries⁹⁷.

14. Hull plate thickness measurements

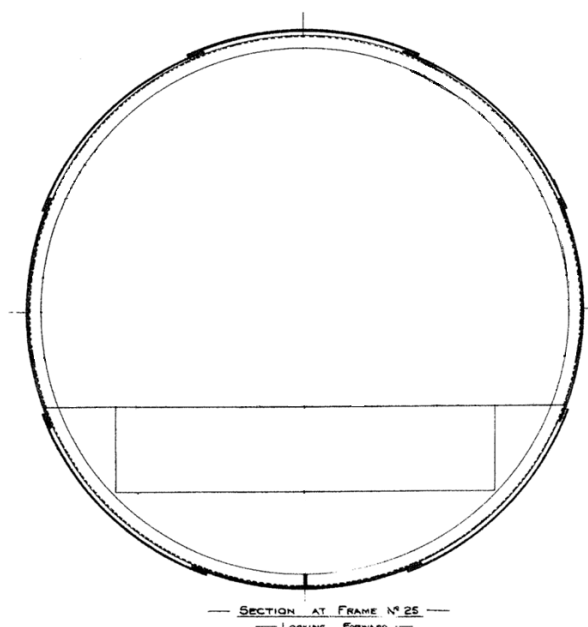
14.1. Introduction

The most significant threat to the A7 submarine is likely to be corrosion; the boat has been immersed in seawater for more than 100 years so the strong steel hull is rusting away, slowly turning into structurally much weaker corrosion products. One of the requirements for the project was that measurements be made of the remaining hull plate thickness as this provides information about the condition of the hull structure and gives some clues about how long the submarine will survive on the seabed.

The thickness of hull plates (strakes) were measured by divers at a number of points on the hull using a Cygnus DIVE Mk2 underwater digital ultrasonic thickness gauge⁹⁸. The ultrasonic thickness (UT) measurements were compared to the original thickness of the plates when the ship was constructed to give an idea of the degree of corrosion of the hull and an estimate of the rate of corrosion. Subsequent measurements made at a later date can be used to improve this estimate of the rate of corrosion.

The circular steel frames used to construct the A class boats were $3\frac{1}{2}$ in. x 3 in. (89 x 76mm) 7.8lb (3/16 in., 5mm) angle spaced 18 in. (458mm) apart.

Eight strakes were used to plate over the frames with 4in. (102mm) laps where two strakes joined. The upper, lower and side plates were 20 lbs (1/2 in., 12.7mm) while the others were thinner at 17½ lb (7/16 in., 11.1mm)⁹⁹. Fig. 59 is a cross section of the boat at frame 25 showing a circular frame overlaid with a section through each strake. The arrangement for overlapping each strake is also shown¹⁰⁰.



14.2. Method

The DIVE UT gauge sends short pulses of very high frequency sound waves from a hand-held probe in contact with the hull plating and measures the time taken for each sound pulse to travel through the plate, reflect off the back wall of the material then return to the probe. If the speed of sound in the material being tested is known then it is possible to calculate the thickness of the material by multiplying the speed of sound by half the total travel time.

A Cygnus DIVE gauge was to be loaned to the project by MOD Salvage and Marine Operations; instead sponsorship was obtained through ProMare and Cygnus Instruments to purchase an instrument for the Project.



Figure 60: Making measurements at point UT7

Experiments were undertaken prior to and during fieldwork on the A7 to determine the most reliable way to record plate thickness measurements. The experiments showed that the best results would be obtained using the 5 MHz twin crystal probe (Type T5B, yellow band) so this is what was used on the A7 hull.

The initial aim was to record measurements at eight locations on the hull. Additional measurements were planned to be made on non-structural elements to provide complementary data from this site to that collected for the First World War Submarine Project run by English Heritage¹⁰¹.

The procedure for making UT measurements is given below:

1. Just before diving, balls of epoxy putty were mixed together then placed in a plastic bag
2. On site, the surface of the metal to measure was prepared by removing the surface concretion with a chisel to leave a clean but pitted surface with an area large enough to admit the UT probe
3. The UT gauge was set to record the next set of measurements in a new logging group
4. The probe was placed on the cleaned area and a minimum of three measurements were made and logged at each location
5. Finally the cavity made in the concretion was filled with epoxy putty

14.3. Results

The intention was to record eight measurement points on the hull; however three of the points were not measured due to lack of time available on site.

The DIVE gauge was very easy to use as it could be worn on the diver's wrist leaving the hands free to operate diving equipment during descent and ascent to and from the wreck. Once on site the display was bright, clear and easily understood in low light, poor visibility and under the effects of narcosis.

The concretion on the pressure hull of the submarine was quite soft with a texture like biscuit so could be removed easily

with a chisel. Under the concretion was a thin, black graphitised layer which was washed or rubbed away leaving bright and shiny metal that was uneven in texture and severely pitted (Fig. 65).



Figure 61: A small area of concretion removed to show the bright but uneven and pitted metal underneath

Although the DIVE gauge was very easy to use underwater there were a few difficulties in making the measurements. If the diver making the measurements left insufficient time between finishing one measurement and starting another, the automatic logging capability in the gauge would not trigger another measurement. This was an operator error rather than a problem with the instrument so changing the operating procedure soon remedied this problem once it had been identified. The uneven and pitted surface of the steel hull made it difficult to hold the probe sufficiently still for a



Figure 62: Testing the Cygnus DIVE gauge underwater on a wreck off Plymouth

measurement to be made as the probe had to give a reading that varied no more than 0.2mm for 2 seconds. The probe needed to be pressed to the hull quite firmly which was found to be difficult for the normally neutrally buoyant diver as pressing down on the probe just pushed them off the hull. The submarine hull itself made matters worse as being smooth there was little to hold on to and the curve of the circular hull limited measurements to the upper area. Initially we had planned to measure the hull thickness on the centreline of the submarine just below seabed level but this was found to be impossible. The diver could not hold the probe sufficiently still while lying upside down on the hull and avoiding damage to the sea fans found growing there. Working from the seabed was also not possible as the overlying silt was so soft the diver would simply sink into it before a measurement could be made, also reducing visibility to nil instantly.

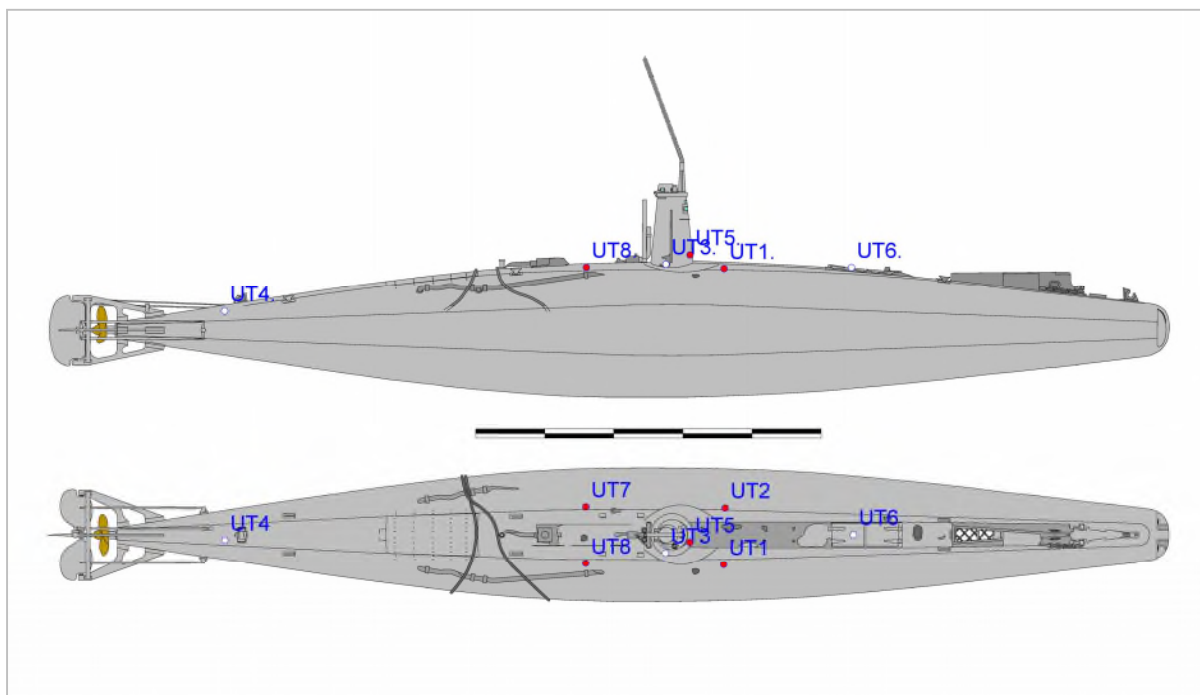


Figure 63: Ultrasonic thickness measurement points on the hull of the A7

Measurements were made at five of the eight points (Fig. 63):

Point	Location	Value	Measurements (mm)	Notes
UT1	Foredeck starboard	5.1	3.4, 5.4 , 5.1	Poor quality
UT2	Foredeck port	8.9	8.0, 8.9	Trace shows first value was short. On strake overlap
UT3	Conning tower fairing	None		Planned but not completed
UT4	Stern, below mud line	None		Planned but not completed
UT5	Conning tower, forward	3.7	4.4, 3.8 , 3.6, 3.8 , 3.7 , 4.0	Some measurements noisy
UT6	Torpedo loading hatch	None		Planned but not completed
UT7	Aft deck port	9.6	10.1, 9.2, 9.6 , 9.6	First & second values have indistinct leading edge
UT8	Aft deck starboard	9.7	8.8, 9.7 , 9.8	First trace is noisy

Point UT1

Point UT1 was on the starboard side, 1m forward of the conning tower, on the second strake just below the lap where it joins the upper strake, which was originally 11.1mm thick. It was difficult to make measurements at this point and those that were made were poor quality; a number of measurements were attempted on two separate occasions. One measurement of 3.4mm was recorded with the others at 5.4mm and 5.1mm but all were noisy so were less reliable. The location is close to hole H1 so the hull plating may be particularly thin or pitted in this area.

Point UT2

The measurement was inadvertently made on the overlap between the upper strake (12.7mm) and the second strake (11.1mm) and only discovered after the concretion had been removed. The remaining plating thickness was recorded to be 8.9mm. This measurement is assumed to be from just the upper strake originally 12.7mm thick. At the point where the measurement was made the second strake overlaps the upper strake and provides a barrier to corrosion for the underside of the upper strake, so it is likely that corrosion of the upper strake will be less at this point.

Point UT5

The conning tower in submarine A1 was in the form of a truncated cone of 15 lbs (3/8 in., 9.5mm) steel plating¹⁰² and A7 is thought to have a conning tower made with the same thickness of steel. Point UT5 was on the front face of the conning tower 0.5m above the casing. Six measurements made at this point gave a repeatable thickness of 3.7mm.

Points UT7 and UT8

Points UT7 and UT8 were 2.2m aft of the conning tower and 0.8m off the centreline on the port and starboard sides. The measurements were made on the upper edge of the second strake which was originally 11.1mm thick. The measurement for UT7 (Port) was 9.6mm and for UT8 (Stbd.) it was 9.7mm. This value is considerably thicker than the equivalent measurements made at points forward of the conning tower. It is possible that both measurements were made directly over a frame which may reduce the rate of corrosion on the inner face of the metal.

Material Loss

Point	Location	Meas. (mm)	Original (mm)	Loss (mm)
UT1	Foredeck starboard	5.1	11.1	6.0
UT2	Foredeck port	8.9	12.7	3.8
UT5	Conning tower, forward	3.7	9.5	5.8
UT7	Aft deck port	9.6	11.1	1.5
UT8	Aft deck starboard	9.7	11.1	1.4

Analysis

The measurements at UT5 on the conning tower were both reliable and repeatable and show a loss of 5.8mm from the steel plating. The estimate of plate thickness lost at UT1 (foredeck starboard) is 6.0mm, this is based on just two measurements so is less reliable, but it does agree with the more reliable measurements on the conning tower. The loss of metal at point UT2 (foredeck port) was just 3.8mm but this is probably caused by the protection to the underside of this plate by the overlapping strake underneath. The measurements for UT7 and UT8 are anomalies as if measured through just the hull plate alone show a metal loss of just 1.5mm.

In conclusion, the most reliable measurement for the loss of hull plate thickness is 5.8mm in 100 years, or a rate of 0.058 mm/year or 58 μ m/year. This is a loss of 61% of the original conning tower thickness and 52% of the original hull plate thickness.

Note that the measurements only include the exposed portion of the hull of A7. The portion of the hull in the seabed is likely to be much better preserved as it is buried so may survive for longer within the seabed after the visible part has corroded away.

Comparison with A1

Wessex Archaeology undertook a similar ultrasonic hull thickness survey on submarine A1 in 2012. This is useful for comparison with the results from the A7 UT survey as the boats share the same design for the pressure hull and A1 sank for the final time just 3 years before A7. Three hull thickness measurements were made in total on the hull of A1 and no calculation of metal thickness lost was included in the report. The location of the points where the measurements were is vague but Figure 1 in the report hints that the measurements were made on the thinner second strake (11.1mm) rather than the thicker upper strake. Measurement point TL2 located approximately 1m aft of the bow gave a thickness of 5.6mm which equates to a loss of 5.5mm of steel from that strake. Point TL 5 was located in line with the front of the conning tower and reported a thickness of 5.7mm, which is a loss of 5.4mm in thickness.

Little can be concluded from a few measurements taken from uncertain locations on the hull of A1 but it is still interesting to note that these measurements are similar to the 5.8mm of steel plate lost from the hull of A7.

Prediction

A simple projection forward in time with this rate of loss of material gives a prediction that the conning tower will have corroded completely in just 63 years and the pressure hull in 87 years.

However these values are likely to be over-estimates as the corrosion products are considerably weaker than the metal they replace. The strakes are likely to collapse under their own weight before all of the metal corrodes and the frames supporting the hull plating were originally only 5mm thick so there may now be little metal remaining within a shell of concretion. Both of these factors will shorten the predicted survival time for the hull. The corroding steel conning tower holds up the gunmetal cap, hatch and periscope so the weight of this top load is likely to collapse the conning tower before the steel in the tower corrodes completely. The hull of the submarine is almost completely sealed at the moment so water flow inside the hull is minimal but as the hull strakes become thinner they will be perforated by small holes which enlarge over time. As holes develop in the hull plates any tidal currents will start to flow through the hull which will increase erosion, and potentially increase oxygen levels within the hull which will then increase the rate of corrosion.

In conclusion, a conservative estimate for the survival of the visible part of hull of the A7 submarine is 40 to 50 years.

15. Identification of targets on the seabed around the hull

In the project design it was stated that results of the marine geophysical survey (Aim 2) will be used as the basis for a detailed debris survey of the seabed within 20m of the wreck by divers or ROV.

The geophysical survey was completed in an area 500m x 500m surrounding the submarine, see section 2. Only one target (GS6) was detected near the submarine at 50° 18.510 N 004° 18.075 W; the object was 1.8m long and proud of the seabed. This target was not considered significant as it was 85m from the hull so was not investigated.

A thick layer of soft silt now covers the original seabed at the time the submarine was lost, so if any objects fell from the submarine they would now be buried.

16. Marine biology survey

Introduction

A survey of the marine life living on and around the submarine was undertaken at the start of the diving fieldwork, the data collection was completed by Allen Murray and the identification by Dr Keith Hiscock. The biology survey was done before the top of the conning tower was disturbed by removing the abandoned trawl net and rope.

The species complement is typical of a steel wreck and quite similar to the nearby *Rosehill* wreck, although with fewer species, but also unusual in that no dead man's fingers *Alcyonium digitatum* were seen. No sea fan anemones, *Amphianthus dohrnii* were seen; these are a nationally scarce and Biodiversity Action Plan Priority Species.

The description of the marine life is separated into four areas on the site; periscope, conning tower, hull and seabed.

Periscope

The copper alloy periscope provides a smooth vertical surface well above seabed level where tidal currents are strongest.

Species noted on the periscope include:

- Plumose anemones, *Metridium senile*

Conning Tower

The steel conning tower itself provides a smooth vertical surface, the copper alloy top and hatch a horizontal surface, the ventilator tubes with their tangle of rope and net offer many hiding places for marine life (Fig. 64). Species noted on the conning tower include:

- Spiny starfish, *Marthasterias glacialis*
- Encrusting bryozoan (seamat), unidentified
- Solitary sea squirt, *Ascidia mentula*



Figure 64: The conning tower and periscope before cleaning, showing the full complement of anemones

- Hydroid, *Ectopleura larynx*
- Coral barnacles, *Megalomma anglicum*
- Devonshire cup coral, *Caryophyllia smithii*
- Pumice stone bryozoan, *Cellepora pumicosa*
- A silty bryozoan/hydrozoan turf of unidentified species
- Erect bryozoan, cf *Bugula flabellata*
- Encrusting bryozoan, possibly a *Schizomavella* sp.
- Barnacles, *Balanus crenatus*
- Unidentified sea squirts Ascidiacea indet.

White dead man's fingers, *Alcyonium digitatum*, were expected to be present but were not seen.

Hull

The outer corroded surface of the steel hull was quite soft and very loose in places (Fig. 65). Species noted on the hull include:

- Common starfish, *Asterias rubens*
- Pink sea fans, *Eunicella verrucosa*
- Hydroid, *Nemertesia ramosa*
- Hydroids *Obelia dichotoma*, *Bugula flabellata*
- Erect branching bryozoan, Crisiidae indet.
- Jewel anemones, *Corynactis viridis*
- Female conger eels, *Conger conger*
- Swimming crab, *Necora puber*
- Edible crab, *Cancer pagurus*
- Common lobster, *Homarus gammarus*
- Topknot, *Zeugopterus punctatus*
- Poor cod, *Trisopterus minutus*

Pink sea fans, *Eunicella verrucosa* were in good condition and had a consistent orientation at right angles to the prevailing water movement which was fore and aft along the hull.

Seabed

The seabed around the submarine is flat and featureless, consisting of very light silt that was easily disturbed then remained suspended in the water column. Burrows in the seabed are possibly from callianasid crustaceans (Fig. 66).

The depth of the silt could not be established but a 1m long probe pushed in to it did not encounter any resistance along its entire length. The 25kg sinker weight from the mooring buried itself approximately 500mm into the seabed in just two weeks.



Figure 65: Base of the conning tower and hull, port side looking aft, with many pink sea fans

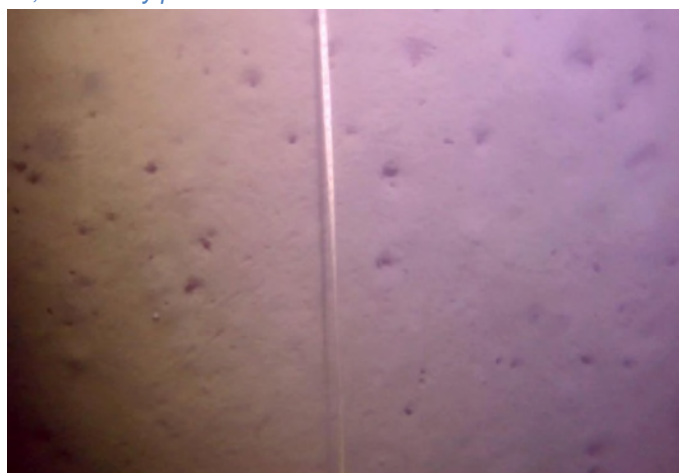


Figure 66: Plan photograph of the flat, silty seabed

During salvage operations on the submarine in 1914 the seabed was described as being 'a bed of sand and mud'¹⁰³; at one point the A7 was 'more covered with sand than before'¹⁰⁴ and later the 'divers found a clean sandy bottom as the mud had been washed away by storms'¹⁰⁵. In 1981 when the submarine was first found by sports divers the seabed was reported as being 'hard silt' and the bed was firm enough for the compass binnacle to be found lying on the seabed beside the wreck.

The seabed is modern and appears to be the result of recent dumping activity nearby. The dumping ground lies just 1400m to the east of the site so the wreck site is likely to be affected by dredge spoil dumped in the area. A seabed sample was collected from the port side amidships.

Conclusion

Areas of the site provided a different habitat for marine life and this was largely differentiated by height above seabed, with the flat seabed, main hull, conning tower and periscope colonised differently. The flat seabed around the hull is comprised of light, easily disturbed sediment that provides little foothold for any colonising life but can provide a home for burrowing animals. The hull of the submarine does provide a horizontal and firm substrate but perhaps a temporary one as the surface of the steel corrodes. The steel conning tower offers a solid, vertical surface but also suffers from the effects of surface corrosion. The top of the conning tower and the periscope are furthest from the seabed so may be washed by stronger tidal currents than the areas below. The copper alloy material from which they are made may also offer a more secure footing for colonising life.

17. Engineering drawings

A search for engineering drawings of the A class submarines located general internal plans for A1, for the second batch A2-A4 and for the unique A13 with its diesel engine in the archives of the National Maritime Museum, Greenwich. No plans showing the external features of this class have been located in any of the archives consulted and no plans at all were found for the third batch (A5-A12) which includes A7.

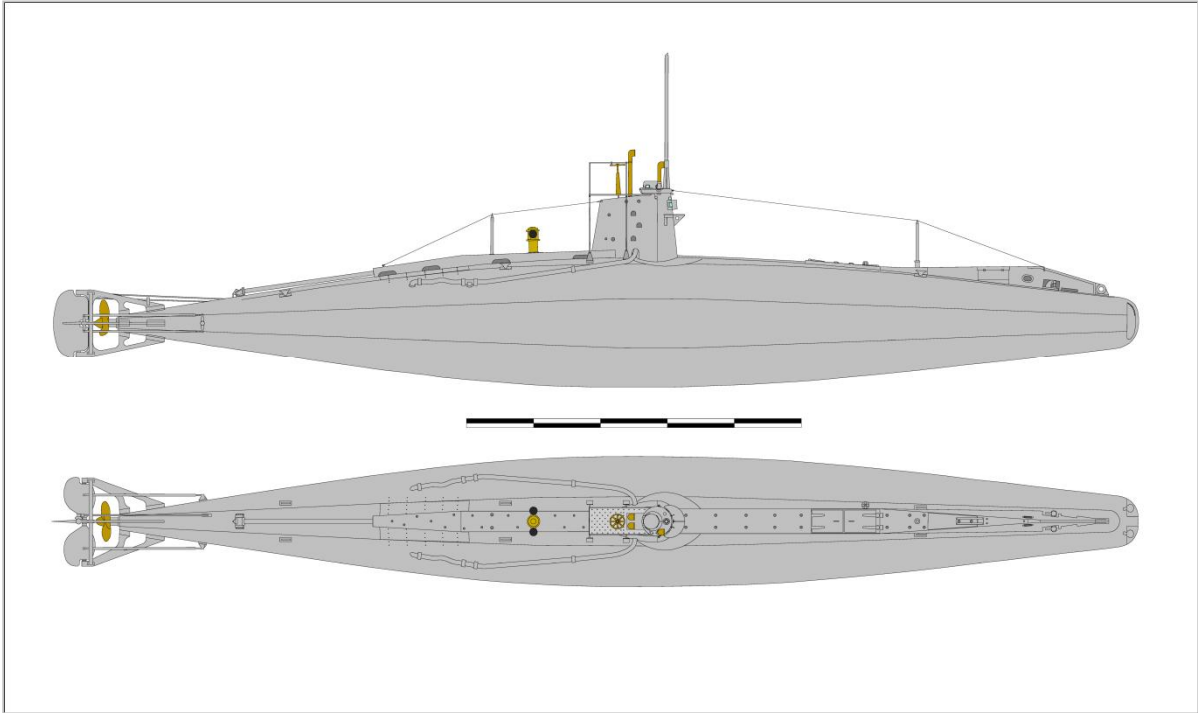


Figure 67: External general arrangement drawing for A7 as she was in 1914 created by the A7 Project

A set of external general arrangement engineering drawings for the A7 have now been completed by the A7 Project team using a combination of all of the information available to the project.

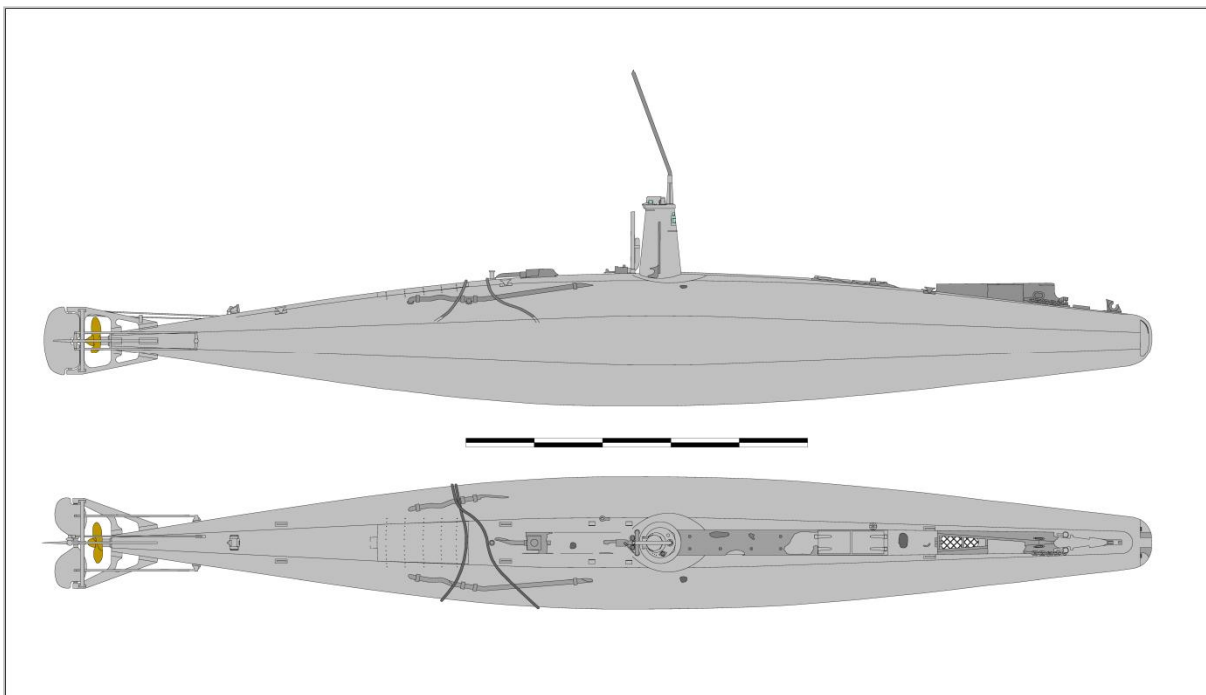


Figure 68: External general arrangement drawing for A7 as she was recorded in 2014 created by the A7 Project

The plans show the external view of the visible hull only so does not include any part of the hull currently buried in the seabed or any of the internal fittings. One set of plans shows the submarine as it was at the time of loss and a second set show the submarine as it is today.

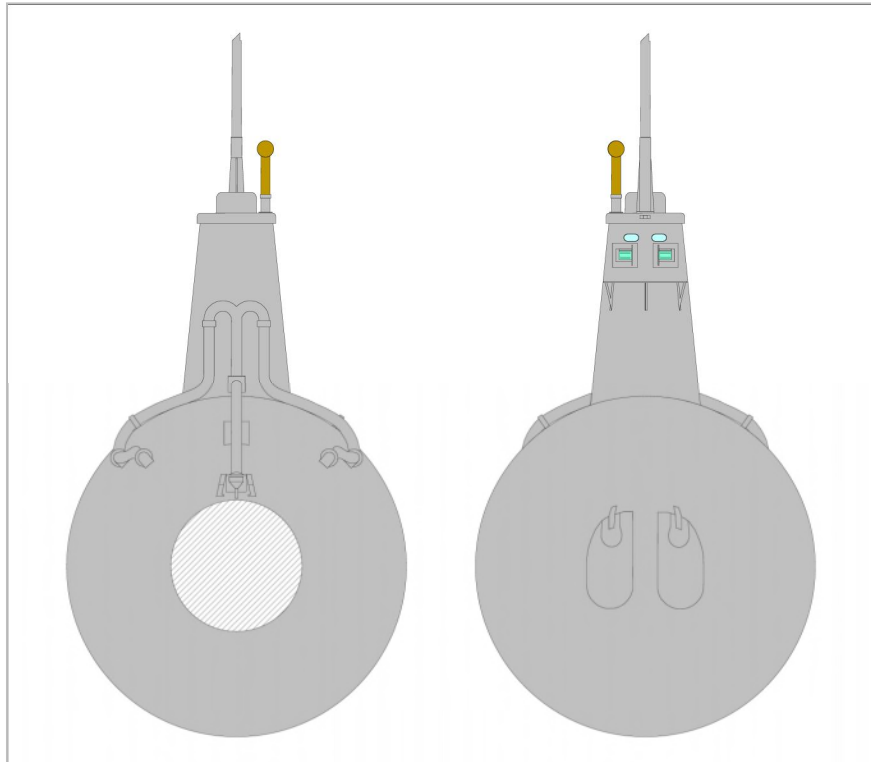


Figure 69: Elevation drawing of the view aft showing the layout of the exhaust pipes (Left) and the view from forward showing features on the front of the conning tower (Right)

One of the possible reasons why the original external arrangement drawings have not been located is that the Admiralty did not wish to publish them even up to the time of the sale of the boats when the submarines were considered obsolete. When the sale of the A class submarines was being considered it was noted that one of the *'most desirable matters to be kept secret is her exact external form as this governs speeds on the surface and submerged and her behaviour in diving'*. The Holland boats were not considered in the same way as they were based on an American design and A1 was not included as she *'is not a form which anyone would be well advised in copying'*. The Director of Naval Construction stated in a memo that *'The remaining boats (A2-A13) are Admiralty designs, and it may be desirable, if they are sold, to take some security from the purchaser that the lines shall not be taken off'* ¹⁰⁶.

18. Outreach

18.1. Introduction

One of the aims of the A7 Project is to raise public awareness about the A7 submarine and her loss.

The story of the sinking of submarine A7 was well known at the time of loss but it has now been largely forgotten. This submarine can be used as a means to raise awareness of its own story, the contribution made by such boats and their crews to the war effort and maritime cultural heritage in general. The history of the boat makes for an engaging story that appeals to more than just maritime historians. The relatively recent loss of the submarine helps make connections with the public whose recent relatives may have served on similar ships or may have been involved with the war effort in Plymouth.

The 100th anniversary of her loss in 2014 provides a good opportunity to tell the story again and to celebrate the A7 as a memorial to her last crew. The submarine is also part of the nation's lost maritime heritage and as such deserves greater recognition.

18.2. A7 Project Web Site

A web site has been created about the submarine and the A7 Project. The site was set up early on in the project so that the work to be done on site could be promoted enabling supporters and sponsors to be engaged to assist. When the research and fieldwork has been completed the web site will then be used to publish the results of the work. This will include as much of the research material that space and copyright limitations will allow, so anyone else researching A7, A class submarines or the creation of the RN Submarine Service can benefit from this work.

Web site address: www.promare.co.uk/a7project



Figure 70: A7 Project web site main page

18.3. 3D virtual reality model

The SHIPS Project in conjunction with Birmingham University is developing a number of Virtual Reality (VR) models of shipwreck sites and now has a VR model of the A7 submarine. A VR model of the wreck site has also been created so more people can experience what it is like to visit the submarine as she is today on the seabed. This facilitates the public 'accessing' the site remotely through VR, thereby rendering the site in effect as a virtual museum of the submarine's exterior without any physical access being involved. This virtual dive concept has already been demonstrated to excellent effect in subsea training projects sponsored by the MOD¹⁰⁷ and in a project entitled the *Virtual Scylla*, conducted in collaboration with the National Marine Aquarium¹⁰⁸.



Figure 72: Virtual Reality model of A7 as she was in 1914



Figure 71: VR model of the A7 wreck site with the submarine partly buried in the seabed

The *Virtual A7* project is being undertaken by the Human Interface Technologies Team based at the University of Birmingham¹⁰⁹. The three-dimensional (3D) computer tools and design procedures for the *Virtual A7* construction process are based on those adopted for a number of previous projects, such as *SubSafe*, a project undertaken for the MoD which involved the use of Virtual Reality technologies and techniques for use in training new recruits to become familiar with the deck and compartment layouts and the location of safety-critical equipment onboard *Trafalgar* Class submarines¹¹⁰.

The baseline 3D model of the A7 was developed using Autodesk's 3ds Max (formerly 3D Studio Max; Fig. 77). 3ds Max is a popular professional 3D modelling package used across the globe for developing content for high-fidelity computer-generated imagery, it is used for film and TV animation productions and is also widely exploited in the development of 3D models and scenes for Virtual Reality and computer games. In addition to its modelling and animation tools, recent editions of 3ds Max also support advanced shading which is used for realistic lighting, shadowing and special effects and particle systems which are an important development for the rendering – 'drawing' – of underwater scenes. The tool benefits from strong international community support in the form of commercial plugins supporting a wide range of real-time rendering effects.

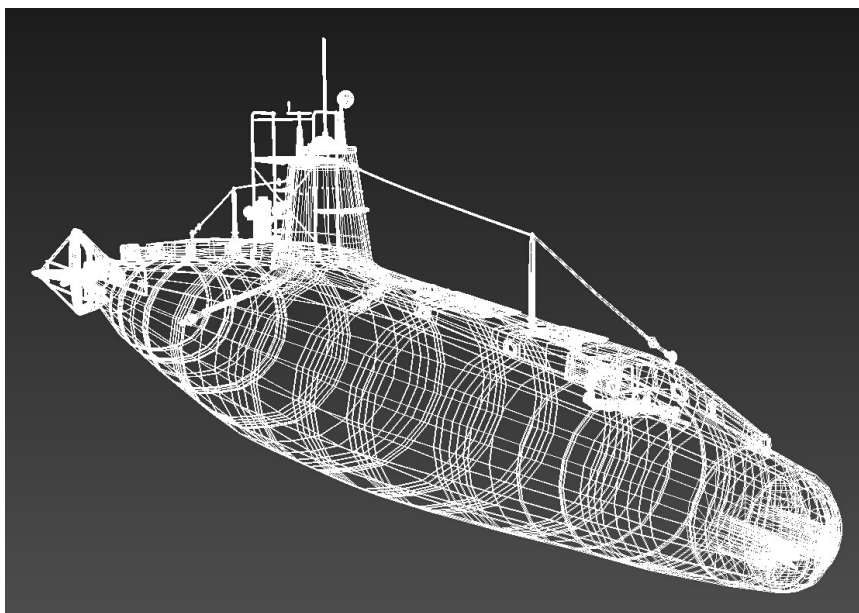


Figure 73: Wireframe A7 Model in 3ds Max

The baseline *Virtual A7* model was constructed using plans and photographs collated from a variety of sources, including the SHIPS Project database, books, the Royal Navy Submarine Museum, online resources and even postcards sourced from *eBay*. The hull surface and component material effects for the completed model were based on information obtained from various subject matter experts and from the design of appropriate texture effects using such desktop imaging packages as *Photoshop* and *Paint.net*.

One particular region of the 3D model demanded additional attention, and that was the outer shutter mechanism of the torpedo tubes, the motion path for which could not be readily ascertained from images of the A Class submarines when out of water, trimmed up alongside depot ships, or when beached. To help with visualising this and, subsequently, developing a realistic bow door animation in 3ds Max and the chosen game engine (see below), an appropriate 3D mechanism (Fig. 78) was developed and tested using the *Solidworks* solid modelling computer-aided design system developed by Dassault Systèmes. This enabled a reasonable approximation of a door-opening animation to be developed.

To enable the users of the *Virtual A7* program to explore the submarine and the wreck site in real time, all 3D and associated 2D assets (including textures used to endow the models with acceptable levels of visual detail) had to be imported into a *game engine*. In brief, a game engine is an integrated core of software modules that allow the contents of a computer game or simulation (2D/3D objects, images or textures, embedded videos, etc.) to be rendered and interacted with by end users using a range of input (controller) and output

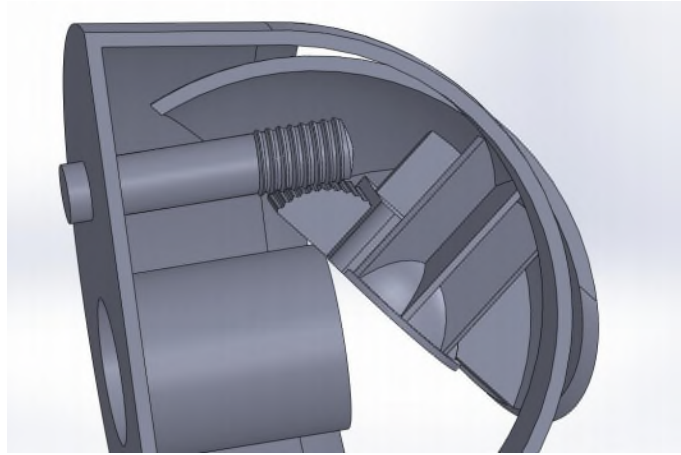


Figure 74: Solidworks Model of A7 Bow Door Mechanism

(display) technologies in real time. A typical game engine will also handle such features as 3D sound, object and environment physics (such as lighting, collisions and particle effects), animation, networking between multiple users, artificial intelligence, scripted behaviours of objects, including virtual humans or 'avatars', and surface/subsea terrain databases. The engine used for the *Virtual A7* project is Unity¹¹¹; Unity is a cross- or multi-platform game engine and, as well as featuring its own plug-in Web Player for Windows and Apple Operating Systems, the product supports development for such operating systems and platforms as Apple's iOS with support for the iPod, iPhone and iPad, Android, Windows, BlackBerry 10, Linux, PlayStation, Xbox and Nintendo's *Wii*. The choice of Unity as the game engine for this particular project was based on such issues as:

- The experience of the development team in using Unity effectively for other VR/games-based simulation projects, including those conducted for Dstl/MoD;
- Unity's user-friendly and powerful multi-window editing toolkit; a highly visual asset, helping to simplify game or simulation development workflow;
- A flexible import pipeline allowing for relatively straightforward import of 3D models, either custom-built (using tools such as 3ds Max, Maya, Blender, *SketchUp*, etc.) or from popular online 3D model resource sites, such as Turbosquid, 3D Cafe, and so on;
- The availability of a wide range of low-cost, sometimes free special-purpose tools and plugins from a dedicated online asset store (also a very active Unity Forum community);
- The fact that games and simulation run-times developed using Unity can be distributed licence-free, without the need for additional large software downloads or dedicated dongles;
- Support for a range of human interface devices, from head-mounted displays, such as the *Oculus Rift* and *Samsung VR Gear*, to popular input devices, such as the Xbox control or gaming pad, *Kinect*, *LEAP* and many others;
- Use of the tool by other, international navy (and submarine) communities, including the Royal Canadian Navy (e.g. for onboard awareness training of the *Victoria* class of submarine) and the Royal Australian Navy (for the *Collins* class).



Figure 75: Images of the initial virtual wreck site

Over time rust, debris, sediment and organic matter have transformed the A7's hull and fin from its once smooth surface to, in effect, a randomly undulating rusty shell. To simulate this level of decay visually (and convincingly), a range of 3D graphics techniques had to be employed. One such technique is 'bump-mapping', a method by which adding additional lighting information can be applied to a texture, thus creating the illusion of greater depth and undulations to the surface of the submarine. To further increase the close-up detail of the A7 site, its exterior hull has been augmented with 3D crustaceans, plant life and rocks located randomly over the surface. It was also necessary to randomise the rotational position and scale of these scattered surface objects in order to avoid the visual distraction of repeating patterns.

The dense particulate matter typically seen in underwater environments is recreated in the A7 wreck scenario by using 500 semi-transparent 'billboard textures' (i.e. flat images that always face towards the camera viewpoint). Each individual texture is an image comprising around 100 individual particles. This gives a visual impression of some 50,000 floating dust particles, whilst the simulation only has to calculate the position of 500. In addition, as with many subsea simulations, simple fogging is used to create the illusion of the underwater environment. Objects appear to fade into the distance as the light is attenuated through the dense water. This simple effect was enhanced by placing 3D cones emanating from each light source and endowing those cones with a semi-transparent animated texture. This gives the appearance that the light sources are illuminating the microscopic dust particles within the water volume.

The virtual camera, which simulates the underwater viewpoint of the end user, has been enhanced with several visual effects. Firstly a 'fish eye' lens distortion effect was added to simulate the curved plastic dome that typically covers underwater cameras leading to a slight distortion of images. Secondly, a 'depth of field' effect was used, such that, by blurring objects that are very close or very far from the camera, it was possible to simulate the focusing limitations of underwater cameras. Finally, a dynamic brightness effect was used to simulate how real-world underwater cameras attempt to adjust to limited amounts of underwater lighting. Within the Unity runtime demonstration of the wreck site it is possible to optionally remove the sea life covering the hull, together with the seabed, thus revealing the original 3D model.

The VR model of the site showing the submarine partly buried in the seabed was created before the diving fieldwork started. This model was used to plan diving operations on the site, plan the tasks that needed to be done by the divers and was also used to train the divers in what to expect in the dark and low visibility conditions on the site.

Future work planned for this project includes:

Exterior (pre-sinking version)

At the time of writing, modifications are being made to the exterior model of the A7 submarine, adding more detail and making corrections to specific structures on the basis of information that has come to light since the original 3D model was developed. Details include an extensive revision of the conning tower area to add features (including the second ventilator, navigation lights and small perforated dome structure on the port side of the tower) and to alter the detail to the base of the periscope.

Exterior (wrecked version)

Also at the time of writing, the current 3D A7 model is being modified based on the revised wreck site sketches generated during the 2014 dives. In particular, the conning tower and periscope representations are being altered to include details that were absent from the original model, including the absent navigation light, the removal of the aft tower fin section, the decimation of the flying bridge (leaving only part of the attachment fittings and through-hull ventilation piping in place) and the bending of the periscope itself. Damage to the cutwater, hull and aft casing, including the holes and torpedo tube doors are being updated and the salvage hawser remains are being included. Basic 3D representations of some of the sea creatures filmed during the dives are also being added.

Interior

Given the lack of photographic detail relating to the interior of the A class of submarine generally, an initial attempt to model the interior will be undertaken. The available plans do not lend themselves well to supporting such a development, but the main internal elements will be modelled at first, and then advice will be sought from subject matter experts in pursuit of adding appropriate detail and internal environmental features (i.e. material finishes, textures, lighting, etc.), and, ultimately, the animation of mechanical components.

18.4. Public lectures, conferences and the media

The A7 Project is a multi-disciplinary exercise that will provide information of interest to a number of academic fields as a series of published papers and reports:

- The A7 Project was the subject of a paper titled 'The A7 Project - An investigation of HM Submarine A7' at the 2015 Society for Historical Archaeology conference in Seattle, USA, in January 2015
- The work of the project has been shown to a wider public audience through a number of newspaper articles¹¹² and in the sport diving press¹¹³.
- Daily updates about the fieldwork on the project were posted on social media sites Facebook and Twitter where the posts were widely viewed and shared resulting in an audience of thousands following our progress
- The SHIPS Project has given many presentations to local history societies, groups and schools about the work of the Project
- The SHIPS Project was the keynote speech at the 2014 BSAC Diving Conference in Birmingham where the presentation included a section about the A7 Project
- Papers on the A7 Project and the results of the ultrasonic hull thickness experiments will be submitted to the International Journal of Nautical Archaeology and related journals
- A paper on the loss of the A7 will be submitted to the journal of the South-West Maritime History Society
- A presentation about the A7 Project was given as part of the Plymouth History Festival in May 2015

18.5. Devonport Naval Heritage Centre display

The project team are now developing a public display about the A7 at the Devonport Naval Heritage Centre in Plymouth, including panels with photographs and interpretive text telling the story of this boat and providing access to the virtual reality model.

18.6. Academic Involvement

Some of the academic objectives of the project have been met by commissioning postgraduate students to undertake the work. The students were tasked with specific research questions which they answered within their dissertations and the results incorporated in the project. This is a mechanism that the SHIPS Project has already used very successfully and is facilitated by the fact that Mr Peter Holt and Mr Michael Williams are an Associate Lecturer and Visiting Research Fellow respectively at Plymouth University and both members of the Marine Institute's Marine & Coastal Policy Research Unit. Professor Stone, although based at the University of Birmingham, is also a Visiting Professor at the University of Plymouth and is also currently active in the tasking of students to develop maritime heritage projects exploiting interactive 3D and Virtual Reality technologies.

18.7. Publication

The main publication for the project is a monograph covering all aspects of the research - British Archaeological Report, reference BAR British Series 613¹²⁷. Publication of the results for a wider audience will be achieved using the project web site.

18.8. Training

This project helped develop the capacity to undertake maritime archaeological projects in the UK by providing practical fieldwork opportunities to students in this field. The need to stimulate and support the development of maritime archaeologists was identified in the English Heritage marine management policy document *Taking to the Water*¹¹⁴. This project has enhanced the skills of a number of avocational divers, students and professionals and it has already encouraged partnership and the exchange of expertise.

The project developed diving and recording methods that could be used in 40m depth, in low light, with low visibility, with a short time on site per day and under the effects of mild narcosis. The methods were developed in parallel with the work-up dives undertaken to get the team used to working in the conditions found on site.

The methods developed to be able to undertake fieldwork on this project have been incorporated in the creation of a new training scheme for the Nautical Archaeology Society.

19. Why was A7 lost?

The reason was never determined why HM Submarine A7 was lost during the training exercise in January 1914. It is not certain if an inquiry was held into her loss; if it was then the report on the inquiry was not found during the extensive search through the archives.

The wreck was found in 37m depth with between six and seven metres of the submarine's stern buried in the muddy seabed and the bow 10m off the bottom¹¹⁵, raised at an angle of 30° to 40° (Fig. 76). The visible part of the pressure hull appears to be undamaged apart from three small holes which were probably caused by corrosion. The damage to the towing eye, cutwater and aft exhaust pipes are consistent with reports of damage that occurred during salvage. The main conning tower hatch and torpedo loading hatch are firmly closed so neither were left open causing the hull to flood.

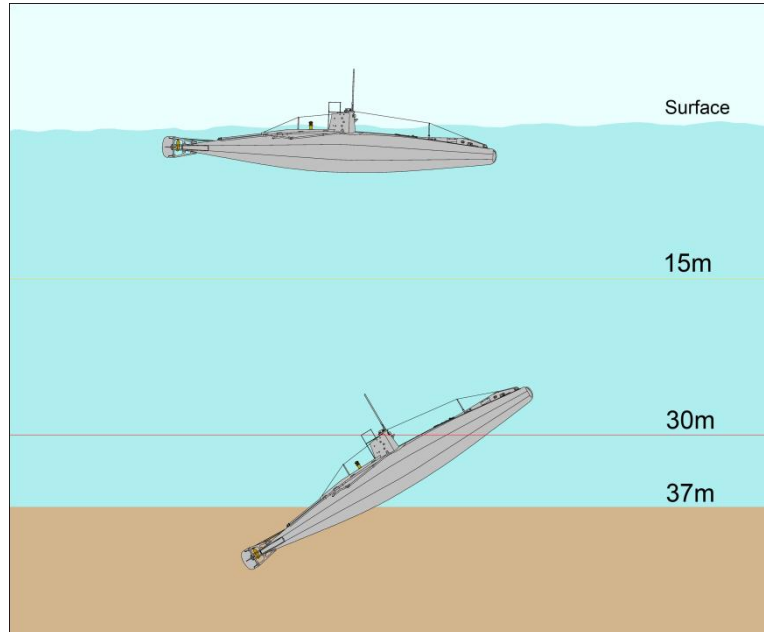


Figure 76: A7 as she was found partly buried in the seabed, also showing working depth (15m) and maximum operating depth (30m)

The positive buoyancy of the submarine should have kept her safe; if the electric motor was stopped while the boat was underwater the submarine should have simply floated back to the surface. So how did the submarine end up with her stern buried on the seabed?

One suggestion for how A7 ended up that way is that she flooded during that first dive in Whitsand Bay, all of the flood water ran to the stern end of the boat and the hull was thrust firmly into the seabed like a dart. Had the submarine been forcibly thrust stern first into the seabed it is likely that the rudder and hydroplanes would have been ripped off in the process, but the stern gear has been seen by sports divers in recent years. So it is unlikely that this is how A7 ended up in her strange predicament.

The A class boats were known for making sudden and unexpected dives¹¹⁶ so a more likely scenario is that the submarine suffered an uncontrolled dive, attempted to surface, struck the seabed with her stern and became stuck. This sequence of events would have happened very quickly; a steep dive to the seabed for a 30m long boat doing five knots in just 37m water depth would have brought the submarine close to the bottom within seconds. If the submarine hit the bottom then a number of factors came in to play which compounded to seal her fate.

The first factor was the action of the hydroplanes. As soon as the crew realised that the boat was diving too fast the hydroplanes would have been angled to bring her back towards the surface and compressed air blown into the ballast tanks to expel the water. A class submarines were of the 'diving' type, boats that dive by inclining their bows down by tipping up the hydroplanes. The hydroplanes on A7 were aft next to the propeller so to angle the bow upward away from the seabed the hydroplanes would need to force the stern downwards towards the seabed. If the boat was close to the seabed at this time then it is likely that she hit the seabed with her stern.

The next factor was the water depth; the Devonport submarine flotilla were usually exercised in water only 30m deep but A7 dived 2 miles south east of her assigned position where the seabed was 37m below. The operational diving depth of the A Class boats was 15m (50ft) with a maximum depth rating of just 30m (100ft), so an uncontrolled dive may have brought the hull below the working depth limit. The hull itself is likely to have been unaffected by the pressure but it was below the depth where the compressed air system would be effective at emptying the ballast tanks. The internal ballast tanks were pressure rated to only 50psi and in an emergency could be fed with a 50psi supply of compressed air. Unfortunately, at 37m (121ft) the difference in water pressure between the outside and inside of the hull is 52.5psi, so with the submarine near the bottom any water in the ballast tanks could not be blown out. A7 was fitted with pumps to empty the tanks but if the accident happened very quickly there would not have been enough time for the pumps to be effective. If forward momentum and the hydroplanes had managed to steer the bows away from the seabed then the submarine would have ended up with her bows pointing upwards at an angle, this would put the forward ballast tanks at a shallower depth than the aft tanks. The reduced pressure forward may have allowed some of the ballast water to be expelled from the forward tanks which would hold the submarine with her bows angled upwards and her stern pointing down towards the seabed.

An additional factor was the type of seabed in the area where she was lost. Rather than the rough gravel and sand found to the north in the shallower area usually used for submarine exercises the seabed where she was lost was a sticky mixture of sand, silt and clay¹¹⁷. Submarines and any other large objects placed on a soft seabed will tend to stick to the bottom by a process known as mud suction; the problem of mud suction will be familiar to anyone who has attempted to pull a walking boot free from soft mud as the mud grips the boot firmly making it difficult to extract. If the stern hit the seabed then mud suction would have held it there with a surprisingly strong grip.

So the most likely scenario was that the submarine ended up with her bows upwards, stuck on the seabed and unable to blow ballast quickly. Thrusting forwards with her propeller she blew a large hole in the soft seabed behind and underneath the hull. The submarine slipped backwards into the hole in the seabed she had just excavated, forcing the stern and the propeller into the sand until the propeller stalled. With the propeller no longer turning, the fluidised sand in the hole settled around the hull and the mud suction held it firmly in place. This idea had been proposed in the local newspaper at the time A7 was lost: *'...after she touched bottom an attempt was made to bring her to the surface by her own motive power, but that her propellers were already in the shifting sand, and when set in motion soon dug a hole into which she sank, and eventually became firmly embedded'*¹¹⁸.

This still leaves the question about why the A7 took an uncontrolled dive to the seabed on that cold January day. The A class boats had been in service for 10 years and the practice torpedo exercise A7 was engaged in when lost was what could be described as commonplace, in addition to innumerable diving exercises, 1,350 attacks were delivered by A boats between January 1912 and January 1914¹¹⁹. What should have been just another routine exercise ended with the loss of eleven men. Looking at the events leading up to the loss of A7 we can see that a number of factors contributed to her loss, taken individually they were not particularly significant but when combined they proved fatal.

Unfortunate as it seems, one of the most significant factors is the readiness of the crew of the submarine as just three of the eleven crew were experienced regulars and none of those were in senior positions. Lt. Welman was assigned to *Forth* in the previous July and was made commander of A7 on 13 November, just two months before she was lost. The second captain, Sub. Lt. Morrison, started submarine training six months previously and joined *Forth* on 4th December, only 6 weeks

before A7 was lost, and up to Christmas had only taken part in one exercise in A7 and three dives in A8¹²⁰. The coxswain Crowley who was in charge of maintaining depth had returned to submarines just two days before after 2½ years on surface ships and it was only his second time on board A7. Northam had joined *Forth* just four months earlier, Dyer joined three months earlier and Harris had been in *Forth* for just 2 months. Venning was a replacement for a sick seaman and he usually worked in the smithy while Jewell had swapped with Lutley for the day, so neither was part of her regular crew.

The A class boats were renowned for their instability and it was well known that they needed a firm and experienced hand on the controls to ensure a safe and controlled dive. The Inspecting Captain of Submarines stated in 1910 that, *'it is one of the most surprising matters in under water work how very rapidly a submarine sinks and how difficult she is to check once she gains any downward momentum'*¹²¹. Although he had plenty of experience in A class boats, the coxswain on A7 had been away from submarines for years so it seems unusual for him to be put in charge of the boat, particularly when both the senior officers had so little experience in that craft.

The A7 was also late on station¹²². Her sister boat A9 had completed two dummy attacks by the time A7 arrived in Whitsand Bay as Welman had been late in leaving the dock, but the reason why he was late is not clear. It is likely that there was a degree of urgency and perhaps haste in the decisions made that morning, which leads on to the second factor, that the submarine was out of position when she dived and was in much deeper water than was good for her. So submarine exercises with this class were usually undertaken in water shallower than the maximum operating depth so that the seabed itself limited the maximum depth the submarine could go to; it was not unknown for training dives in these boats to include rapid transits from the surface to the seabed and back. Where A7 chose to dive the water is deeper than was usual for training exercises and the seabed is soft, sandy clay rather than the sandy gravel found in the exercise area to the north. The deeper water will have made the task of surfacing the boat much more difficult but not impossible, A class boats had been deeper and had surfaced unharmed, but being trapped by the soft seabed most probably sealed her fate.

20. Project Archive and Reporting

A documentary archive of information has been created about the A7 submarine, its life and loss, and includes more general material about development of early RN submarines. The archive also includes information about similar submarine wrecks, archaeological fieldwork undertaken on those wrecks and long-term management of those sites.

The project has:

- Included the products of the documentary research
- Created a detailed report on the work of the project
- Created digital plans of the submarine
- Collated and scanned relevant documents and photographs
- Collected relevant geophysical survey data and processed results
- Included all photographs and video from diving operations
- Included all raw and processed survey data collected during the project
- Included all mentions of the project in the media

The digital archive has been created and published according to current best practice recommendations in the *MoRPHE Technical Guide 1: Digital Archiving & Digital Dissemination*¹²³ and in *Archaeological Archives*¹²⁴. Data has been recorded and stored in digital format wherever possible.

The archive will be available to the public in a number of forms via the project web site. On completion the project will be signposted with an entry in OASIS.

The spatial information has been recorded in digital form in a Geographic Information System (GIS) using Site Recorder software from 3H Consulting Ltd.¹²⁵ Although the data will be published as a fully integrated and linked archive using Site Recorder, the entire archive will be made available as separate components in non-proprietary formats for inclusion in other data management systems.

Metadata from the project complies with the Dublin Core standard¹²⁶.

21. Further Work

Suggested options for further work on the site include:

Site Monitoring

An annual inspection of the site would allow any changes to the site to be recognised and reported to the MOD within a short period.

Hull thickness measurements

The hull thickness measurements undertaken on the A7 suggest that the hull has corroded to a point where approximately 48% of the visible hull plating remains after 100 years on the seabed. The corrosion process is likely to continue and is also likely to accelerate as more holes form in the pressure hull allowing water currents to flow through what is currently a semi-sealed vessel. A better estimate of the actual rate of corrosion of the hull can be obtained by making more measurements on the hull and further hull thickness measurements at periodic intervals.

Net and rope removal

The trawl net draped over the ventilator pipes and cutwater is likely to cause the structure under the net to collapse more quickly so it should be removed by divers as has already been done on the periscope and top of the conning tower.

Detail Recording

Some of the fieldwork planned for 2014 was not completed because bad weather limited the amount of time that could be spent diving on the site. Some features on the submarine still need to be recorded in detail as they are the only record of the design of this type of submarine.

22. Appendix 1: Summary of damage to submarine A7

The damage to the submarine that has occurred after the site was abandoned in 1914 is listed below:

Compass binnacle

Prior to the start of the project the only object known to have been recovered from the submarine was the compass binnacle, originally found by sports divers lying on the seabed by the conning tower on the starboard side of the hull.

Telegraph

The nuts attaching the telegraph to the conning tower top were removed.

The control rod connected to the telegraph was cut with a hacksaw and the telegraph removed. A request to the local diving community resulted in four nuts and two studs being anonymously donated to the project.

Periscope

The periscope is bent backwards approximately 30° and was in this condition when first seen by sports divers in 1981, so the damage occurred during salvage or after the wreck was abandoned in 1914. Divers have tried to remove the periscope by cutting through it just above the supporting collar. The nuts holding down the supporting collar have been removed leaving just the studs fixed to the top of the conning tower.

Main hatch

The glass in the two side scuttles fitted in the main conning tower hatch are broken.

Port side navigation light

The port side navigation light has been removed from its fitting on the front of the conning tower.

Torpedo loading hatch

One corner of the aft torpedo loading hatch shows signs that a diver has attempted to prise it open.

Holes in the pressure hull

There are three significant holes in the pressure hull, see section 13.13 Pressure hull

Conning tower

Fishing net is draped over the aft side of the conning tower and ventilator tubes

Cutwater

Fishing net is jammed into the anchor locker in the cutwater and there has been some damage in that area

23. Appendix 2 - Project Team

The fieldwork for this project was conducted by the SHIPS Project team under the direction of Peter Holt. The SHIPS Project team have been carrying out similar investigations on other wrecks around Plymouth for the last three years.

Post	Personnel	Details
Project leader, diver	Peter Holt	SHIPS Project manager - Pilgrims SAC
Project consultant	Mike Williams	Plymouth University - OUUEG
Diver	Mallory Haas	SHIPS Project - Pilgrims SAC
Submarine consultant	Innes McCartney	Periscope Publishing
Hydrographer	Gwyn Jones	Plymouth University
Diver	April Cunningham	SHIPS Project intern – BSAC Direct
Diver	Jose Quijano	SHIPS Project intern - OUUEG
Hydrographer	Mawgan Doble	Plymouth University, MSc student
Hydrographer	James Williams	Swathe Services Ltd.
Environmental consultant	Prof. S. Hill	Plymouth University - Pilgrims SAC
VR Consultant	Prof. R. Stone	University of Birmingham
VR Consultant	Dr R. Guest	University of Birmingham
VR Consultant	Hossein Moghimi	University of Birmingham
Dive supervisor	Peter Bernardes	SHIPS dive team – Pilgrims SAC
Diver, video specialist	Steve Fletcher	SHIPS dive team - OUUEG
Diver	Allen Murray	SHIPS dive team - Pilgrims SAC & Totnes SAC
Diver, NDT specialist	David Pelly	Sandford & Down Ltd - Plymouth Sound BSAC
Diver	Mark Prior	Diver, Plymouth Sound BSAC
Diver	Mark Pearce	Diver, Licensee <i>Coronation</i> wreck
Diver	Jon Reynolds	SHIPS Project intern 2013
Diver	Ben Kellett	In Deep Dive Centre
Researcher	Nicola Fyfe	SHIPS Project volunteer
Researcher	Adam Bush	SHIPS Project volunteer

24. Appendix 3 – Fieldwork

This section details the fieldwork undertaken on the site:

Date	Activity
04 Dec 13	Side scan sonar survey 1 - GeoAcoustics, relocated the site
26 Mar 14	Multibeam sonar survey 1
05 Jun 14	Multibeam sonar survey 2
16 Jun 14	Side scan sonar survey 2 - CMax high resolution
07 Aug 14	First dive, assessment, set up mooring, Video, Familiarisation
15 Aug 14	Biology survey, photography
19 Aug 14	Photography, Lay baseline, identify features
20 Aug 14	Biology survey, Cleaning conning tower
02 Sep 14	Survey foredeck features, Cleaning conning tower, remove netting
03 Sep 14	Video record of entire hull, Photograph conning tower
04 Sep 14	Probing aft to find rudder and hydroplanes, UT measurements on the foredeck
05 Sep 14	Orcalight photos, Clean periscope, conning tower lights, deadlights
22 Sep 14	Investigate torpedo tubes, Photography and video
23 Sep 14	Photography and video, Record exhaust manifold, UT measurements aft deck, video and assessment
29 Sep 14	Record features, UT foredeck, tower features recording. Remove mooring.

25. Appendix 4 - Project Supporters

This section identifies connections with supporting organisations, connections to other projects and links to similar projects:

25.1. Project Supporters

Name		Role	Contact
Plymouth University	School of Marine Science and Engineering	Marine geophysics	Gwyn Jones, Lecturer in Hydrography
Plymouth University	School of Geography, Earth and Environmental Sciences	Environmental analysis	Prof. S. Hill, Professor of Analytical Chemistry
University of Birmingham	School of Electronic, Electrical and Computer Engineering	Virtual reality modelling	Prof. R. Stone, Chair in Interactive Multimedia Systems
Swathe Services Ltd.		Multibeam sonar processing	James Williams, managing director
MSubs Ltd.		Submarine consultancy	Brett Phaneuf, managing director

25.2. Related Projects

Name	Project	Contact
Nautical Archaeology Society	Lost Beneath the Waves Project	Mark Beattie-Edwards (NAS, 2013)
English Heritage / NAS	Condition assessment of the Holland No.5 submarine, Project 6654	Mark Beattie-Edwards (Beattie-Edwards, 2013)

26. Appendix 5 - Diving Plan

The diving plan below was provided to each member of the dive team and is included here so that it can be reused and adapted for subsequent projects on similar sites.

26.1. Diving Conditions

The site is exposed from east, south and west and waves from the south-west can travel over many miles.

The wreck lies on a flat, soft clay seabed in 37m depth plus height of tide. The tides are directed parallel to the coastline running north-west to south-east and vice versa, with the ebb tide being the strongest.

- At spring tide the current reaches 1kt in an east-west direction over the site and the tide height is between 1.0m and 5.5m above LAT, a range of 4.5m.
- At neap tide the current reaches a maximum of 0.5 kt and the tide height is between 2.1m and 4.5m above LAT, a range of 2.4m.
- The time of slack water is three hours before and three hours after high water at Devonport.
- The prevailing wind is from the south-west and the site is exposed from that direction so is affected by significant wave action.

Underwater visibility on site varies between zero and 10m depending on weather during the preceding days.

26.2. Rules for Dive Team Members

Participation in the A7 project is subject to a number of rules listed below. Failure by a team member to observe these rules will result in their removal from the license to visit the A7 submarine site and may incur extra penalties imposed by the Ministry of Defence if the license terms are breached.

- The license issued for the work is only applicable to divers named on the license so only named divers can visit the site. No guests or visitors will be allowed to dive on the site.
- No dives will be undertaken on the site without permission of the project manager
- No attempts will be made to access the inside of the submarine
- Any human remains, clothing or personal effects seen on the site are not to be touched and are to be reported to the project manager, who will report them to the MOD
- No objects of any kind are to be removed from the site without the permission of the project manager. The project manager will obtain any necessary permissions from the MOD
- All photographs and video taken on site or on the dive boat are the property of the A7 Project. No photographs and video from project fieldwork is to be published by any means without the permission of the project manager
- No information, photographs, interviews or other contact with the media is to occur without the permission of the project manager

26.3. Pre-Dive Requirements

Each diver will ensure that they have:

- A copy of their diving qualifications logged with the project manager
- A copy of their diving medical logged with the project manager
- A copy of their Nitrox diving qualification logged with the project manager

- A copy of their rebreather qualifications logged with the project manager if a rebreather is to be used
- Signed the A7 Project release and waiver (see Appendix 2)
- Dived to 40m within 1 month of a dive on the site for the Project

26.4. Dive Teams

- Dive teams will be managed by a Dive Supervisor, nominated by the Project Manager
- A dive team will consist of two divers, the Task Diver and the Safety Diver
- The Safety Diver will provide dive support for the Task Diver who will be undertaking a recording task
- The Safety Diver is responsible for dive management for that dive including dive time, depth, decompression, gas monitoring for both divers. The Task Diver will also monitor their own dive time, depth and gas
- The Safety Diver may also be responsible for providing lighting for the Task Diver
- A single dive team of three divers will be allowed where it is not desirable to operate as two separate teams, such as some filming and photography tasks

26.5. Dive Vessels

- Dives will be undertaken from the SHIPS Project's 6.5m RIB *Seahorse* or In Deep's dive vessel *Seeker*

26.6. Tide and Currents

- Dives will be done at slack tide so water movement on site will be minimal
- If divers find that there is a current at the time they are due to dive then the dive is to be aborted.

26.7. Visibility

- A dive is to be aborted if the visibility on site is less than 2m

26.8. Lighting

- Both divers in a team will each carry a main and a spare torch
- The dive is to be aborted in the event of the failure of two of the four torches

26.9. Abandoned Fishing Gear and Nets

- If abandoned monofilament net is found during a dive then the dive is to be aborted, see note on the First Dive below

26.10. Dive Times, Gas Mixes and Decompression

Project dives on the A7 submarine using open circuit SCUBA will use Nitrox 27 (EAN27).

A planned dive to 42m with a maximum 20 minute bottom time (start of descent to start of ascent) on EAN27 requires 15 minutes of stops at 6m. Maximum ascent rate will be 10 metres per minute so ascent time will be 4 minutes.

Total run time for the dive will be 38 minutes.

Actual decompression done by each dive team will be managed by the diver's own dive computers:

- Each dive computer will be set to the bottom mix of EAN27
- Where possible, each team will be allocated divers using similar types of computer
- If the computers in one team are different then the one computer will be used for controlling decompression times

- The computer used for controlling decompression will be decided before the dive starts
- Divers in a team will undertake the same decompression schedule based on the one selected dive computer
- The type of computer used by each diver will be noted on the Project release form

The seabed depth of the A7 submarine is 37m plus tide height, so the actual depth of water on the site varies between 38m and 42m. The PO₂ for open circuit dives on this project is 1.4 bar, and EAN27 has a maximum operating depth (MOD) of 42m at this PO₂. With EAN27 the equivalent air depth at 38m is 34.4m and at 42m it is 38.1m.

- Decompression gas will be Nitrox 40, provided in a drop tank deployed at 6m on the mooring line
- Decompression will be done with the dive computers set to EAN27 rather than EAN40 allowing an additional margin of safety
- Divers will carry EAN27 in their pony cylinders rather than the decompression gas EAN40

The pony cylinders will be filled with EAN27 because the pony may need to be used at 42m and the PO₂ for EAN40 at this depth is beyond the 1.4 bar limit allowed for dives on this project.

For simplicity, the deeper depth will be assumed for all dives so dives shallower than 42m have an additional safety margin. This avoids the need to tailor gas mixes and decompression according to the state of the tide.

Access to and from the wreck will be via the mooring line installed on the site. Any ascent not using the mooring will be treated as an emergency and the emergency plan will be started, see below.

The support team on the surface will deploy a drop tank full of decompression gas and attach it to the mooring line so it is suspended at 6m depth. The drop tank will have a regulator with two second stages attached to it so the divers should carry out their stops using the gas in this tank. The drop tank regulator will be pressurised but switched off so the divers will need to switch on the gas supply before use.

For timing purposes the end of the dive is the time arriving at the bottom of the mooring, not the time leaving the work area, so the travel time between the two needs to be allowed for.

Dive Computer Failure

Each diver will carry a waterproof card which has the decompression schedule printed on it. The card will be used in the event of failure of all dive computers carried by a dive team so decompression has to be controlled by a dive timer only. The decompression schedule on the card will include additional decompression as a safety factor.

Air Consumption

At a rate of 20 litres per minute for light work the volume of gas used for a 20 minute dive plus decompression will be 2300 litres (GAP calculation).

A 15 litre tank filled to 220 bar provides 3300 litres, allowing a 50 bar reserve it provides 2550 litres.
A 2 x 10 litre tank filled to 220 bar provides 4400 litres, allowing a 50 bar reserve it provides 3400 litres.

Actual gas consumption by the divers in the team will be established during the work-up dives.

Time on site uses 20 l/min x 5.2 bar = 104 litres per minute

For 16 minutes this uses 1664 litres

So descent, ascent and decompression uses 626 litres, approximately 42 bar from a 15 litre cylinder.

This suggests that divers using 15 litre cylinders should leave bottom when 90 bar is reached.

There are a number of built-in safety factors:

- A reserve of 50 bar in the main cylinder has been included
- The diver is carrying an additional emergency supply of gas in a 3 litre pony cylinder
- Decompression gas will usually be provided by the drop tank on the mooring, or in the event of a problem a second drop tank attached to the divers delayed SMB

26.11. Closed Circuit Rebreathers

Closed circuit rebreathers will be used on the project. Divers wishing to use this equipment must be suitably qualified and experienced in their use.

26.12. Lost Diver

Dive teams should not get separated underwater. The Safety Diver should concentrate on supporting the Task Diver and should not wander off. In the event of divers becoming separated underwater:

- The divers should spend a minute looking for their buddy but still remaining in visual contact with the wreck
- If the divers are not reunited they should make their way to the bottom of the mooring and wait one minute
- If the divers are still not reunited they should make their way to the surface independently using the mooring, completing any necessary decompression stops
- If a diver loses sight of the wreck then they will send up a delayed SMB and surface up the SMB line, see Uncontrolled Ascents below.

26.13. Uncontrolled and Emergency Ascents

Normal access to and from the wreck will only be via the mooring line installed on the site.

Any diver or dive team unable to ascend via the mooring line will send up a delayed SMB and surface up the SMB line. The support team on the surface will deploy a drop tank full of decompression gas and attach it to the divers' marker buoy line so it is suspended at 6m depth. The drop tank will have a regulator with two second stages attached to it so the divers should carry out their stops using the gas in this tank. The drop tank regulator will be pressurised but switched off so the divers will need to switch on the gas supply before use.

If any divers do an uncontrolled ascent and are unable to complete their decompression stops then this is considered to be an emergency. If just one diver fails to complete their stops then the other divers in the team must complete their stops. The dive team on the surface will recover the divers, administer oxygen and contact the emergency services.

In the event of an emergency, all divers will be recalled to the surface. The surface team will let off two thunderflash pyrotechnics in succession, one to alert the divers and the second as confirmation. On hearing this signal any divers on the site will stop work immediately and return to the surface via the mooring line undertaking any required decompression.

26.14. Mooring Line

A temporary mooring will be installed on the site, preferably located 5m from the bow. This will mean that the entry and exit point to the site will be the same for each dive. It avoids the first divers having to find the sub each time and avoids any accidental damage to the hull by dropping a shot weight on it.

The seabed depth of the A7 submarine is 37m plus tide height, so the actual depth of water on the site varies between 37m and 42m. The mooring will consist of a 25kg steel weight backed up with one or more ground anchors. The mooring line will be 46m long with a large can buoy attached on the surface. A small float will be attached to the mooring rope 5m above the bottom if required to keep the rope away from the submarine at low tide.

The mooring sinker will be installed close to the bow of the submarine with a rope leading from the mooring to the submarine.

The crew of the NCI lookout station on Rame Head will be approached to see if they will keep an eye on the mooring buoy for us (01752 847387).

The Marine Management Organisation will be notified about the deployment of the temporary mooring.

26.15. First Dive

The first dive on the site will need to be done with caution. It is not possible to tell from the sonar images if the wreck is covered in monofilament net. This type of net is a hazard to divers as they can get very tangled in it very quickly. So for the first dive the team will assume the wreck is netted until they can prove otherwise. The risk to divers will be assessed by the first divers on the site. We may be able to remove or tie up a small amount of net so it is no longer a hazard. If we find the site is wrapped in a large amount of net then this will be left in place and diving abandoned.

The first divers will also be tasked with looking for any visible human remains, clothing or personal effects. The type and location will be noted and reported to the dive supervisor and project manager.

26.16. Human Remains, Clothing and Personal Effects

A significant point to remember during all operations on this wreck is that it is a war grave and must be treated with respect.

- No intrusive activity will be undertaken. In particular no attempt will be made to enter the hull or to record the interior of the vessel. All photographs and video will be taken from outside the hull.
- If any images taken from outside the hull inadvertently record any human remains these images will not be put into the public domain and will be restricted in circulation to MOD and English Heritage.
- If, in the unlikely event, that human remains are encountered outside the hull the composition and location will be recorded and the matter referred immediately to MOD for further direction. ProMare will then implement the further directions received from MOD at no cost to MOD.

26.17. Munitions

It is not anticipated that ordnance will be found. It is assumed that the torpedoes present on site will be exercise torpedoes which remain within the hull. If any torpedoes are encountered outside the hull they will be recorded but, in accordance with the Project's 'no recoveries' policy, no intrusive activity will be directed at them.

26.18. Environmental Risks

- The existence of any environmental risks encountered e.g. leaking oil, lubricants etc. will be reported to the Project Manager
- Large conger eels live in the submarine so care is needed when working around any holes in the hull

26.19. Equipment Requirements

Each diver will ensure that they are carrying the following equipment on each Project dive:

- Dive knife
- Secondary independent air source, such as a pony bottle
- Dive computer plus dive timer or second dive computer
- Delayed surface marker buoy, orange colour
- Underwater torch plus one spare
- Net cutters
- Decompression schedule on a waterproof printed card
- Tools required for the allocated task

In addition:

- Diving cylinders used on the project must be in test
- Diving regulators used on the project must have been serviced within 12 months
- Rebreathers used on the project must have been serviced within 12 months

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