Operational military use of the HUGIN AUV in Norway

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Abstract

In 2002, the Royal Norwegian Navy's mine hunter KNM Karmøy was upgraded for permanent use of HUGIN class Autonomous Underwater Vehicles (AUVs). While the development of a full capability dedicated military AUV is still ongoing, the existing HUGIN I vehicle has been mobilised and used operationally from the MCMV on a number of occasions over the past year. The primary purpose of these operations has been to collect high-quality environmental data in areas of vital military importance, while at the same time gathering valuable operational experience.

Lessons learned from the operational military use of the HUGIN I system are being fed directly into the HUGIN Mine Reconnaissance System (HUGIN MRS) development effort at FFI and Kongsberg Simrad. The HUGIN I vehicle will be replaced by a pre-production HUGIN MRS system by the end of 2003. A full capability HUGIN MRS for forward mine reconnaissance and covert rapid environmental assessment (REA) will be delivered to the Navy on commercial terms in 2004/05.

1 Introduction

After the initial MCM and REA demonstrations carried out with the *HUGIN I* AUV on a mine hunter in 2001 [1], the HUGIN Mine Reconnaissance System development program has been gaining significant momentum. Few months after the demonstrations, the Royal Norwegian Navy (RNoN) decided to upgrade the mine hunter *KNM Karmøy* with the necessary infrastructure for permanent use of HUGIN class AUVs. The upgrade was completed in August 2002, and AUV operations with HUGIN I started the following month.

HUGIN I was built 1995-96 as a research, development, test and demonstration system, and this imposes some rather strict constraints to daily operational use. For example, it has an endurance of only 5-6 hours – compared to the commercial HUGIN 3000 vehicles, which feature some 50 hours of endurance. Nevertheless, HUGIN I has been valuable as a first taste of what AUVs can offer the military community, and it will continue to contribute actual military worth in 2003.

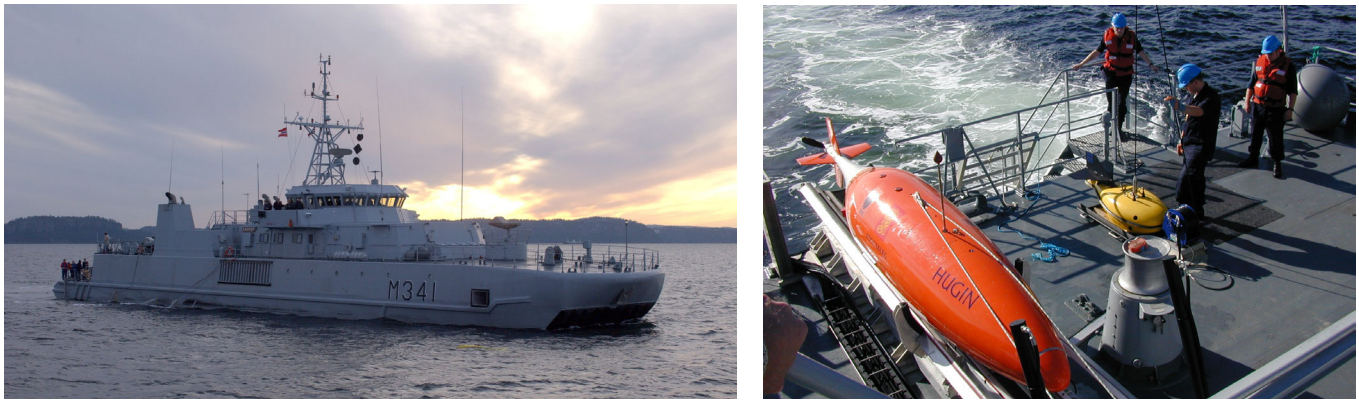

Fig. 1. Left: KNM Karmøy. Right: HUGIN I on the aft deck of KNM Karmøy immediately before launch

The original HUGIN MRS program included the production of one AUV, to be delivered at the end of 2004. Partly as a result of the initial success with HUGIN I, an extended and accelerated schedule has been adopted. This includes the production and delivery of a pre-production HUGIN MRS in 2003. This vehicle will be superseded by the full-capability HUGIN MRS in 2004/05.

1.1 Abbreviations and acronyms

ADCP	Acoustic Doppler current profiler
AUV	Autonomous underwater vehicle
EMDW	Expendable mine disposal weapon
GPS	Global Positioning System
HiPAP	High-Precision Acoustic Positioning
HUGIN MRS	HUGIN Mine Reconnaissance System
MBE	Multi-beam echo sounder
MCM	Mine countermeasures
MCMV	Mine countermeasures vessel
MWDC	Mine warfare data centre
REA	Rapid environmental assessment
RF	Radio Frequency
RNoN	Royal Norwegian Navy
SAS	Synthetic aperture sonar
SSS	Side scan sonar
USBL	Ultra-short baseline
UTP	Underwater Transponder Positioning
VSS	Volume search sonar

2 The military AUV program in Norway

Since the early 1990s, the Norwegian military AUV program has been linked to the commercial HUGIN AUV program. From a common pool of resources, long-term solutions for military applications have been developed alongside robust and user-friendly systems for civilian customers [2]. The commercial success of the HUGIN 3000 system has led to further synergy between the two programs.

The military AUV program has now reached a phase of technical and operational evaluation. In parallel, improved AUV systems are being developed and put in active service. A positive outcome of the evaluation may lead to a full-scale acquisition program around 2007.

The military AUV program currently comprises the following activities:

- MCMV upgrade for AUV operations
- HUGIN MRS system development
- Delivery of pre-production HUGIN MRS “version 0”
- Military AUV operations
- Establishing concepts of operation for the various uses of the system

Additionally, a decision to procure one full-capability HUGIN MRS “version 1” system is expected this year.

2.1 MCMV upgrade

In August 2002, the RNoN completed the upgrade of KNM Karmøy for HUGIN-class AUV operations. This includes installation of a launch and retrieval system, acoustic positioning and communication systems, and integration with the ship’s navigation and tactical systems. A second installation on a sister MCMV is being evaluated.

The aft-deck launch and retrieval system is similar to the ones used by the commercial HUGIN customers. These systems have been used successfully in very rough seas since 1997.

The acoustic positioning system installed is the market-leading Kongsberg Simrad HiPAP 500 ultra-short baseline (USBL) system. HiPAP allows robust and accurate acoustic positioning of HUGIN at all water depths, and also serves as a bidirectional emergency communication link. The HiPAP transducer is mounted on one of the hulls of the MCMV, and can be lowered several meters into the water using a telescopic arm.

While the purpose of installing the HiPAP system onboard the MCMV was to provide accurate positioning for the HUGIN vehicle, it can also be used for other tasks, such as positioning of mine dummies with acoustic beacons. A version of the Minesniper expendable mine disposal weapon (EMDW) that uses HiPAP is also planned.

To limit the amount of physical modification to the vessel, the acoustic link transducers are mounted on a small towbody (visible next to HUGIN in Fig. 1). One of the ship's existing cranes is used for handling of the towbody. This solution provides excellent quality communications, at the cost of moderate operational limitations to the MCMV.

The operator systems for HUGIN and HiPAP are installed in the main operations room. A new "HUGIN network" was installed, with a bridge to the ship's tactical system network. This allows the flow of position, heading, attitude and time data to the HUGIN system. Waypoints, HUGIN position info, etc., may be transferred back to the MICOS tactical system, but this has not yet been done in practice. The MICOS system, manufactured by Kongsberg Defence & Aerospace, is currently being upgraded, and the new version will feature better integration with the HUGIN systems.

Although KNM Karmøy is a modern MCMV, it was in no way designed for the operation of AUVs. The relative ease with which the HUGIN support systems were installed, demonstrates that the cost of performing such an upgrade can often be quite manageable.

2.2 HUGIN MRS features

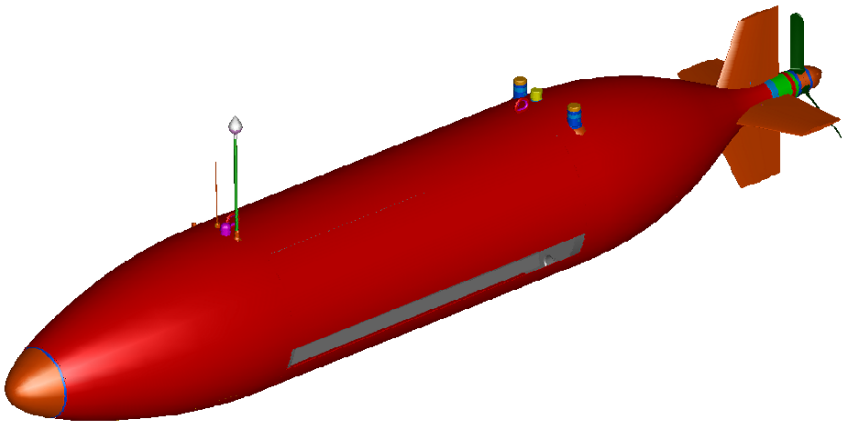

Fig. 2. HUGIN Mine Reconnaissance System AUV

The first full-capability HUGIN Mine Reconnaissance System (HUGIN MRS) AUV can be delivered around the end of 2004. As per the current state of the project, it will have the following features and capabilities:

- Vehicle dimensions: 4.4 m long, diameter 75 cm, volume 1.4 m^3
- Cruising speed 4 knots, operational speed 2-6 knots
- Power source: Pressure tolerant Lithium ion batteries (2 or 3 battery modules)
- Endurance: 18-30 hours, depending on speed, sensor use, and number of battery modules
- Turn-around time: Less than 5 hours (limited by battery recharge)
- Communications: Acoustic, RF, and satellite links; 100 Mbit/s Ethernet on deck
- Payload sensors:
  - Interferometric synthetic aperture sonar (IFSAS), resolution < 5×5 cm, area coverage rate > 1000 m^2/s
  - Volume search sonar (VSS)
  - High resolution multi-beam echo sounder (MBE)
  - Acoustic Doppler current profiler (ADCP)
  - Conductivity, Temperature, Depth (CTD) sensor
- Navigation system: Aided inertial navigation system (AINS) using a 1 nmi/h class IMU, aided by
  - Doppler velocity log
  - GPS or differential GPS (at surface)
  - HiPAP USBL acoustic positioning (when followed by surface craft) [3]
  - SAS micronavigation (when available) [4]
  - Underwater Transponder Positioning (UTP) – acoustic positioning using one or more subsea beacons (when available)
  - Bathymetric navigation [5]

The specification of the pre-production HUGIN MRS was frozen in early 2003. It shares many of the features of the full-capability system; the main difference is that the pre-production version has a simpler payload sensor suite. The "version 0" payload sensors are a synthetic aperture sonar capable of 10×10 cm resolution with 800 m^2/s area coverage rate, and a Kongsberg Simrad EM3000 MBE, plus an ADCP and CTD sensor. Although simpler than the full-capability HUGIN MRS, this is nevertheless one of the most advanced and capable AUV payload sensor suites in the world.

2.3 Concepts of operation

While mine hunting has been the main incentive for the development of HUGIN MRS, the system is designed to fill a number of roles. The main operations for HUGIN MRS are:

- High quality bathymetric mapping – collect data for generating a high resolution, hydrographic quality bathymetric map of an area.
- MCM route surveys – collect a wide range of data (bathymetry, seafloor objects, bottom type, sea currents, etc) from a Q-route in peacetime for ingestion in national mine warfare data centre (MWDC), to be used in later MCM operations.
- Mine reconnaissance – determine whether an area is mined or not (exploratory MCM operations).
- Mine detection, classification and positioning – collect data sufficient for classification of any mine-like objects in an area, and for re-localisation with an EMDW such as the Minesniper (clearance operations).
- Overt (category 2) REA – collect various types of data from an area in advance of a potential military operation.
- Covert (category 3) REA – rapidly collect and process data from an area possibly under enemy control, without disclosing the operation, before an imminent military operation.
- In-stride (category 4) REA – collect and process data after military actions in the area have started.

The mode of operation, coverage rate, and data collected will vary a great deal between these tasks. For instance, the first two tasks will normally be performed in a *controlled* or *semi-autonomous* mode, where the AUV maintains contact with the MCMV through acoustic, RF and/or satellite links. Mine reconnaissance and mine detection, classification and positioning operations, on the other hand, will be performed in a fully autonomous mode. Similarly, the AUV will operate at different altitude and with different sensor settings depending on the mission type.

FFI and the RNoN are currently developing detailed descriptions of the concept of operation for the various tasks. The concepts will evolve as operations continue. This means that by the time the full-capability HUGIN MRS system is put in active service in 2005, mature and well-tested operational descriptions will be available.

3 Operational experience

The civilian HUGIN vehicles have surveyed a total of some 30,000 line km, outside four continents, from tropical heat to arctic winters, for dozens of customers [6]. The massive amount of experience has led to numerous improvements in the HUGIN system, and has helped give HUGIN MRS a flying start in terms of capabilities and operational flexibility.

3.1 Military operations to date

The first operational AUV demonstrations were performed in December 2001, using a provisional installation onboard KNM Karmøy [1]. After the MCMV was upgraded with a permanent AUV infrastructure, a series of training operations was conducted in September 2002. AUV missions were interspersed with a 500-nmi transit Bergen – Stavanger – Kristiansand – Tønsberg – Horten – Oslo - Horten. Both controlled and autonomous operation was tested, and the crew onboard KNM Karmøy was trained in AUV operation and handling procedures.

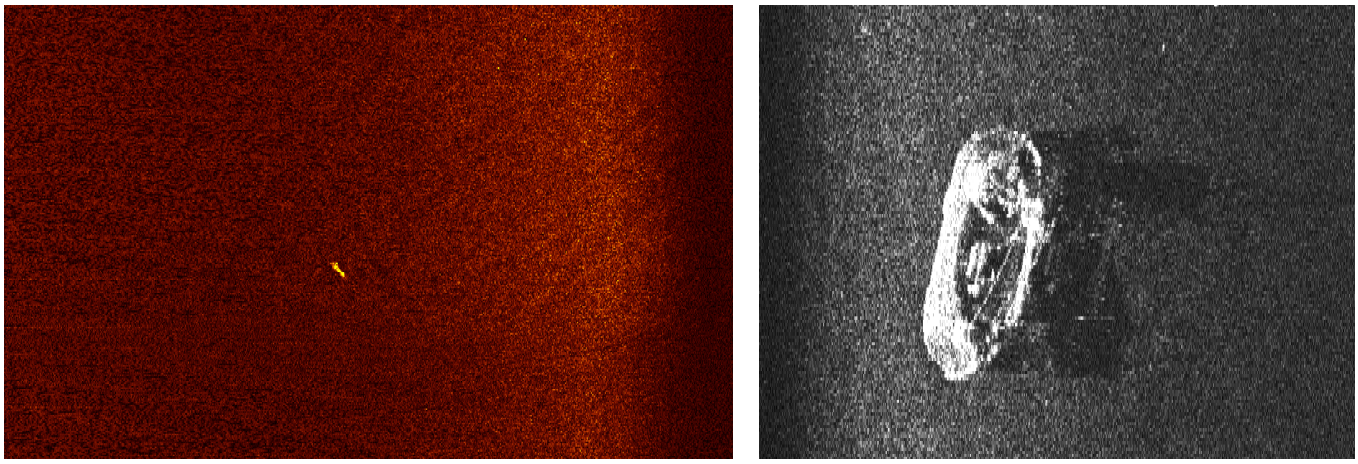

Fig. 3. Side scan sonar imagery from HUGIN I missions in September 2002. Left: An MP80 dummy mine on the seabed at approximately 50 m range; right: A small boat wreck (approximately 20×5 m). Water depth 180-200 m, altitude 15 m.

In November 2002, MCM route survey missions were performed in Northern Norway. Excellent performance and data quality was achieved. Fig. 4 shows raw bathymetry data collected during two missions at 69° N. The data as shown in the figure was displayed onboard the MCMV less than an hour after AUV retrieval.

Data from the AUV missions in Northern Norway is being added to the Norwegian MWDC.

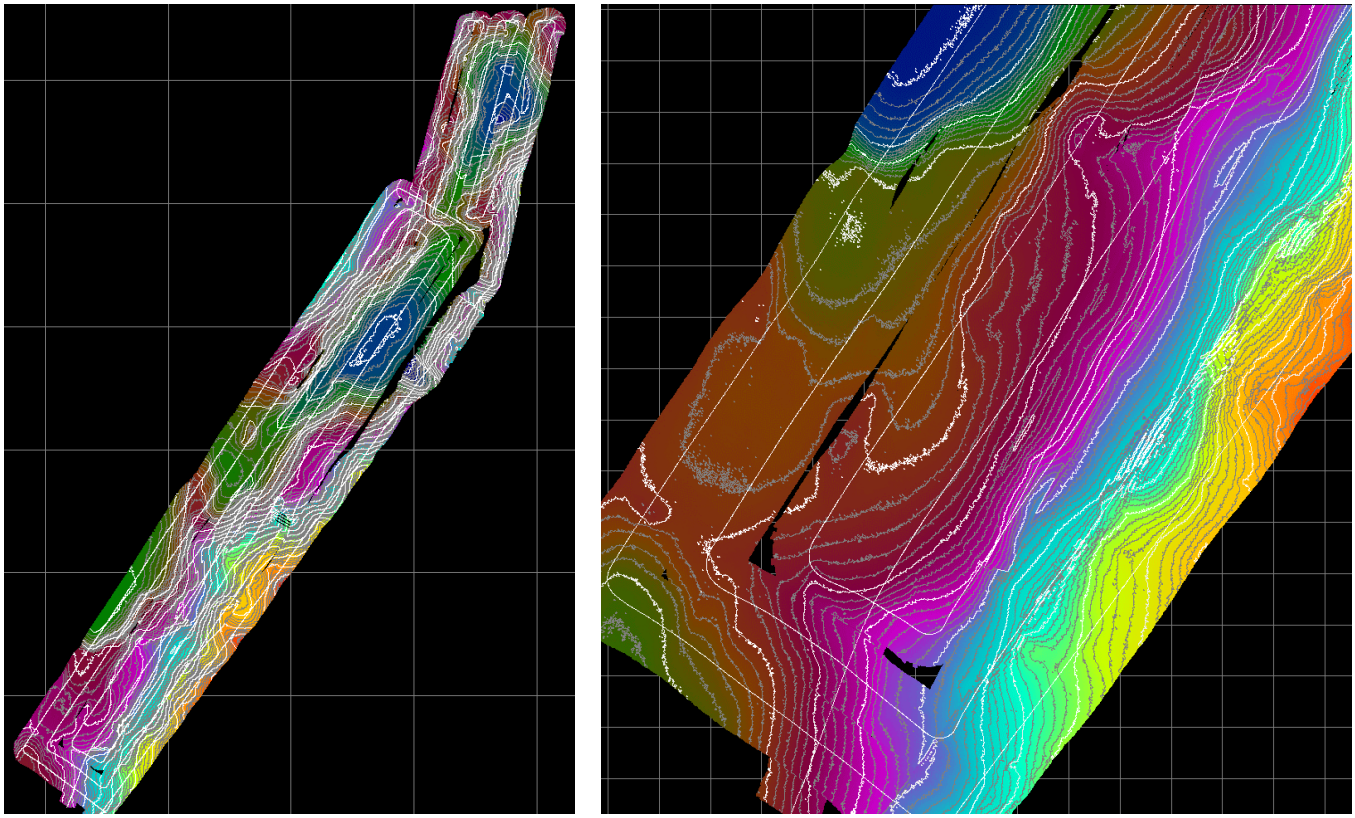

Fig. 4. Bathymetry data collected during two HUGIN I missions in a narrow strait in Northern Norway, November 2002. Water depth 20-120 m. Depth contours 1 m (grey), 5 m (white). Left: Complete area (approx. 500×4000 m); right: Detail showing near-perfect alignment of data from 8 AUV passes, even during turns.

3.2 Future plans

Due to a fire in another RNoN ship, the military AUV operations have been suspended for a few months. A new series of HUGIN missions from KNM Karmøy in Western Norway is scheduled for May 2003. In the following months, the HUGIN I vehicle will be used for operational testing of the new features of the HUGIN MRS (real-time bathymetric navigation, synthetic aperture sonar, etc.).

In September 2003, KNM Karmøy and HUGIN I will participate with REA operations in the NATO exercise Northern Light, outside Scotland. Later the same month, a series of AUV missions will be performed in the archipelago of Finland, including route surveys and mine reconnaissance.

In early 2004, operations with the new pre-production HUGIN Mine Reconnaissance System will begin. This system features dramatic improvements in endurance and sensor capabilities, and will be heavily used in Norway and internationally.

4 Conclusions

Using the HUGIN I test and research vehicle, the Royal Norwegian Navy has already begun operational use of AUVs for various purposes, and AUV systems are already contributing actual military worth to the RNoN. With the delivery of a pre-production HUGIN Mine Reconnaissance System AUV by the end of 2003, the operational flexibility and capability will increase dramatically, and a number of new operations are to be expected in the coming year.

In parallel with the development, production and evaluation of HUGIN MRS, FFI and the Navy are developing and refining concepts of operation for the various roles of this system. Such operational descriptions will be extremely useful in the planning of new operations, and for introducing HUGIN MRS to new users.

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