

Network Centric Warfare with Autonomous Underwater Vehicles – Results from Experimentation with HUGIN 1000

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Abstract – HUGIN Autonomous Underwater Vehicles (AUVs) have been used with considerable success onboard a Norwegian mine hunter since 2001, mostly as an integral part of the mother ship. Recently, more emphasis has been placed on using the AUV as a sensor for other assets than the host platform, and for other applications than mine hunting. This was first demonstrated during the NATO exercise Northern Light 03 in Scotland, where HUGIN data was used in a rapid environmental assessment operation to prepare an amphibious landing in the area. Data was made available to the operations HQ approximately one week after the AUV missions took place.

During the Azalea Festival in Norfolk, VA, USA in April 2005, this was taken one step further in that data from a HUGIN mission in Norway was transferred in real time from the AUV to a display in Norfolk. Visitors were able to see high-resolution bathymetric maps be built in real time, and were also able to modify HUGIN's mission remotely. All data was processed onboard the MCMV, and final results sent to Norfolk within 1-3 hours after AUV recovery. This was a powerful demonstration of how AUVs can contribute in a network centric warfare.

I. INTRODUCTION

The concept of a network based defence has grown pervasive across most branches of the armed forces in recent years. For the underwater world however, it remains to be seen how this concept will apply. This is partly due to the lack of robust, broadband, networkable underwater communications, but also because the roles of the traditional underwater asset – the submarine – did not require extensive communications. The introduction of the autonomous underwater vehicle (AUV) to the military community is one reason why this will change in the near future.

Two generations of HUGIN AUVs have been used with considerable success onboard the Royal Norwegian Navy (RNoN) mine hunter KNM *Karmøy* since 2001 [1][2]. For the most part, the AUV has been used as a sensor organic to the mine hunter, and formed a part of the local mine countermeasures (MCM) system. For example, AUV sonar data has been used to detect and classify objects later identified and disposed of by *Minesniper* expendable mine disposal vehicles onboard the mine hunter.

Recently, more emphasis has been placed on using the AUV as a remote sensing unit for other assets than the host platform, and for other applications than mine hunting. This was first demonstrated during the NATO exercise *Northern Light 2003* in Scotland. HUGIN was used in a Rapid Environmental Assessment (REA) operation to verify existing data and plan MCM operations to be performed by other vessels. The data was processed to standard AMLs (Additional Military Layers) by FFI and NATO Undersea Research Centre (NURC), and made available to the operations HQ in Northwood, UK approximately one week after the AUV missions took place [3].

During the Azalea Festival in Norfolk, VA, USA in April 2005, this was taken one step further in that data from a mission in Norway was transferred in real time from the AUV to a display in the USA. This demonstration formed part of a Concept Development and Experimentation (CDE) programme by FFI and the RNoN.

II. THE HUGIN MRS PROGRAMME

HUGIN Mine Reconnaissance System (HUGIN MRS) is a joint programme between FFI, the RNoN, and Kongsberg Maritime. The objective of the programme is to provide the RNoN with a forward, autonomous sensor capability for MCM and REA applications [4].



Fig. 1. The HUGIN 1000 AUV on the aft deck of KNM *Karmøy* outside Bergen, Norway in April 2005

Throughout 2002 and 2003, the RNoN conducted a series of operations using the HUGIN I test and development AUV on loan from FFI. A pre-production prototype of the military HUGIN 1000 system was delivered in January 2004, and has since been used extensively in Norway and abroad. The pre-production HUGIN 1000 AUV is equipped with an EdgeTech 4400 synthetic aperture sonar (SAS) or 4300-MPX side scan sonar, a Kongsberg multibeam echo sounder, a high quality CTD sensor, and a state of the art aided inertial navigation system [5]. A collection of acoustic, RF and satellite communications and positioning devices are available.

Currently, the full capability HUGIN 1000-MR (MCM/REA) system is being manufactured. Delivery is planned for 2006. In addition to a substantially enhanced payload sensor suite (including a Kongsberg HISAS 1030 interferometric SAS [6][7]), this system will feature a number of enhancements and modifications based on years of operational AUV experience within the Navy.

III. CONCEPT DEVELOPMENT AND EXPERIMENTATION

FFI and the RNoN are involved in a Concept Development and Experimentation (CDE) programme aimed at defining roles for HUGIN in a network based defence structure – transitioning the AUV capability from an organic part of the MCMV, to a generic remote sensing system. Some of the questions this programme hopefully will help answer are:

- Are other units able to effectively task the AUV?
- What are the main obstacles and limitations in mobilising the HUGIN 1000 system on a new host platform, possibly with a long transit?
- Is the HUGIN system and operator able to plan and execute the tasked mission fast enough for the data to be relevant?
- How much emphasis should be placed on (near) real-time data transfer?
- How important will real-time, automated in-vehicle sensor data analysis be?
- Would a different or extended sensor suite significantly improve the utility of the HUGIN system?
- Is it feasible to perform all post-processing on-board the AUV's host platform, immediately after recovery?
- Will the other asset(s) be able to receive, handle and act upon the data collected by HUGIN?
- Will the data collected by HUGIN have a significant influence on the outcome of the operation?

A series of experiments will be conducted to illuminate different aspects of these issues. The experiments will be coordinated with national and international exercises where possible.

IV. THE 2005 AZALEA FESTIVAL EXPERIMENT

The first experiment in the CDE programme was performed in conjunction with the Azalea Festival in Norfolk, VA, USA in April 2005 [8]. At this year's festival, Norway was chosen as the "Most Honoured Nation", and therefore played a very active role. The HUGIN experiment was executed in conjunction with the conference *Transforming Maritime and Environmental Security and Safety*, presented by the Royal Norwegian Embassy, NATO Allied Command Transformation (ACT) & Old Dominion University.

The HUGIN 1000 AUV was launched from the mine hunter KNM Karmøy in a fjord outside Bergen, Norway. Mission planning, supervision and post-processing were performed by the regular AUV team on the MCMV (two officers), assisted by one scientist from FFI. The team was highly experienced, having performed military HUGIN missions since 2001-02.

Mission objectives included surveying a 4-km² section of the fjord (bathymetry and seabed imagery), as well as relocating and performing a detail survey of the US arctic research submarine *Nautilus*, sunk by her own crew in 1931 after a failed attempt to dive under the polar ice cap [9][10].

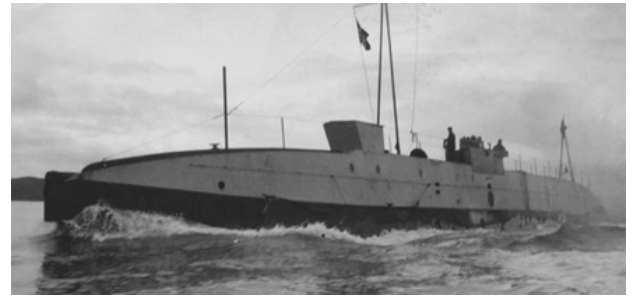


Fig. 2. The arctic research submarine *Nautilus* (formerly USS O-12)

Throughout the 7-hour HUGIN mission, vehicle and payload sensor data was transmitted acoustically to the surface vessel, then via a 128 kbit/s Inmarsat satellite link installed on the ship to the USA. The data being recorded in Norway was displayed on a remote HUGIN monitoring application, and also in the Norwegian Battle Lab and Experimentation (NOBLE) Common Operational Display System (CODS), integrated with real-time information from various other sources around the world.

Visitors, including the Norwegian Minister of Defence Kristin Krohn Devold, the Norwegian Ambassador to the US Knut Vollebæk and the US Secretary of the Navy Gordon England, were able to see high-resolution bathymetric maps be built in real time. It was also possible to modify HUGIN's mission remotely. Additionally, a two-way live video connection was established between the mine hunter and Norfolk, VA on the same satellite link.



Fig. 3. The Common Operational Display System (CODS) in Norfolk, showing a synthetic view of the Norwegian fjord during the HUGIN mission.

Within two hours after AUV recovery, the personnel onboard KNM Karmøy had produced a digital terrain model (DTM) of the surveyed area, and gone through the sonar data recorded using their Triton Imaging post-processing software. A number of 2D and 3D contact views were transmitted to Norfolk, VA on the Inmarsat link.

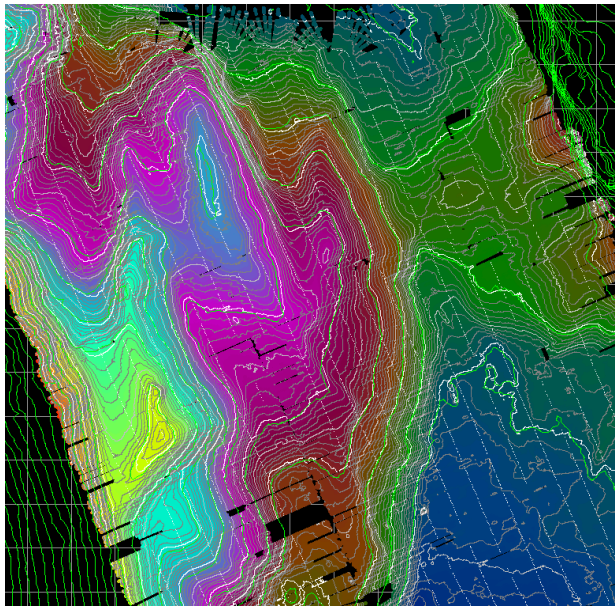


Fig. 4. Multibeam bathymetry data transferred in real time from HUGIN 1000 in Norway and displayed in Norfolk, VA during mission. Note the excellent correspondence between the 10-m depth contours from an a priori map (green) and the real-time HUGIN data (white). Water depth 200 – 400 m. Gaps in the coverage are caused by occasional dropouts on the acoustic data link from HUGIN to the surface ship.

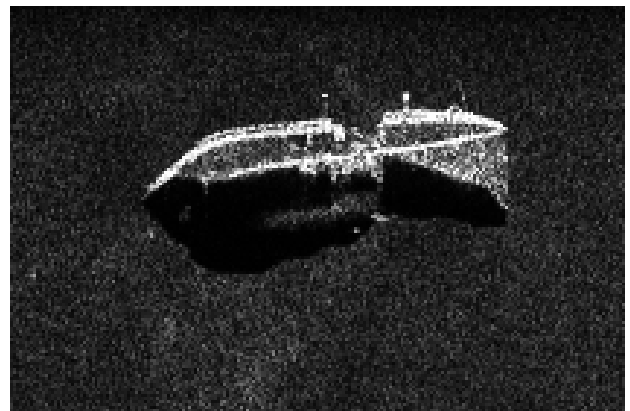
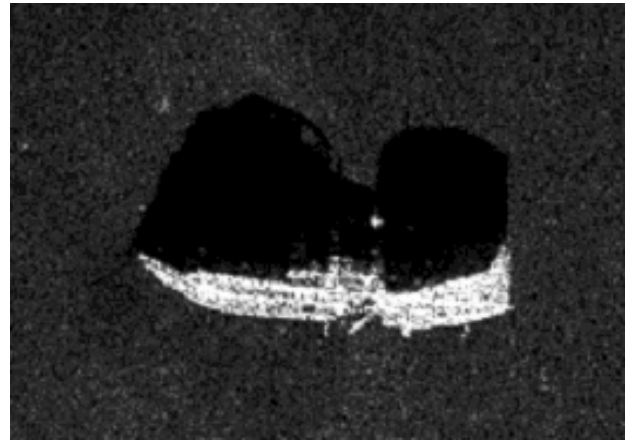


Fig. 5. Two views of the submarine *Nautilus* from the EdgeTech 4300-MPX side scan sonar (range 40 and 60 m), sent from KNM Karmøy to Norfolk less than two hours after AUV recovery.

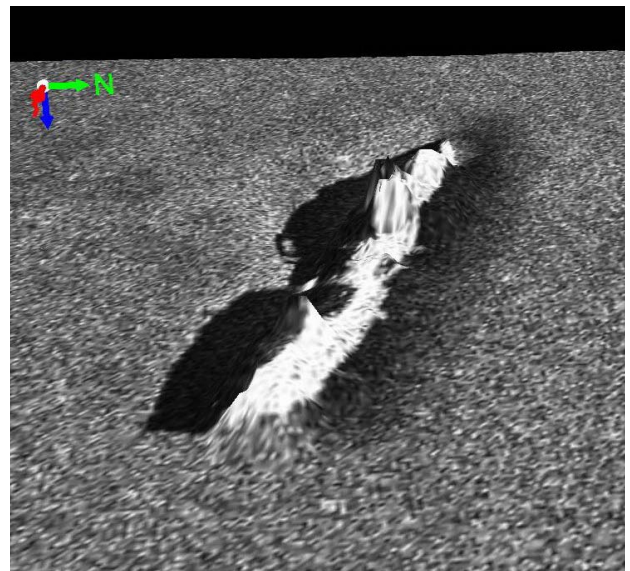


Fig. 6. Side scan imagery of *Nautilus* draped over multibeam bathymetry, providing a 3D view. Data post-processed onboard KNM Karmøy and transmitted to Norfolk two hours after AUV recovery.



Fig. 7. Side scan sonar image of various other objects on the seafloor, range 70-140 m.

V. CONCLUSIONS

The Azalea experiment demonstrated the ability to perform an REA operation with an AUV anywhere in the world while providing live information to any relevant party. The experiment also showed that a small, but experienced crew was able to perform all phases of the operation highly efficiently – from mission planning to delivery of high quality post-processed data.

Being a reasonably controlled experiment, certain aspects of the operation were not stressed extensively, and many important questions remain unanswered. However, this experiment is only the first in a series. Future experiments aim to address questions such as the ability to mobilise the system on a vessel of opportunity, other means of (near) real-time data transfer, and closer interaction with manned submarines.

The HUGIN CDE programme is currently limited in scope to look at the AUV as a tool for information gathering. There are obviously other ways in which AUVs may contribute in a network based defence, e.g. in areas such as anti-submarine warfare. Plans are underway to look at roles for AUVs in such scenarios.

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