# ACOUSTIC MINE IMAGING (AMI) PROJECT AN UNDERWATER ACOUSTIC CAMERA FOR USE IN MINE WARFARE

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## Abstract

There have been significant advances in sonar processing, imaging and synthetic apertures processing being made in the Australian Defence Acquisition Project SEA 1432 Acoustic Mine Imaging (AMI). This paper will detail the Australian based development of the "AMI" an underwater acoustic camera for the detection, classification and characterisation of mines and other underwater objects in turbid water where optical imaging is ineffective. The paper will consider the phases of this project and detail the very high computational capability and sub-millimetre transducers in a 2D matrix array developed within the program. The paper will then present the recent trial results and discuss the ongoing development plans to enhance visualisation

## Introduction

There have been significant advances in sonar processing, imaging and synthetic apertures processing being made in the Australian Defence Acquisition Project SEA 1432 Acoustic Mine Imaging (AMI) led by the Mine Warfare and Clearance Diving SPO. This project is for the development of the "AMI" an underwater acoustic camera for the detection, classification and characterisation of mines and other underwater objects in turbid water where optical imaging is ineffective. The technical complexity of the AMI has demanded very high computational capability and sub-millimetre transducers in a 2D matrix array. Significant technical and operational challenges had to be addressed. Recent Trial results have established the capability is on track but have also shown that display enhancements will needed to fully address Royal Australian Navy (RAN) requirements.

## The Mine Warfare Requirement

The RAN require that the remotely operated SBUS Double Eagle™ Mine Disposal Vehicle (MDV) onboard their HUON Class Minehunter Coastals (MHC) be capable of prosecuting mines in all water conditions. The MDV currently uses a low light video camera for mine *'identification',* that is separation of detected POSsible MINes (POSMINEs) into either non threat objects (NONMINEs) or proven mines and thence for *'categorisation'* of different mine types. The current optical based technology does not permit positive identification or categorisation in the turbid water conditions prevalent around the Australian sea-board.

These turbid water conditions currently require RAN clearance divers to undertake *'tactile identification'* that is, use of touch, for positive identification or categorisation of sonar contacts. This is a time-consuming and extremely dangerous mission. Recent RAN Clearance Diver operations during the Umn Qasr clearance in zero visibility highlighted the urgent need for an alternative imaging capability.


**Figure 1 - AMI fitted to SBUS Double Eagle MDV**

## AMI Development Progress

AMI is a collaborative development by the Commonwealth's Defence Materiel Organisation (DMO), Defence Science and Technology Office (DSTO), Thales Underwater Systems Pty Limited (TUS) and the CSIRO. AMI has been designed to enhance the mine identification and catergorisation capability of the RAN’s MHC.

SEA 1432 Phase 1 developed a concept demonstrator with a large and unwieldy 550 kg array. This phase established the fundamental principles of the AMI and proved that the frequencies would provide tactically useful acoustic range, fidelity and insensitivity to turbidity. All processing in this phase was non real-time using MATLAB™.

SEA 1432 Phase 2 was implemented to develop the concept demonstrator into an operational prototype deployed onto the MDV. This phase has seen the achievement of significant milestones including the miniaturisation of the matrix array into a 36 kg unit fitted to the MDV, development of real-time processing, integration of this capability into the existing MHC combat system and development of enhanced Human Computer Interfaces (HCI).

The AMI Signal Processing Sub System (SPSS) was developed to meet the very high computational requirements. The SPSS utilises state of the art Field Programmable Gate Array (FPGA) technology in order to process the signals coming from the array at an average rate of 1 Gigabit/s to generate a 3 Million Voxel 3D image with a refresh rate of up to 8Hz.

This real-time performance was only achievable by developing flexible high speed processing hardware. A total of six different types of digital boards have been developed by TUS for the project; some of which are at the forefront of the FPGA technology. The heart of the machine is the "BeamFormer" (BF) board. This board uses advanced near-field beamforming algorithms developed with CSIRO. Each board uses five Xilinx Virtex II devices interconnected together and communicating with the rest of the system via a DPIO port and a 2.5 Gigabit/s link.

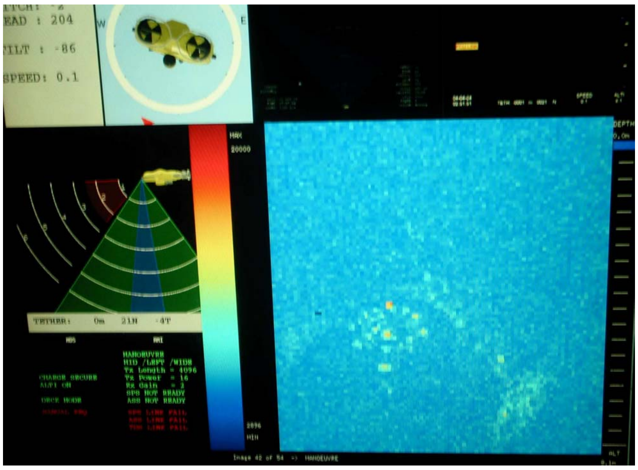


**Figure 2 - New MDV HCI**

Overall, the SPSS achieves a processing power close to one TeraOps using 30 FPGAs and 18 Motorola G4 Microprocessors. The power consumption is less than 500 W and it fits a GU 19-inch rack. This processing power is the equivalent of several thousand modern Personal Computers that would require hundreds of kilowatts and would not fit inside the Operations Room of the MHC.

Another key milestone has been the development of the new MDV HCI in collaboration with RAN MDV operators. This new HCI overcomes many of the situational awareness limitations of the original HCI, which has previously led to MDV crashes in mine warfare operations. The Navy operators were so impressed by the new intuitive HCI that they have sought early implementation of the HCI into the MDV's under a separate project.

# Trials

The first trial was a successful harbour trial in November 2003 of the AMI modified MDV and the new HCI at HMAS WATERHEN in Sydney. This trial proved the MDV's hydrodynamic performance and mission envelope were not affected by the AMI system. This trial also confirmed that enhanced operability of the new HCI.

Factory Acceptance Testing (FAT) and Harbour Acceptance Testing (HAT) then followed in 2004. These test period proved that the real-time processing architecture functioned correctly and that the MDV could be controlled using AMI imagery to approach and interact with targets including RAN test mine shapes and rope obstructions. These phases also highlighted that the raw data displays were sub-optimal for operator recognition of mines and that improved display methodologies were required to optimise function in any future production system.

The AMI was then integrated into the existing MHC mine warfare combat system onboard the MHC, HMAS NORMAN. This successful integration was another key milestone and proved the robustness of the AMI system for future operations. The AMI modified MDV was operated from HMAS NORMAN for the Sea Acceptance Trials (SAT) in June. The AMI was controlled from the combat system by RAN operators in simulated real missions, and the collected data was successfully passed to the combat system, however, the limitations in the raw data display meant that operator recognition of mine targets was sub optimal.

## The Road Map

TUS is undertaking a post SAT self-funded analysis and re-development phase to address the noted limitations in the operational prototype's data display. This phase will analyse the collected HAT and SAT data to identify the steps required to improve the clarity of AMI displays. This 'road map' phase will include re-calibration of the array, audit the processing chain and implementation of the display improvements. Display improvement will include the introduction of ping-to-ping integration, improved display latency, provision of automated recognition databases and implementation of synthetic surface presentation of the raw data for unambiguous operator appreciation. This phase will also see the introduction of a AMI test-bed to provide rapid testing and validation of the identified enhancements.

## Conclusions

In SEA 1432 Australia has collectively made a major leap forward in acoustic technology. This innovation, development, integration and test process has produced the world's highest resolution three dimensional sonar. Notwithstanding the need for further development, this collaborative project by DMO, TUS, DSTO and the CSIRO has been a major step forward in acoustic technology. The aims remains to provide a new more efficient and far safer capability to the RAN to undertake mine identification and categorisation