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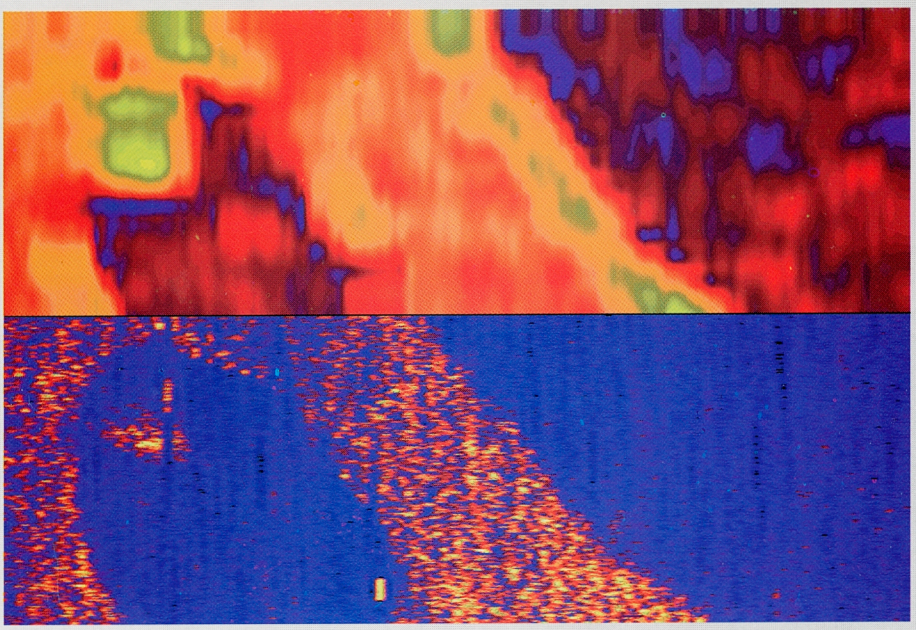

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ADVANCES IN COTS SIDE SCAN SONAR FOR MCM APPLICATIONS

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Abstract

- *The Persian Gulf War has elevated the awareness to the problems of shallow water mine detection. Today's high technology shallow water anti-invasion mines, such as the Italian made "MANTA" and the Swedish manufactured "ROCKAN", have been designed with stealth shapes and from materials to make detection by sonar systems difficult. Recent trials at NUWC (Naval Underwater Weapons Center), Newport R.I., have demonstrated the advantage of the latest generation of COTS (commercial-off-the-shelf) Side Scan Sonars employing full digital designs in detecting these mine types. This poster session will summarize the design features of these new systems and example results will be presented.*

1. Introduction

NUWC (Naval Underwater Weapons Center), Newport R.I., has an on going AUV (autonomous underwater vehicle) development program for MCM applications. The selection process of a COTS side scan sonar for installation on the AUV involved deploying a test mine field and evaluating sonar performance against various mine types. A test mine field consisting of a MANTA, ROCKAN, SSLM (submarine launched mobile mine), and a Russian air dropped conventional ground mine were laid in 20 meters of water depth off Gould Island, NUWC'S test range. Several different sonars were tested including the U.S. Navies older C-MK I Shadowgraph, an ultra high resolution system operating at 1.3 and 1.4 MHz. Klein Associates participated in the trials with their new System 2000, an all new 100% digital side scan sonar system.

A second trial was organized to push the speed envelope for the detection of various mine types. A new mine field was again deployed consisting of a MANTA, a MK 52, a Mk 6 moored mine and a RM-1 moored mine. The Klein System 5000, the first commercially available COTS high speed, dynamically focused multi-beam side scan sonar, was tested against these mines at speeds up to 12.0 knots. This system employs the same design principles for creating continuously range focused receive beams as found in the U.S. Navy's helicopter towed AN/AQS-14 side scan sonar manufactured by Westinghouse.

2. Klein System 2000Description

The System 2000 is an all digital, simultaneous dual frequency, COTS side scan sonar consisting of a small light weight instrumented towfish, a single coaxial towcable and the surface processing unit.

2.1 Towfish

The towfish has port and starboard transducers which contain high performance 100 kHz and 400 kHz arrays. The 100 kHz has a 1.0 degree horizontal by 40 degree vertical beam and the high resolution 400 kHz has a 0.2 degree horizontal by 40 degree vertical beam. Transmitters are of a synthesized tone burst design allowing stable variable transmit pulse

Model 2260NV Instrumented Towfish

lengths to be selected. The pre-amplifier is designed for very low noise with a noise figure of less than 1 db. A TVG (time-variable-gain) amplifier with a digitally synthesized range-gain law ensures a wide backscatter dynamic range compression prior to signal digitisation. The 12 bit digital multiplexed data is transmitted to the surface through a single coaxial conductor towcable. Integrated into the towfish is a sensor package which includes a heading, pitch & roll sensor, a pressure sensor for depth, a temperature sensor and an optional responder for use with a USBL acoustic tracking system. The sensor data is very valuable when used in the target position calcultation since it reduces error in the calculated geographic position of targets on the seafloor.

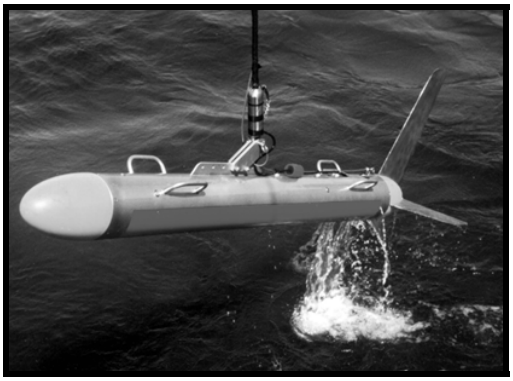
2.2 Surface Processor

The System 2000 surface unit is a no compromise integration of the sonar processor, a high resolution color video display, a very high resolution 300 dpi, 256 true gray shade thermal printer, and high density digital tape drives for archiving the sonar and navigation data. The hard copy thermal printer can display 2 channel single frequency data or simultaneous dual frequency (100/500 kHz) data. Positioning data is received from the navigation system and on the video display, via the trackball/cursor, real time positioning of mine like targets as well as target mensuration is done This target information is stored on the digital recording tapes and exported to host computers for real time plotting of the target locations, etc. Other standard features included are mapping display (slant range and speed correction), real time target zooming, delay and expand functions. An optional 3.5 kHz sub-bottom profiler can be added onto the system which is a valuable sensor to aid in the classification of bottom hardness, data which is helpful for Q-Route selection.

System 2000 Surface Processor

3. Klein System 5000 Mk II Description

The Klein System 5000 Mk II Focused Multi-Beam side scan sonar is designed for high speed (10+ knots), 100% bottom coverage while maintaining very high resolution over the full swath of up to 300 meters. The towfish houses port and starboard transducer arrays that operate a 455 kHz, giving operational ranges of up to 150 meters per side. A complete sensor package containing heading, pitch, roll, pressure, temperature and acoustic responder is included. Phase shift processing techniques are used to develop 5 simultaneous digitally formed receive beams per side. In addition, these beams are dynamically range focused to maintain 20 cm. along-track resolution in standard mode and 10 cm. along-track resolution in high resolution mode. The beam forming, focusing, time variable gain (TVG), and digital multiplexing / de-multiplexing of the sonar (up-link) and control (down-link) data is accomplished in the towfish. The control and sonar / sensor data is bi-directionaly multiplexed on a single coaxial conductor towcable. Data display of sonar imagery and detected MLO's (mine-like-object) is on a PC based image processing system which also handles target position calculations and target mensuration.

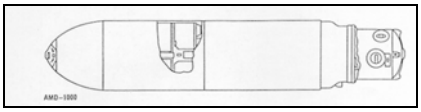


System 5000 Mk II Towfish

4. Mine Target Descriptions

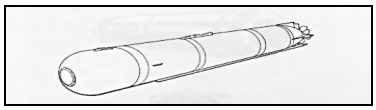
The two trials used mine types which are representative of both traditional steel mines and the newer high technology plastic / stealth types. A summary of the mine types and characteristics follow.

4.1 AMD - 1000 (emulation)



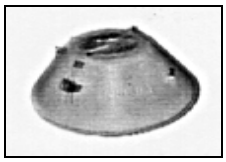
The AMD - 1000 is a conventional steel cased influence ground mine. The dimensions are approximately 2.85 meters long by 0.53 meters in diameter. This target was used for the **System 2000** trial.

4.2 Submarine Launched Mobile Mine (SSLM)



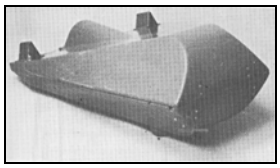
The SSLM mine is essentially a torpedo modified with mine components. The body is metal cased and the dimensions are approximately 4.1 meters in length and 0.50 meters in diameter. This target was used for the **System 2000** trial.

4.3 Manta Mine



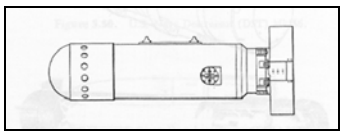
The Italian made Manta mine is one of the newer high technology anti-invasion ground mines. This influence mine is plastic cased and has a low profile conical shape making it one of the more difficult types to detect with a sonar system. The dimensions of the Manta are 0.98 meters in diameter at the base and 0.47 meters high. This mine was used for both the **System 2000** and **System 5000** trials.

4.4 Rockan Mine



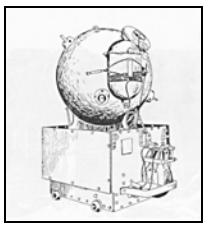
The Swedish made Rockan, which because of it's shape and plastic case, was the most difficult mine to detect during the trials. The sloping angled faces and low profile of this mine make it truly a stealth design. The Rockan is 1.02 meters long, 0.80 meters wide and 0.38 meters high. This mine was used for the **System 2000** trial.

4.5 Mk 52 Mine



The U.S. Mk 52 mine is a traditional steel cased cylindrical ground mine. Due to it's shape and material it is one of the easier mines to detect. The Mk 52 is 2.25 meters in length and 0.85 meters in diameter. This mine was used for the **System 5000** trials.

4.6 Mk 6 Moored Mine



The U.S. Mk 6 mine is an obsolete moored contact mine. This mine was used as a representative mid-water spherical MLO. The mine is approximately 1.0 meters in diameter. The Mk 6 was used for the **System 5000** trials and was moored approximately 2 meters off the bottom.

4.7 RM-1 Rising Mine

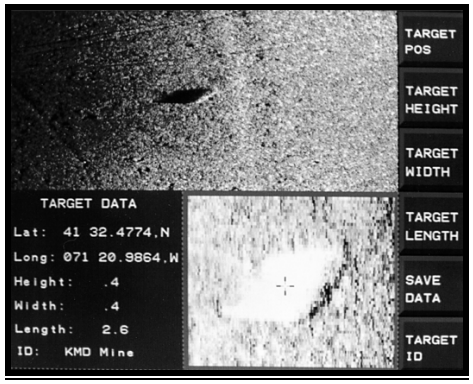
The RM-1 rising mine is a steel cylinder that is moored above the bottom. This mine acoustically senses a target and then is propelled to the target. The cylindrical moored mine case dimensions are 2.76 meters high by 0.64 meters in diameter. This mine was used for the **SYSTEM 5000** trials and was moored 2 meters above the bottom.

5. Trial Results

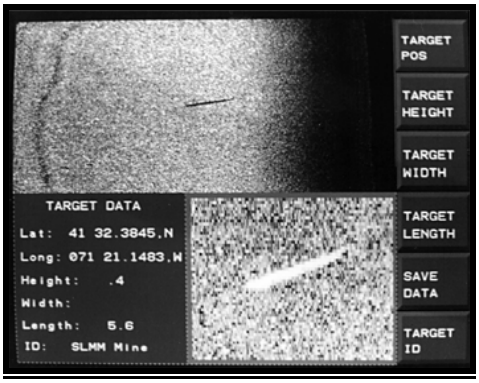
The trials for both systems were conducted off the NUWC torpedo recovery vessel #841 which is 35 meters in length. Navigation was controlled by an integrated navigation computer using differential GPS input. Both sonar systems were hand deployed on light weight towcables.

5.1 System 2000 Trial Results

The **System 2000** trial was run at towspeeds of 3 to 4 knots and at various sonar ranges up to a maximum of 100 meters. The sample images are from the **System 2000** video display. The upper half of the display shows the un-zoomed sonar image in a reversed gray scale. The lower right sonar image is the zoomed display to full sonar resolution of the mine and in a positive gray scale. The lower left part of the display shows the target data which includes it's geographic position on the seafloor as calculated from the navigation input, and measurements made of it's length, width, and height. All of this data is stored in a target file on the digital tape and exported through an RS 232 port to 3rd party processing systems. Representative sonar images from the **System 2000** of the 4 different mine types used in the trial follow:

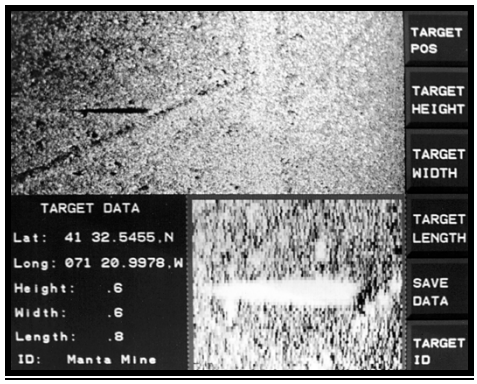


Sonar Image #1: AMD-1000

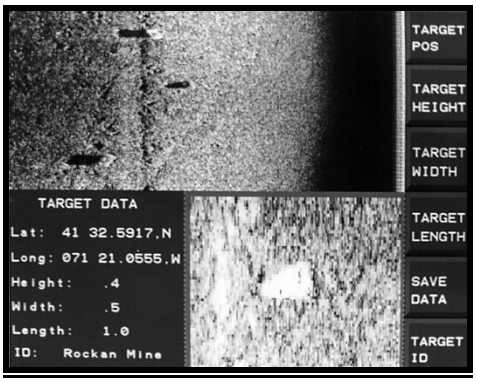


Sonar Image #2: SSLM

The conventional cylindrical steel cased **AMD-1000** and **SSLM** mine were very easy targets to detect and classify using the echo return and characteristic parallelogram shaped acoustic shadow. These two targets were successfully detected on all sonar ranges up to the maximum 100 meter sonar range used during the trial.



Sonar Image #3: MANTA



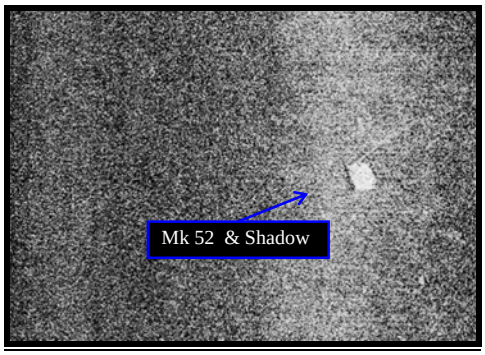
Sonar Image #4: ROCKAN

The **Manta** was a somewhat more difficult mine to detect due to it's plastic case, conical shape and low profile height. In the image the acoustic shadow shape clearly implied a conical shape. The **Manta** was repeatedly detected on all ranges up to a maximum of 75 meters. The linear feature nearby is an old drag scar probably from a fishing trawler.

The **Rockan** was the most difficult mine to detect with it's very low profile, plastic case and unusual shape. Classification was aided by the acoustic shadow which clearly showed a sloping up surface which abruptly drops back down. The **Rockan** was repeatedly detected on all ranges up to a maximum of 75 meters. The two other rectangular objects seen above and below the **Rockan** in the upper part of the video display are New England lobster traps.

5.2 High Speed System 5000 Trial Results

The **System 5000** trial was run at towspeeds of 9 to 12 knots and on various sonar range scales up to a maximum of 100 meters. This trial clearly showed the advantage of modern digitial design against to ambient noise pick-up. The towfish at these high speeds was riding (most of the time) directly in the propeller wash and noise would typically be seen on the sonar imagery. The **System 5000** sonar images were clean with no detectable noise displayed. Representative sonar images of the 4 different mine types used in the trial follow:



This **System 5000** sonar image of the **Mk 52** was made at a speed of **11.9 knots** and the sonar was set to a 50 meter range scale. The image is comparable to the image produced by the single beam **System 2000** at **4 knots**.

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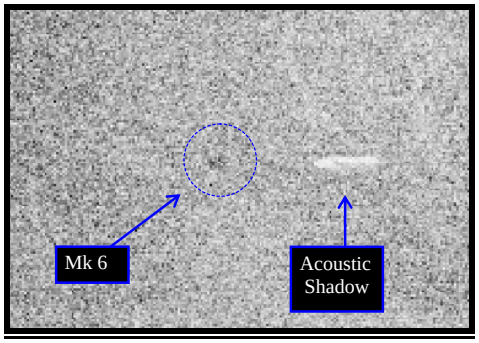
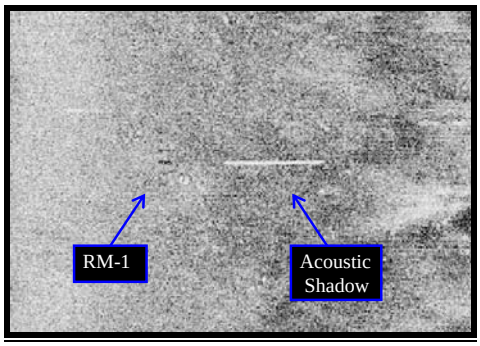
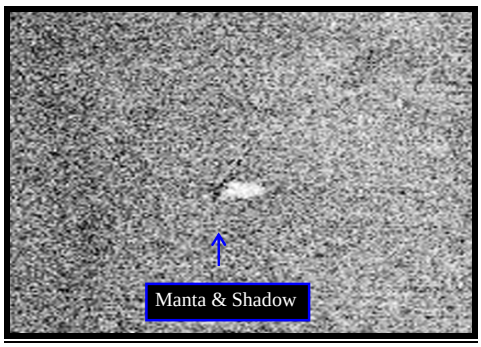


This **System 5000** sonar image of the **Mk 6** moored mine was made at a speed of **9.0 knots** and the sonar was set to a 75 meter range scale. The acoustic shadow is detached from the mine since it is moored above the sea floor.



This **System 5000** sonar image of the **RM-1** rising moored mine was made at a speed of **11.8 knots** and the sonar was set to a 75 meter range scale. The sonar successfully detected this mine at very high speed even though, suspended vertically on it's tether, it presented a very small along track dimension to ping on.



This **System 5000** sonar image of the **Manta** mine was made at a speed of **11.8 knots** and the sonar was set to a 75 meter range scale.

6. Conclusion

The imaging results from the first trial with the System 2000 showed the advantage of an all digital design compared to the older analog and analog/digital hybrid designs. The image resolution and range performance were clearly superior when compared to older systems and even surpassed the resolution generated by the ultra high frequency C-Mk I Shadowgraph. On this basis a re-packaged System 2000 was selected for installation into the NUWC AUV test platform.

The System 5000 results showed that the large aperature, multi-beam, continuous range focusing techniques provided high speed (10+ knots), full bottom coverage mine detection out to ranges of 100 meters. The sonar image resolution and quality was comparable to that made with the single beam System 2000 at slower tow speeds (less than 5 knots).