

World Archaeological Congress 4

University of Cape Town

10th - 14th January 1999



Symposium: Maritime Archaeology - Challenges for the New Millennium.

REMOTE SENSING IN MARINE ARCHAEOLOGY: PRELIMINARY RESULTS FROM THE SNOW WHITE PROJECT, ARCTIC NORWAY

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Introduction - Remote Sensing in Marine Archaeology

The use of remote sensing technology in marine archaeology has escalated at an ever increasing rate and rapid developments within marine geophysical survey and related fields guarantee that an even wider array of sophisticated equipment with archaeological applications will become available as we enter the new millennium. The most formidable methodological challenge in marine archaeology is the physical barrier of the underwater environment which substantially increases the amount of planning, effort, time and money required to accomplish even the most fundamental tasks commonly performed by the terrestrial archaeologist. For this reason, marine archaeologists have come to rely on remote sensing technology to a greater extent than their colleagues on land, where low tech solutions tend to predominate.

Modern underwater remote sensing technology has a variety of advantages that supplement and extend the range of conventional diving in archaeological survey.

The greatest advantage lies in the ability to survey large areas in a systematic and detailed fashion collecting substantial amounts of data rapidly.

Cost efficiency- Although initial costs for equipment and trained operators may be high, greater efficiency and speed significantly reduces overall costs compared to diving.

Safety- The constant risk associated with diving is completely eliminated and safe access is provided in situations of high risk and reduced effectiveness for divers such as zero visibility, rough seas and strong currents.

Access to subsurface data - The ability to locate buried cultural remains and map deposits using sub-bottom profilers and other equipment is a distinct advantage over the "sounding rod" approach commonly employed by divers.

Deep ocean access- Technological advances enabling survey at ever greater depths are providing new opportunities and challenges for marine archaeology.

While the utility of remote sensing technology should not be understated, it is important to keep in perspective its role as a tool for addressing archaeological problems more effectively rather than the focal point of archaeological research in its own right. In other words, it is a means to an end rather than an end in itself. As we all know, field methods must be selected on the basis of their appropriateness in addressing specific problems within the framework of a research design. Marine archaeologists are not immune to the tendency of discussing field methods, and advanced technology in particular, in isolation from a broader archaeological context. When methodology is brought to the fore, there is a greater risk that the overall research framework and justification for the selection of a particular method or methods will be dealt with superficially or left out altogether. A dependence on technical specialists with little or no archaeological background to interpret remote sensing data exacerbates this situation. The trend toward remote sensing in deep water necessitates an even greater reliance on technical expertise which can increase the communication gap between those controlling the technology and the archaeologists using it. The focus on increasingly sophisticated technology in marine archaeology also reinforces the impression among our terrestrial brethren that we are fixated on "high tech toys" rather than the advancement of archaeological method and theory (Jasinski et.al. 1995). While this attitude may stem in part from a long standing ignorance of what marine archaeology is all about, it is our responsibility to insure that what we do is relevant to the field at large and communicate this effectively. It is ironic that conferences such as this one which provide us with a platform for communicating with a wide audience continue to group maritime archaeologists in a single session rather than integrating them to a greater extent within sessions relevant to particular research topics.

One means of breaking down communication barriers within the discipline is an integrated approach to remote sensing in which marine geophysical specialists work hand in hand with marine archaeologists in the development and field testing of new technology. An example of this type of interdisciplinary approach is a formal agreement initiated in 1993 at the Norwegian University of Science and Technology in Trondheim between the Department of Marine Systems Design and the Institute for Archaeology (more information can be obtained from their www-pages at: <http://www.ntnu.no/vmuseet/fakark/marin/engelsk/>). As a result of this ongoing program, competence within the field of marine technology has been shared through the involvement of maritime archaeology researchers and students and cooperation in the development of new field methods involving sidescan sonar, sub-bottom profilers, remotely operated vehicles (ROV) and integrated documentation systems tailored to marine archaeological surveys (Søreide et.al. 1996). The use of existing marine technology in archaeological surveys has provided a test of equipment capabilities and data to assist in defining the specifications for new methods and equipment.

The remainder of this paper will explore the potential for an integrated approach to remote sensing in marine archaeology using an example from northern Norway, the Snow White project. The study area is located on the periphery of Europe in an Arctic setting which is characteristic of the special set of conditions confronting marine archaeologists in the region. With a population clustered along a coastline of 25,000 km, by far the longest of any single nation in Europe, the inhabitants of Norway have always had a maritime orientation. Although a significant amount of archaeological research in Norway has been directed towards the maritime sphere, data collection from the marine environment has lagged far behind that on land and focused in large part on coastal zones near population centers in the south. Basic survey data from marine archaeology in northern Norway is minimal and the

challenges for future research immense. Remote sensing is a promising means of addressing the challenges of this vast, poorly documented region and the case study we present is an initial attempt at harnessing this potential.

Marine Cultural Resource Management and the Snow White Project

Underwater cultural resources in Norway are protected under the Norwegian law on ancient monuments (kulturminneloven), including the physical remains and contents of vessels built over 100 years ago and submerged archaeological sites from both salt and fresh water. The task of enforcing this portion of the law has been allocated to five museums, each responsible for a given region. Professional staff were first assigned by the Directorate for Cultural Heritage to the museums in Oslo and Trondheim in 1989 with a position later established in Bergen and a fulltime position at the Tromsø Museum since 1996. The fifth museum, in Stavanger, has yet to receive its promised position (**overhead - map with location of museums**)

In accordance with the ancient monuments law, notification of the appropriate authorities at each of the five regional museums is required in advance of proposed developments by the public or private sector which may adversely impact marine cultural resources within their respective regions. Archaeological field investigations subsequently undertaken to assess and mitigate the impact of proposed development are financed by the developer.

The Snow White project is an example of proposed development in northern Norway where archaeological survey was required by law within a cultural resource management (CRM) framework (**overhead - schematic and map of pipeline**). This project entails plans by the Norwegian State Oil Company (Statoil) to construct a pipeline for the transport of natural gas from three offshore fields, one of which is named Snow White, over a distance of ca. 150 km southeast to the small island of Melkøya located along the coast of Finnmark county where an LNG terminal will be constructed. The LNG facility will be located in close proximity to Hammerfest, the world's northernmost town situated at 70°39'48" N. This pipeline will be the first of its kind in northern Norway and the two alternative pipeline corridors currently under consideration extend to depths in excess of 400 m (**overhead - topo. map of pipeline**). Until 1994 pipeline corridors and other offshore installations in Norwegian waters were not investigated by marine archaeologists, but recently these sites have become targets for investigations (Hovland et.al. 1998).

Research Strategy and Goals

Tromsø Museum, whose district includes all of northern Norway, had overall responsibility for conducting an underwater archaeological survey of the area to be impacted by the proposed Snow White project as one component of an environmental impact assessment. Due to the substantial size and depths within the survey area, the primary focus of the survey was on remote sensing supplemented by conventional diving. Although the survey was undertaken in response to CRM requirements and the project area defined on the basis of planned development rather than archaeological objectives, it provided an unprecedented research opportunity to explore the potential of advanced remote sensing technology in marine archaeology from northern Norway. Given the multi-disciplinary nature

of the survey coupled with limited resources and lack of expertise in remote sensing technology at the Tromsø Museum, a cooperative multi-institutional approach was felt to be most productive. The involvement of researchers from the joint program on the use of marine technology in archaeology at the Norwegian University of Science and Technology (NTNU) provided a means of expanding the scope of research within this program and testing new technology currently under development. Proper methods had already been developed by NTNU on another pipeline project from 1994 to 1997 (Søreide & Jasinski 1998). The Norwegian Institute for Cultural Heritage Research (NIKU) was also involved in the project and provided expertise in sub-bottom profiler technology.

Apart from the goal of testing remote sensing applications in marine archaeology, a set of archaeological problems specific to the survey area provided a general research framework for the investigations. The first problem area to be investigated was the potential for submerged prehistoric features and site deposits in the vicinity of Melkøya where recent land-based archaeological survey has documented Mesolithic residential structures and associated features. Potential archaeological features consisting of circular stone rings recorded in shallow water adjacent to a prehistoric settlement at Slettnes on the nearby island of Sørøya also suggested the potential for similar finds within the project area.

A second research focus was on the documentation of evidence for maritime activity at the port of Hammerfest since its founding at the end of the 17th century, primarily in the form of shipwrecks. The establishment and growth of Hammerfest was due in large part to its excellent natural harbor which became an important link in maritime commerce and communication along the coast of Finnmark (**photo/overhead - old print of H. harbor**). Maritime activity at Hammerfest can be divided into three major categories which overlap chronologically. In addition to locally based small scale fisheries, the commercial trade in stockfish (dried cod) exported to southern Europe, which was of critical importance to the economy of Finnmark, also played a central role in the economy of Hammerfest since its founding. The second category of maritime activity was the so called Pomor trade for which Hammerfest was a principal port from the middle of the 1700s until the close of World War I (**photo/overhead - Russian ships in Hammerfest harbor**). This trade involved Russian trading vessels from the White Sea area which brought vital goods such as flour and grain to be exchanged for fish and a range of other goods and products. The true volume of trade is difficult to quantify as much of it was unregistered. This is especially true of the earliest period when the trade was illegal. Some impression of the amount of activity can be gleaned from Norwegian records indicating that between 350 and 400 Russian vessels entered ports in Finnmark each year during the mid-1800s and average figures rarely dropped below 300 vessels during the second half of the century. Russian documentation of the number of vessels involved in the trade and those which sank also exists but the precise location of wrecks is lacking. The third category of activity was the outfitting of vessels for hunting expeditions to Spitzbergen in the high-Arctic. The first successful overwintering expedition set out from Hammerfest in 1819 and activity expanded steadily during the following decades (Jasinski 1993).

Field Investigations - Methods and Results

During the initial planning stage for the Snow White survey, the project area was divided into shallow and deep water zones for survey purposes (**overhead - chart with project area marked**). The shallow water survey zone was restricted to depths of less than

30 m around the island Melkøya where the LNG terminal will be built and along the adjacent shoreline of Kvaløya southward to the northern edge of Hammerfest harbor. The deep water zone includes the pipeline corridor alternatives and several pockets up to ca. 60 m deep in the vicinity of the proposed LNG facility. Archaeological survey in 1998 was limited to the shallow water zone.

A preliminary seabed mapping survey of the pipeline corridor alternatives was carried out by Statoil using multibeam echosounder, sidescan sonar, visual inspection by ROV mounted video cameras, and a sub-bottom profiler. An inspection of the survey data indicated that the sonar resolution (100 kHz) was inadequate for archaeological purposes and further diminished by the speed of 4.5 knots at which the towfish was traveling. The video footage only covers a small sector of the inshore portion of the pipeline. Due to the inadequacy of the equipment used and coverage during the initial Statoil survey, an additional archaeological survey is planned in conjunction with Statoil's detailed remote sensing survey of the final pipeline corridor in the year 2000, based on the methods developed by NTNU on the other pipeline project in 1994-97 (Søreide & Jasinski 1998). This survey will therefore utilize adequate equipment which will meet criteria specified by marine archaeologists who will determine the survey parameters in the field. Additional archaeological survey of locations with archaeological potential along the pipeline corridor and the deep water pockets in the vicinity of Melkøya independent of Statoil's survey are also planned.

The shallow water survey in 1998 was divided into three phases under the overall direction of Tromsø Museum. The initial two phases involved systematic survey of the project area by side-scan sonar and sub-bottom profiler directed by researchers from the other two institutions involved in the project, NTNU and NIKU. The third and final phase of the investigations consisted of conventional diving oriented by the results of the first two phases of fieldwork.

Phase I - Sidescan Sonar Survey

This survey component was carried out by NTNU under the direction of Marek E. Jasinski (Institute of Archaeology) and Fredrik Søreide (Department of Marine Systems Design) with field operations led by Morten Kvamme. **[Overhead - boat, towfish and equipment in operation]** The survey was completed over a period of one week. The system used was a 600 kHz SeaScan sidescan produced by Marine Sonic Technology Ltd. Using a Trimble differential GPS system and digital sea charts, the sonar was towed behind a 60 ft. research vessel in the survey area in systematic search patterns. The high resolution images offered by this system enabled possible cultural remains to be separated from the complex and steep underwater terrain, filled with rocks and other seabed features. This would not have been possible using a low frequency sonar.

A total of 41 targets of potential archaeological interest was registered during the sonar survey (**overhead - digital chart with survey route and targets**). These points were reduced to seven targets to be visually inspected by divers following the elimination of natural features and locations at depths exceeding 30 m. A majority of the most interesting locations occurred in two clusters: around the southwest end of Melkøya and along the shoreline of Kvaløya between Melkøya and Hammerfest harbor (**overhead - digital chart with clusters**). The remains of one 20th century wreck was documented; a previously recorded German trawler named "Anna" which was built in 1915 and ran aground in 1931. The collective results revealed no evidence of wrecks protected by law (those built over 100 years ago) or any other remains of archaeological interest, although a number of promising points were located at depths in excess of 30 m where visual inspection by divers was not possible. Targets at greater depths will be investigated by an ROV at a later date.

Phase II - Acoustic High-resolution Sub-bottom Profiler Survey

This phase of the field investigations was carried out under the direction of Ole Grøn from NIKU with field operations led by an archaeological consultant from Denmark over a one week period. The survey covered the same general area as the sonar survey using a 20 ft. fiberglass boat as a platform. An Ashtech DGPS combined with the program Navipac from the Danish firm Eiva was used for positioning enabling navigation precision of under one meter. The survey was conducted with a Chirp II acoustic profiler system from Datasonics. This system sweeps the interval from 2-23 kHz on two channels and shows good penetration even in sandy sediments and water as shallow as 0.3 meters. An initial course grained survey of the project area was undertaken to be followed by a more detailed recording of locations of potential archaeological interest. In this instance, the initial survey sweep was enough to demonstrate that the potential for intact cultural deposits or even layers of sediment finer than sand is minimal due to a combination of strong currents and exposure to wave action along the shoreline. In light of the negative results, a more detailed investigation was unnecessary.

Phase III - Conventional Diving Survey

The final phase of the survey consisted of diving to a maximum depth of 30 m with a crew of four under the direction of Stephen Wickler from the Tromsø Museum over a 10 day period. The objectives were twofold: visual inspection of locations of potential archaeological interest pinpointed during the sonar survey, and systematic coverage of the general survey area. A total of 23 dives was made during the course of the survey using cable communication with a single diver in the water in most instances. Targets with archaeological potential identified at depths of less than 30 m by the side-scan sonar were relocated by DGPS and marked with buoys. These locations were then inspected and the objects located by sonar were identified and recorded. Apart from the recent wreck previously mentioned, remains were limited to items of recent origin (i.e., discarded machinery, anchors, fishing nets, etc.) of no archaeological significance. Diving was hampered to some extent by heavy waves and strong currents, particularly along the exposed northern side of Melkøya. Despite these problems, segments of the coastline which will be directly impacted by the proposed development were surveyed in a systematic fashion.

Concluding Discussion

Despite the negative overall results of the Snow White project to date, the field investigations have provided us with valuable experience on several fronts.

Firstly, the use of state-of-the-art remote sensing technology combined with diving insured that the survey was conducted in the most thorough fashion possible and increases the likelihood that the results accurately reflect the actual distribution of material remains on and below the seafloor. This is much more than can be said for the majority of archaeological surveys which are limited to visual inspection by divers and limited subsurface testing based on sounding rods and a few test trenches. Although underwater survey can still be likened to a search for the proverbial needle in a haystack, an integrated remote sensing approach reduces the odds stacked against us dramatically. From a CRM perspective, the increased effectiveness and overall cost efficiency of an integrated remote sensing approach is of benefit to both the archaeologist and the developer.

Secondly, the Snow White project demonstrates the potential for integrating research and CRM. As nearly all of the marine archaeology in Norway is CRM related, there is a clear need and obligation to insure that this work is research oriented and extends beyond the mere cataloging of finds. For the field of marine technology and remote sensing, CRM projects provide an arena for testing new technology and its applications in marine archaeology. This applies not only to larger projects or those in deep water but extends to smaller survey areas in shallow water as well. The expense of remote sensing and the need for technical expertise has been a factor in limiting its use in smaller projects but trends in technological development have made equipment more accessible and economical so that this is no longer the impediment it once was. Access to technology does not insure that it will be actively integrated within a research framework, however. The dependence on operators and technicians with expertise in remote sensing but no archaeological training can be a significant obstacle for the integration of this data in archaeological research. The degree to which remote sensing data found in the appendices of CRM reports are integrated into the main body of the report varies considerably and is dependent on the degree of communication between the specialist and the archaeologist.

Thirdly, the Snow White project has demonstrated the effectiveness of a team approach in which researchers from three institutions with expertise in remote sensing and marine archaeology cooperated in planning and executing problem oriented field research. The mutual exchange of ideas and expertise between specialists in marine technology and marine archaeology has provided common ground for the development of remote sensing technology which will be of central importance in the new millennium.

As a parting thought, we want to emphasize the need for an outward looking global approach. This is especially true in a country such as Norway with a vast coastline and limited resources for maritime archaeology, where it is essential that we pool our resources for the good of the whole and look beyond our respective regions to work toward collective goals at the national and international level.

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NTNU www-pages can be found at
<http://www.ntnu.no/vmuseet/fakark/marin/engelsk/>