HUGIN 1000-MR: A Multi-role AUV for the Royal Norwegian Navy

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ABSTRACT

The underwater battlespace has always been among the most challenging arenas of warfare, in particular due to the difficulty of sensing (as well as communicating and navigating) under water. With the ongoing shift towards asymmetric warfare, the focus is moving from blue water into the littorals, which presents even more challenges.

One of the most promising technological advances in the underwater domain over the last two decades is the emergence of the autonomous underwater vehicle (AUV). The inherent advantages of AUVs include increased safety (keeping man out of harms way) and the possibility of performing covert operations. In addition, the fact that the AUV brings the sensors closer to the seafloor and objects of interest can increase data quality, even with relatively inexpensive sensors. When used in combination with high end sensing technologies, AUVs can bring entirely new capabilities to the underwater battlespace – at a very reasonable cost. This article describes some of the recent advances in AUV technology, with examples of how such systems can be employed and what types of information they can collect.

1.0 INTRODUCTION

Development of autonomous underwater vehicles has been ongoing since the 1970s, and several success stories have been reported over the past decades [1][2]. It is likely that such systems are now on the verge of a major military breakthrough. Some navies have already experimented extensively with AUVs, primarily as a force multiplier for mine countermeasures (MCM). The first major Navy contracts have been signed, and military users are gradually accepting AUVs as off-the-shelf commodities and not high-risk research projects.

Figure 1: Three generations of RNoN AUVs. Left: The HUGIN I AUV onboard the RNoN MCM vessel HNoMS *Karmoy*, 2002. Centre: The HUGIN 1000 pilot system being launched from the same MCMV, 2004. Right: The HUGIN 1000-MR AUV being recovered after a sea trial, 2007.

The Royal Norwegian Navy (RNoN) has operated HUGIN AUVs on a regular basis for more than five years. This includes participation in several NATO and other international exercises (Northern Light 03, Joint Winter 04, Blue Game 04, MCOPLAT 05, Cold Response 06, Northern Sun 06, Cold Response 07, etc), deployment in the NATO standing MCM force (MCMFORNORTH) in 2004, participation in the NATO Undersea Research Centre (NURC) trials MX3 and SWIFT in 2005, as well as dozens of national exercises and operations.

While the primary application has been MCM, considerable experimentation is also taking place for applications such as rapid environmental assessment (REA), intelligence, surveillance and reconnaissance (ISR), and submarine rescue operations. The Norwegian Defence Research Establishment (FFI) and the RNoN are in the process of completing a roadmap for introduction of AUV components in the Navy, supported by concept development and experimentation (CD&E) activities led from the national Joint Headquarters. See e.g. [3] or [4] for more details on the HUGIN programme.

2.0 THE HUGIN 1000-MR AUV SYSTEM

The years of Navy experience with the HUGIN vehicles have helped the RNoN, in collaboration with FFI, define the precise requirements for an operational military AUV. The result is the HUGIN 1000-MR system. The first HUGIN 1000-MR AUV will be delivered to the RNoN in early 2008. Similar vehicles will also be delivered to another European navy. The system is developed by Kongsberg Maritime and FFI, and is a natural next step from the existing HUGIN 1000 system [4].

The specifications of the AUV are listed in Table 1. The system is equipped with an extensive set of emergency and fail-safe systems to ensure safe vehicle recovery in case of a subsystem malfunction.

Table 1: HUGIN 1000-MR basic specifications

Dimensions	Length 4.5 m, diameter 0.75 m
Dry weight	700-860 kg
Depth rating	1000 m
Power source	Lithium polymer batteries (standard)
Endurance	>20 hours @ 4 knots; >30 hours @ 3 knots
Speed range	1.5 – 6 knots Cruise speed 3 – 4 knots
Sensors	Kongsberg HISAS 1030 interferometric SAS Kongsberg EM 3000 multi-beam echo sounder FSI MicroCTD 2 Honeywell HG9900 inertial measurement unit RDI WHN-600 Doppler velocity log (bottom and water-referenced velocity) HiPAP transponder for USBL acoustic positioning Novatel GPS receiver Down and forward looking single beam echo sounders
Communications	UHF radio link Iridium satellite link High speed acoustic uplink Long range two-way acoustic link Emergency acoustic link using HiPAP

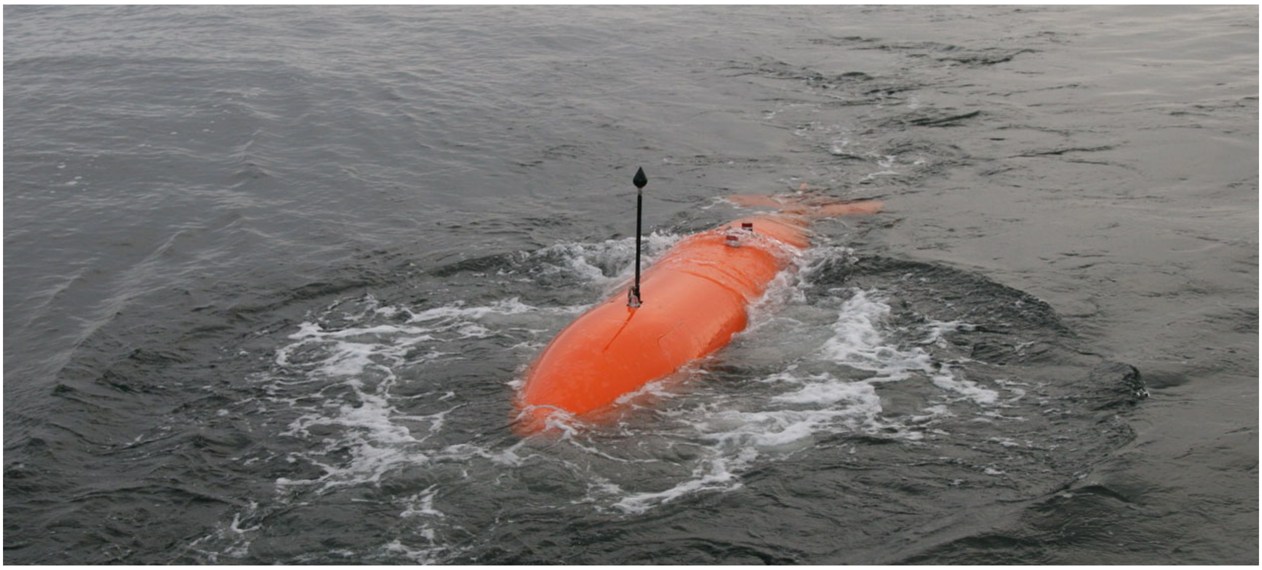

Figure 2: HUGIN 1000-MR immediately after launch, 2007

3.0 THE HISAS 1030 SYNTHETIC APERTURE SONAR

HUGIN 1000-MR is equipped with a state-of-the-art high-resolution interferometric synthetic aperture sonar (SAS), called HISAS 1030 [5]. Compared to other existing sonars, HISAS provides higher resolution (around 3x3 cm) and larger area coverage (more than 2 km^2/h). One of the main motivations for developing such a sensor was the need to detect and correctly classify mines on the rocky seabed typical of the Norwegian littorals – with the aim of turning previously unhuntable areas into huntable ones. The high-resolution imaging capability also makes the sensor well suited to detect other types of objects such as improvised explosive devices (IEDs) [6].

Figure 3: HISAS transducer arrays on HUGIN 1000-MR

In addition to being a "better side scan sonar", a high-resolution SAS can provide the user with new data sets and facilitate new detection and classification techniques. The wide transmit beamwidth of HISAS facilitates generation of multi-aspect imagery from a single pass of a scene, allowing the data analyst to see how echoes and shadows from an object of interest vary with aspect angle. Additional techniques such as fixed focus shadow enhancement (FFSE) and autofocus are available to enhance the shadow cast by an object and the echoes reflected back from the object [7].

3.1 HISAS sonar imagery examples

The following figures show examples of data collected with HISAS 1030 on HUGIN 1000-MR. All data is processed with the FFI FOCUS SAS processing toolbox [8], and the images shown are streaming data without any manual tuning.

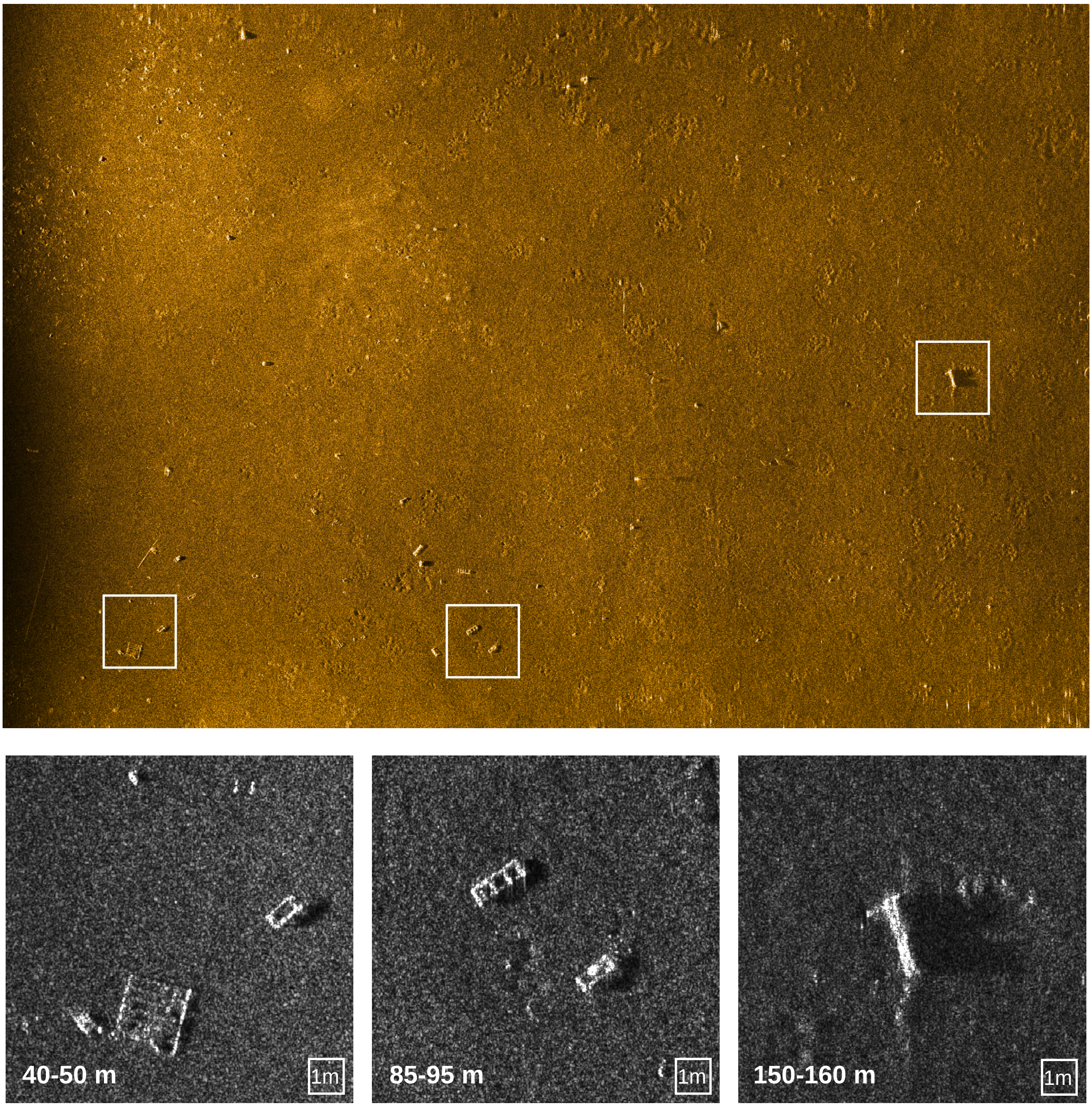

Figure 4: Example HISAS imagery. Water depth 70 m, AUV altitude 22 m. Top: A 100x150 m section of the starboard swath, range 25-175 m. Bottom: Zoom on three 10x10 m areas with debris, centred at (left to right) range 45, 90, and 155 m.

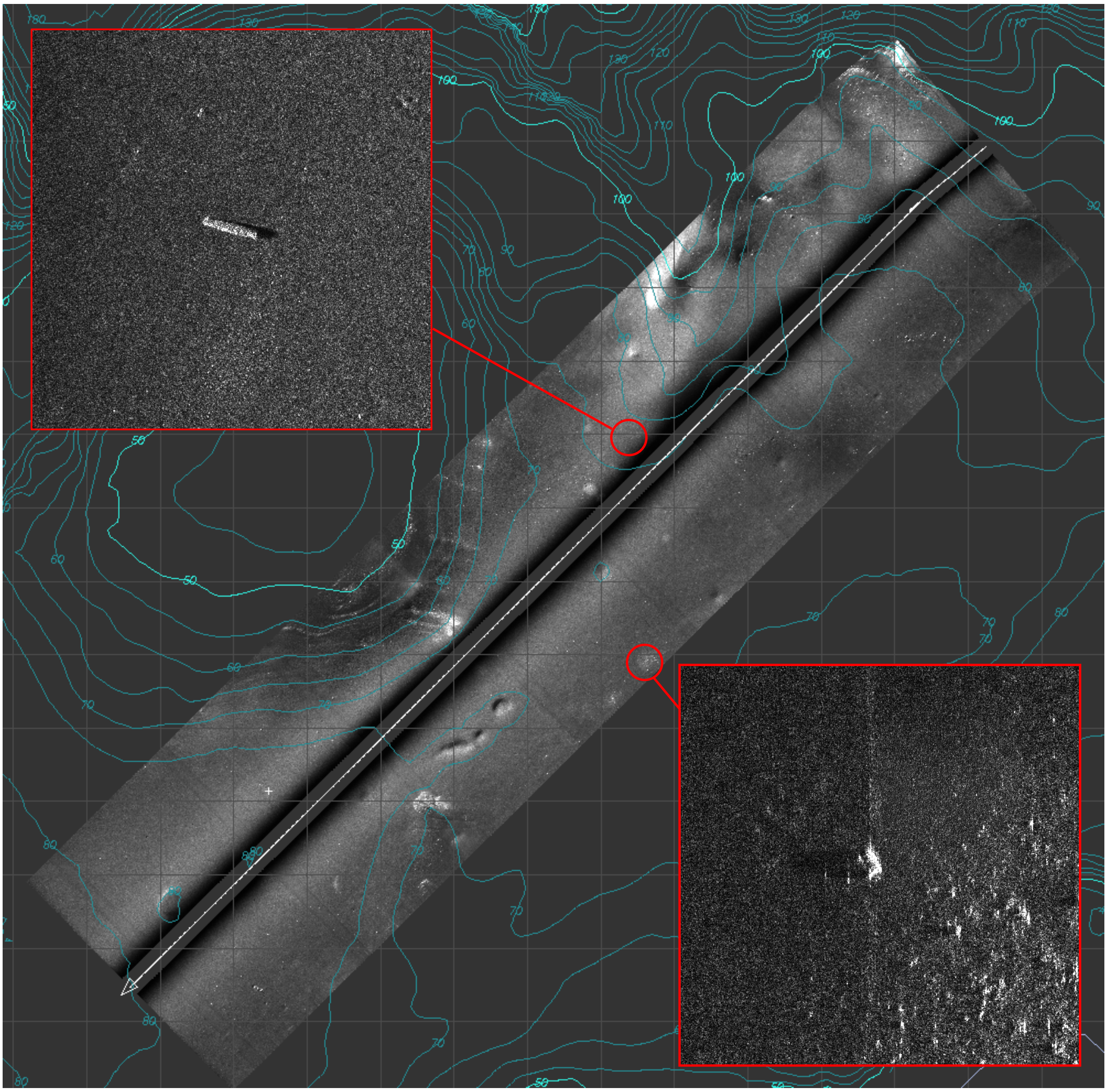

Figure 5: Georeferenced HISAS imagery. Grid size 100x100 m. Water depth 50-100 m, AUV altitude 25 m, sonar range 2x200 m. The area covered is 0.67 km^2, from 15 minutes of AUV operation. Top inset: Zoom of a 20x20 m area with a 2.5-m cylindrical object at 50 m range. Bottom inset: Zoom of a 20x20 m area with an oil drum at 190 m range.

3.2 Bathymetry

The use of dual receiver arrays on each side of the AUV enables generation of high-resolution bathymetry in addition to imagery [9]. Side scan bathymetry, with resolution on the order of 1x1 m, is available as a rapid product (and is used in the SAS processing for improved robustness in rough terrain). HISAS side scan bathymetry provides resolution comparable to that of a multi-beam echo sounder (MBE), but with a wider swath. As HUGIN 1000-MR is equipped with both types of sensors, the MBE can be used as a gap filler for the SAS coverage gap around nadir (see Fig. 6).

In addition very high resolution SAS bathymetry (typical resolution 10x10 cm) can be generated for all or parts of the area covered. Normally this product will only be generated near objects of interest. The combination of SAS imagery and very high resolution bathymetry provides the data analyst with a three-dimensional representation of the scene.

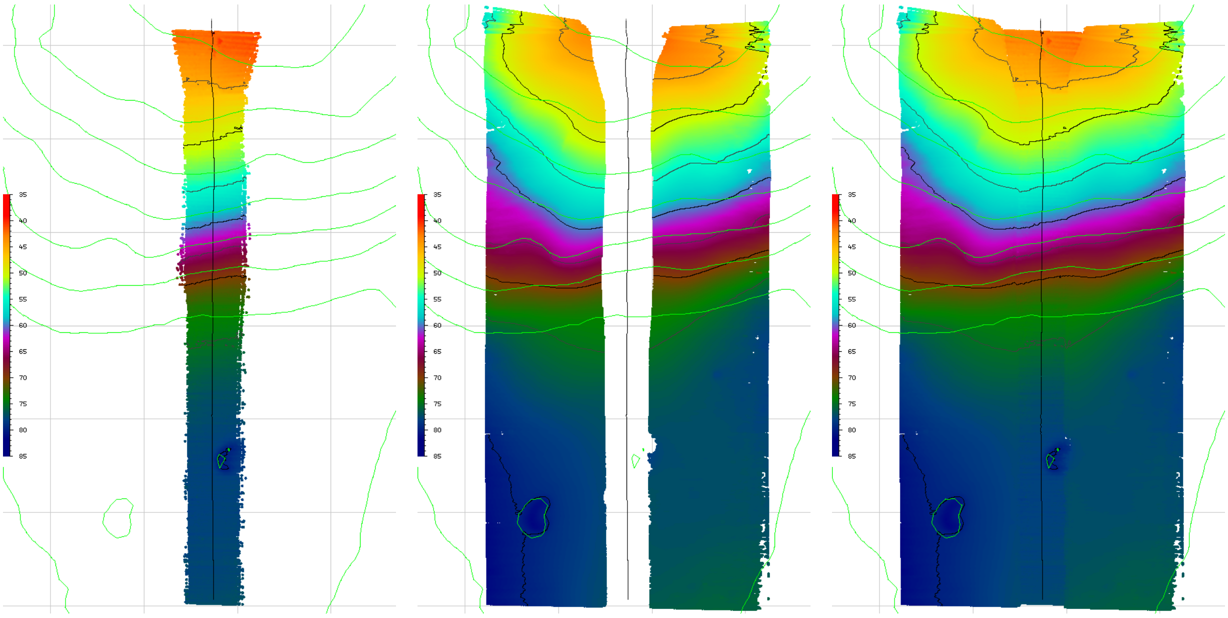

Figure 6: HUGIN 1000-MR bathymetry. Left: Bathymetry from EM3000 multi-beam echo sounder. Middle: Side scan bathymetry from HISAS 1030. Right: Merged bathymetry.

3.3 Automated target recognition

The HUGIN 1000-MR system delivered to the RNoN will also include automated target recognition (ATR) functionality, developed at FFI over more than 10 years [10]. These can be used on both the rapid products (side scan imagery) and the full-resolution SAS imagery. The ATR system can also utilise HISAS bathymetry for further clues about the object. The ATR module includes a set of independent detection algorithms, followed by a fusion of detections to reduce the number of false alarms.

Automated target recognition serves to separate purposes. First of all, it can reduce post-mission analysis time by supplementing or even replacing the human operator(s). Secondly, by implementing an ATR system in real time in the vehicle, it becomes possible to have the AUV act upon this information during mission (reinvestigate, transmit contact data to host platform, find alternate route, etc).

4.0 OPTICAL IMAGING FOR AUVS

FFI is also in the process of implementing a high-quality optical sensor on a HUGIN vehicle. The system comprises custom designed panels of light-emitting diodes (LED) as the light source and high quality digital still image cameras, mounted as far away from each other as possible.

The combination of optical imagery, linear or circular SAS imagery and SAS bathymetry will provide a very rich data set for "super-classification" and identification. As mentioned in Ch. 3.3, a likely consequence of automatically detecting and classifying an object from the sonar data can be to change the mission plan to allow optical imaging of the contact.

5.0 DISCUSSION

Sea trials of the new HUGIN 1000-MR AUV with the HISAS 1030 interferometric SAS show the ability of such an AUV to provide sensor data of very high resolution with high area coverage. This will facilitate rapid detection and classification of even very small targets.

In cluttered areas such as ports and harbours, change detection should be used whenever possible to eliminate known objects from further investigation. However, in e.g. expeditionary operations this will often not be possible. In many cases, post-mission analysis and the following re-investigation may then be the limiting factor for overall system effectiveness. Performing automated target recognition and optical identification during the initial data collection mission should help alleviate this.

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