CASE STUDY

AI helps make oceans safer.

CMRE uses machine learning to detect naval mines.

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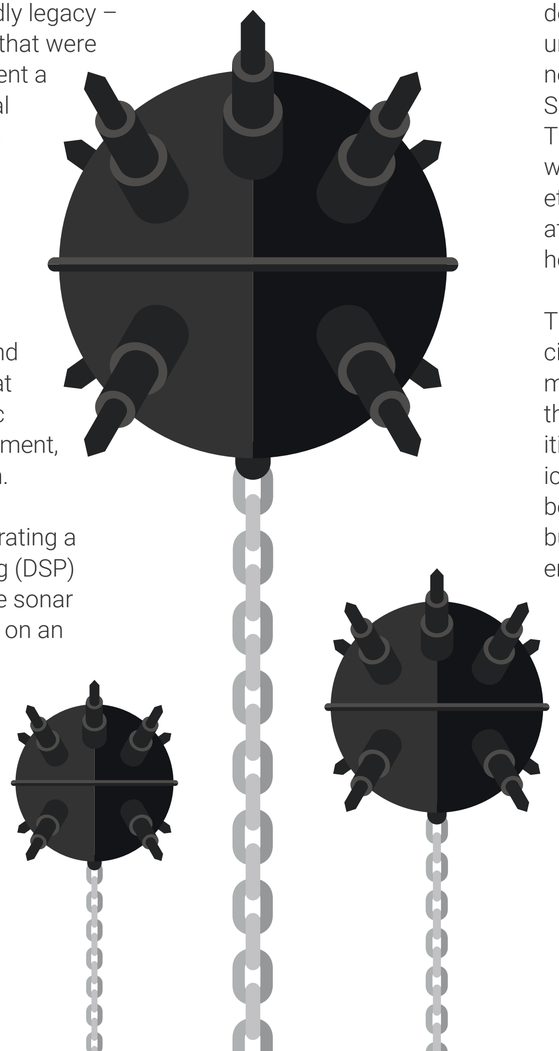
Overview

Naval mines have been in use since the Ming dynasty (1368-1644), and were also deployed during the American Civil War. Two world wars left European oceans with a deadly legacy – many thousands of naval mines that were lost or abandoned. These represent a substantial danger to commercial shipping, and clearing them is an imperative.

Previously known as NATO Undersea Research Centre (NURC), the Centre for Maritime Research and Experimentation (CMRE) is a scientific research and experimentation NATO facility that organizes and conducts scientific research and technology development, centered on the maritime domain.

CMRE was tasked with demonstrating a real-time digital signal processing (DSP) capability for a synthetic aperture sonar application that would be hosted on an autonomous submarine.



The challenge

The Autonomous Mine Search Using High-Frequency Synthetic Aperture Sonar project focused on enhancing NATO mine detection and neutralization capability with unmanned underwater vehicles (UUVs) – notably, the MUSCLE (Minehunting UUV for Shallow water Covert Littoral Expeditions). The MUSCLE is based on the Bluefin-21 UUV, which is 16.2 feet long, 21 inches in diameter, and weighs 1,650 pounds. It can operate as deep as 14,763 feet, and for up to 25 hours between battery recharges.

The project focused on increasing the efficiency and effectiveness of the full range of mine search missions by greatly improving the processing and decision-making capabilities on-board the MUSCLE. Various synthetic aperture sonar processing algorithms had been developed over several years at CMRE, but none of them were ideally suited for an embedded and near real-time application.

> The GPU-accelerated MUSCLE AUV makes mine hunting faster, more affordable, more reliable, and safer for NATO. Without GPU acceleration, real-time detection and classification of munitions was practically unfeasible.
>
> *Francesco Baralli, Principal Scientific Assistant, CMRE*

The challenge was to significantly speed the processing of collected data to allow for more responsive countermeasures. CMRE quickly determined that the solution would have two key characteristics.

First, it would leverage the power of AI and machine learning technology to turn the captured sonar data into detailed acoustic images of the sea bed, creating meaningful, actionable information in as close to real time as possible.

Second, in order for the solution to be integrated within the submarine such that the MUSCLE UUV could undertake truly autonomous operations, the solution would need to be small, light weight and consume minimal power – the latter to maximize mission length. Moving the algorithms and behaviors on-board the UUV had the potential to significantly increase the speed of operation for mine countermeasure missions.

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The solution

Abaco proposed the MAGIC1 SWaP-optimized rugged subsystem, designed to satisfy the rapid growth in demand for on-platform capabilities to handle enormous quantities of sensor-generated data and turn it into actionable intelligence. The MAGIC1 combines an Intel Core i7 processor operating at 2.4GHz state-of-the-art CPU technology with a CUDA-enabled 384-core NVIDIA EXK107 Kepler GPU (graphics processing unit) to deliver a subsystem that fulfilled the requirement for both minimal footprint and AI capability.

CMRE were able to re-design the entire processing chain in C++ and CUDA. This enabled the researchers to meet their first objective of using techniques from machine learning to develop UUV behaviors that could help ensure complete coverage of a mine hunting area. It also enabled them to develop automatic target recognition (ATR) algorithms that would increase confidence that an object would be classified as a mine: accurate classification is key to efficient autonomous mine countermeasures.

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The outcome

CMRE conducted a series of successful sea trials, leveraging GPU technology and associated development tools like the CUDA libraries to enable execution of the full sonar processing chain on the autonomous vehicle during the mission. The acceleration enabled by GPU technology increased the level of autonomy, allowing adaptive behaviors.

Historically, UUVs have needed to follow pre-determined routes, recording data for subsequent processing elsewhere. The MAGIC1's support for GPU technology and AI has allowed the MUSCLE the flexibility adapt the mission according to new information – making the hunting of mines faster, more reliable, more cost-effective and safer. Real-time classification of objects is now possible, thanks to the Kepler GPU, which is 50-100x faster than a traditional CPU in this type of application.

Because the UUV can now react to what it 'sees' it can make intelligent course corrections, making it more effective and productive and maximizing the time it can spend on-mission before its onboard batteries require a recharge.

> "Previous work with AUV mine hunters was slow and inefficient," said Baralli. "With GPU acceleration, our missions are more productive, and our SAS imaging results are dramatically improved. It is rewarding work to make the seas a safer place."
>
> *Francesco Baralli, Principal Scientific Assistant, CMRE*

Because AI and machine learning enable the MUSCLE to determine whether an object is in fact a mine, and thus take appropriate action, the identification process became significantly more efficient. Previously, the data would have been sent back to the host ship – equipped with racks of servers – for processing and analysis. Only then – often several hours later – would mis-identification be discovered, and the MUSCLE would need to be redeployed.

Such was the success of the demonstration that CMRE initiated a project to ascertain the potential benefits of upgrading the GPU and of evaluating multi-GPU subsystems. Beyond this, the organization concluded that GPU-accelerated data acquisition and analysis had potential in other areas such as object location after a natural disaster.

Thanks to the efforts of CMRE and the success of the program to provide the MUSCLE with significantly improved performance and functionality, enabled by AI and machine learning, the Adriatic and other European seas now benefit from commercial shipping lanes that are safer – and an environment that is cleaner. ●

MAGIC1 Rugged Display Computer.

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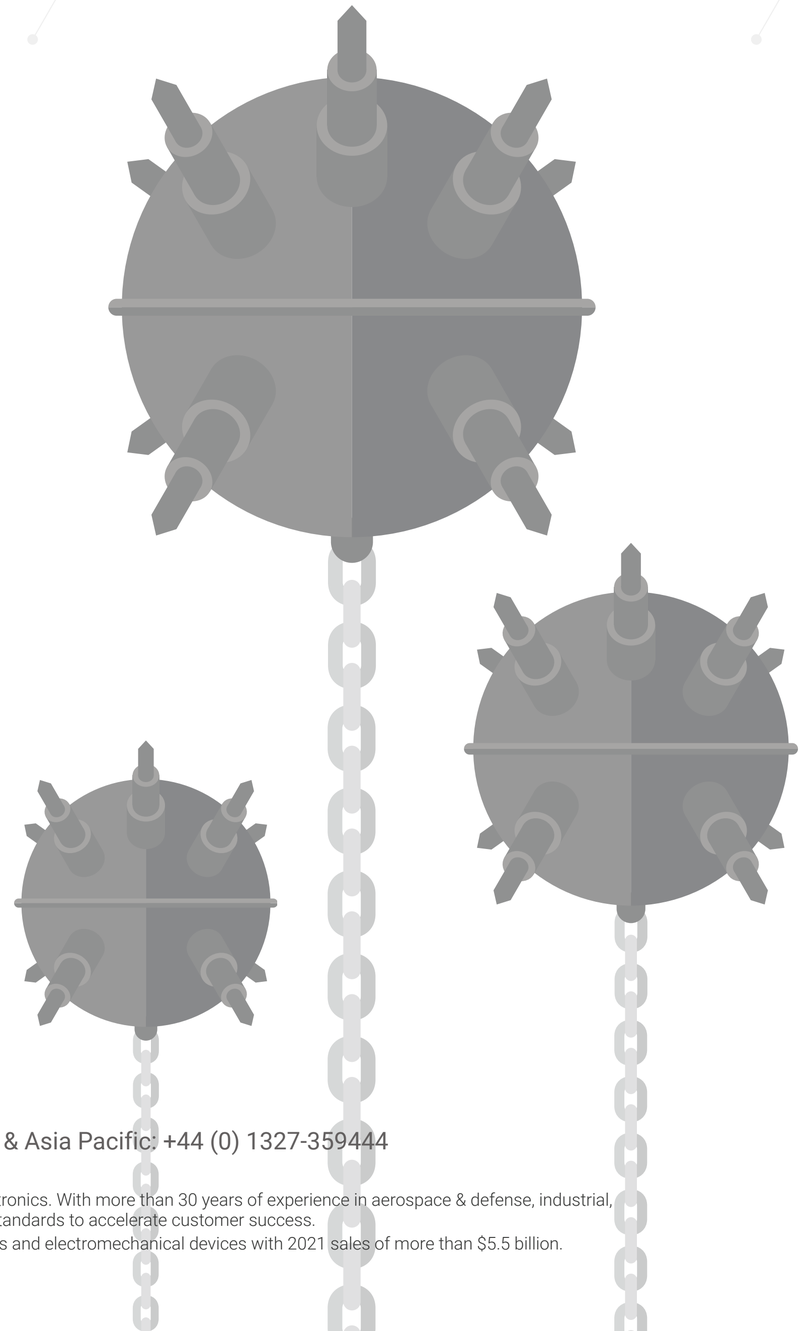

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Abaco Systems is a business unit of AMETEK, Inc., a leading global manufacturer of electronic instruments and electromechanical devices with 2021 sales of more than $5.5 billion.