HUGIN-AUV Concept and operational experiences to date

Roar Marthiniussen, Karstein Vestgård and Rolf Arne Klepaker,

Kongsberg Simrad AS, P.Box 111, 3191 Horten,Norway.

Nils Størkersen,

FFI – Norwegian Defence Research Establishment, P.Box 25, 2027 Kjeller, Norway

Abstract **- During the last few years autonomous underwater vehicle (AUV) technology has evolved from concept demonstrators towards commercial products. The driving forces are the move for energy exploitation towards deeper waters, naval applications and the Internet driven need for more intercontinental underwater communication cables. Other applications emerging for the future will be within environmental research and monitoring and deepwater exploration.**

Deepwater developments beyond the continental shelf will require the same level of survey data quality and intervention access as established for shallow water. The potential for cost savings is two folds.

Firstly, there is a reduction in the survey cost it self and secondly there is a considerable cost saving by avoiding over design of subsea installations due to lack of sufficient documentation of the field. In this scenario, there is an increasing understanding that underwater robotics and in particular AUVs will play an important role in future survey and subsea engineering work.

The AUV as a free swimming underwater survey sensor carrier has several advantages compared to cable controlled ROV's and deep towed systems:

The paper prepared for the OCEANS'04, Kobe, Japan will focus on the HUGIN AUV concept and field results from the North Sea and GOM.

I. THE HUGIN HISTORY

Kongsberg Simrad (KS) developed its first AUV late 1980 ties. Since early 1990, there has been a close co-operation with the Norwegian Defence Research Establishment (FFI) on the HUGIN developments and field activities. The main focus has been towards civilian applications and the military use of AUVs for mine countermeasures, etc.

The dual developments have been directed towards the main applications:

- Commercial offshore surveying
- Military naval applications (mine countermeasures, etc.)
- Research and environmental monitoring
- Other key team members have been:
- Statoil.
- NUI AS (Norwegian Underwater Intervention AS)
- The Norwegian Navy
- C&C Technologies Inc, Lafayette, USA
- Geoconsult AS, Norway
- BP
- Norsk Hydro

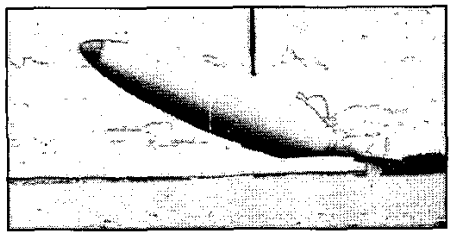
The dual development strategy has allowed naval and research resources and funding to be focused towards the development of the key enabling technologies (power, navigation, vehicle control, payload integration, etc.) while the parallel offshore surveying has provided valuable feedback and experience on the HUGIN concept, technology components and reliability.

II. THE HUGIN VEHICLES

A. AUV Demo Vehicle.

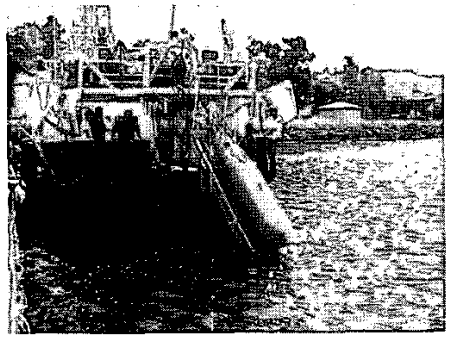
The AUV Demo Vehicle was developed by FFI early 1990 to test basic AUV principles, i.e. hydrodynamics, navigation and vehicle control. Included was also the development and test of a novel sea water battery technology.

0-7803-8669-8/04/$20.00



B. HUGIN I.

The HUGIN I was the first vehicle developed for the offshore surveying application. It has been successfully used for commercial offshore pipeline route surveying, starting in 1997. The vehicle mission endurance is limited to 6 hours, initially using rechargeable NiCd batteries. The power for this vehicle is now rechargeable Li-Ion battery technology. Today HUGIN I is used as a general test platform for new technology development and evaluation. Since 2002, the vehicle is operated by the Norwegian Navy from one of their ships to gain experience on using AUV for mine countermeasures.



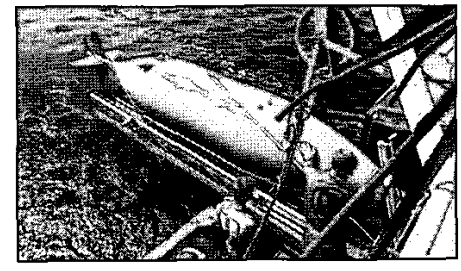
C. HUGIN 3000.

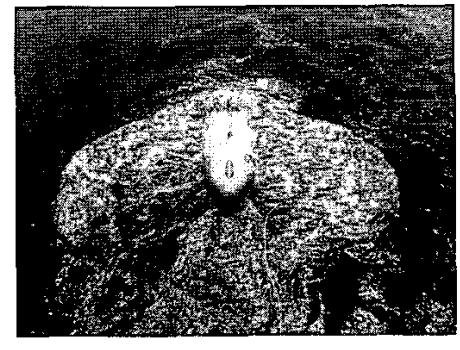
The HUGIN 3000 is the latest AUV model in the HUGIN family. The depth capability is 3000 meters.

The power source is a novel semi fuel cell battery providing >60 hours endurance with all survey systems running (MBE, SSS, SBP and CTD).

As of November 2002 two HUGIN 3000 systems are in commercial offshore use. The first HUGIN 3000 was delivered late 2000 to C&C Technologies Inc. C&C has since then, very successfully operated the vehicle in the Gulf of Mexico, off the west coast of Africa, off Brazil and in the Mediterranean. The vehicle has been operated in different water depths down to 2850 meters. A total of more than 18.000 survey line km has been successfully covered.

The second HUGIN 3000 was delivered August 2002 to the Norwegian survey company Geoconsult AS. The company has started work with HUGIN in the North Sea.

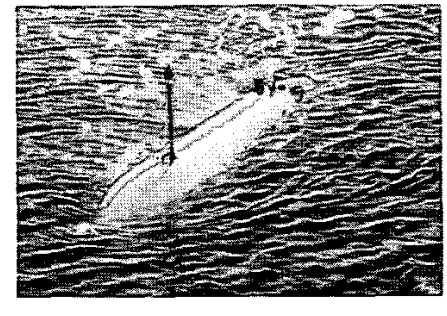




D. HUGIN 1000.

HUGIN 1000 is a dedicated vehicle towards naval (MCM/REA) applications. The vehicle is smaller compared to the HUGIN 3000 with a depth rating of 600 meters and an endurance of approximate 24 hours, depending upon speed and payload configuration. Building on commercially viable HUGIN 3000 technology in daily use,

HUGIN 1000 provides robustness and sound technical solutions to the challenging demands of modern navies. HUGIN 1000 and HUGIN 3000 will co-exist on the same technology base mutually benefiting on the advances made for its different applications. HUGIN 1000 is part of the Norwegian HUGIN Mine Reconnaissance System (HMRS) program.



III. FIELD EXPERIENCE

Since 1997, the HUGIN vehicles have been used for several commercial, scientific and naval applications. A summary of the variety of experience obtained with the HUGIN vehicles are presented in the following.

E. Pioneer pipe route surveying

An important milestone was the first commercial survey operation with HUGIN I for the Åsgard Gas Transport Pipeline Route, autumn 1997. This survey confirmed that the expected improvements in efficiency and data quality were realistic.

Main characteristic of survey:

- Detailed seabed topography survey
- 200 km route corridor
- The results from these operations documented the following:
- In general, HUGIN showed an offshore operational performance and reliability well beyond most expectations.
- Even in shallow waters HUGIN collected data at a significant (4 times) greater efficiency than what was achieved by the ROV.
- The handling system prototype proved to be an adequately efficient and safe method for launch and recovery of the vehicle throughout the weather conditions of this operation (even when operated in Sea State 5).

F. Pipeline pre-engineering surveying

Another important milestone was passed in October 1998 with an exceptional challenging pre-engineering survey carried out in a deep fjord at the West Coast of Norway. The survey covered a seabed area of extremely rapidly varying topography with water depth in the range of 300-550 m, including narrow passages. This survey operation fully confirmed the capability of HUGIN to operate in this type of terrain with respect to navigation, positioning, communication, vehicle operation, as well as the performance of the survey sensors.

G. Environmental monitoring and fishery research

In June 1998, the first environmental test survey was carried out by the Institute of Marine Research (IMR), Norway using HUGIN II to map an area scattered with coral reefs. In a single 6–hour mission, an area of 7000 × 600 m (4.2 km^2) was mapped.

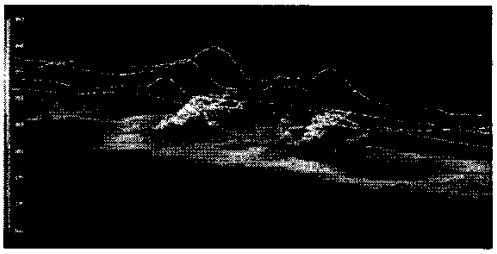


Figure: Bathymetry of coral reefs, West Coast of Norway. Surveyed by the Institute of Marine Research Institute, Bergen, Norway and NUI AS

In January 1999, Institute of Marine Research (IMR) tested HUHIN II as a sensor carrier for fishery research instrumentation. The EM3000 MBE was replaced with a 38 kHz Simrad fishery sonar. Apart from realistic testing of the system configuration, the objective of the operation was to determine the noise level of HUGIN. Excellent quality echograms were recorded, and noise measurements verified that HUGIN has a very low noise level for the application.

Since then more fishery research projects with HUGIN have been carried out with the latest one in November 2002 surveying the extreme concentration of herrings in the Ofotfjorden, North Norway.

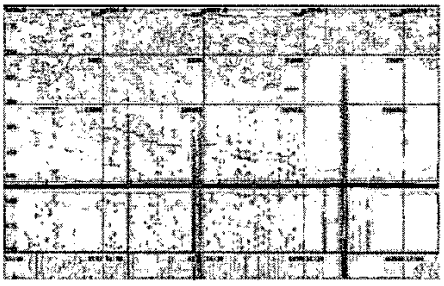
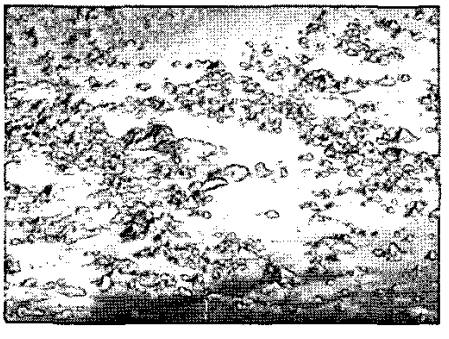


Figure: Echogram of hearing concentration in Ofotfjorden and NUI Explorer swimming through the shoal. Surveyed by the Institute of Marine Research Institute, Bergen, Norway and NUI AS.

H. Offshore surveying - North Sea

One example from offshore surveying with HUGIN is the survey operations carried out at the Ormen Lange gas field in the Norwegian Sea in 2000, 2001 and 2002. Ormen Lange is a significant gas province located in an area with water depths exceeding 800. Parts of the area contain very rough terrain with significant slide areas.

In order to provide sufficient and detailed survey data for the subsea installation design phases, Norsk Hydro decided to use AUV survey technology. Significant detailed site and pipeline route survey has been carried out by the Norwegian survey companies Geoconsult and Stolt Comex. The survey results have shown high efficiency, high accuracy and level of details. The detailed information unveiled by the survey will contribute significantly to the further work of planning and selecting the most optimal site and route for the production and pipeline installations, according to Norsk Hydro.



Figures: The Ormen Lange field survey. Data processed from EM 3000 on NUI Explorer.

I. Offshore Surveying - Gulf of Mexico, West Coast of Africa, Mediterranean and Brazil

During the last two years, C&C Technologies Inc. has successfully operated the HUGIN 3000 on a regular basis in the Gulf of Mexico. Surveying has been carried out in water depths down to 2400 metres proving the HUGIN 3000 survey capabilities in the rough escarpments leading down to BP's GoM deepwater fields. C&C Technologies Inc. has also and very successfully operated the vehicle off Vest Coast of Africa, off Brazil and in the Mediterranean. A total of more than 18.000 survey line km has been successfully covered in water depths down to 2850 meters.

The intended increase in cost-efficiency, data resolution and precision has been repeatedly demonstrated. The actual time and cost consumption by use of the Hugin-vehicles have been proved to be in the range of 1/3 to 1/2 of the traditional deep tow systems. The user feedback on the HUGIN 3000 AUV survey results, both efficiency and data quality is unambiguously positive.

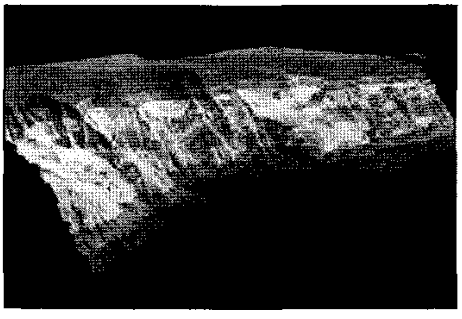


Figure: HUGIN Data Samples from GoM. The Sigsbee Escarpment mapped by HUGIN 3000 with EM 2000 Multibeam echo sounder. C&C Technology Inc.

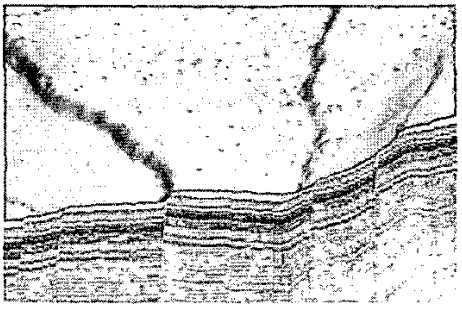


Figure: HUGIN Data Samples from GoM. Combined swath bathymetry and sub-bottom profiler data. C&C Technology Inc.

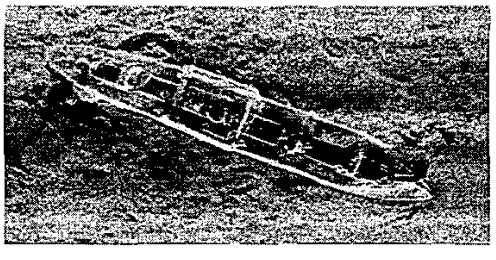


Figure: HUGIN Data Samples from GoM. Side scan sonar data (Alcoa Puritan, a 6759 ton cargo freighter. C&C Technology Inc.

IV. THE HUGIN MINE RECONNAISSANCE SYSTEM (HMRS)

The Norwegian long-term program for military use of autonomous underwater vehicles (AUVs) reached an important milestone in December 2001, when the concept of AUV based mine hunting and rapid environmental assessment (REA) was demonstrated using HUGIN from KNM Karmøy, one of the Oksøy class MCM vessels.

Within one day, the HUGIN AUV was programmed and launched from the MCMV, performed an acoustically supervised survey, proceeded to carry out an autonomous mine reconnaissance survey in a forward area with dummy mine-like objects, and returned to the MCMV for recovery. Through automatic mine detection and classification algorithms, a list of mine-like contacts was established, and data from these contacts was evaluated manually. The end result was that four out of four dummy mine were detected, classified, and accurately positioned.

Four months after the successful demonstrations, the Royal Norwegian Navy approved a project to develop the HUGIN Mine Reconnaissance System (HMRS), the first HUGIN system developed specifically for military applications. Current plans are to introduce the first HMRS vehicle to the Norwegian MCM forces in 2004/05.

The mine hunting vessel KNM Karmøy has been prepared with all necessary infrastructures (HUGIN launch/recovery system, acoustic links and acoustic positioning system (HiPAP)) to operate the HUGIN vehicles. Awaiting the first HUGIN HMRS system the Norwegian Navy will mobilise and use the HUGIN I vehicle at regular intervals to carry through MCM related operations and to obtain training and experience in using AUV technology for the MCM application.

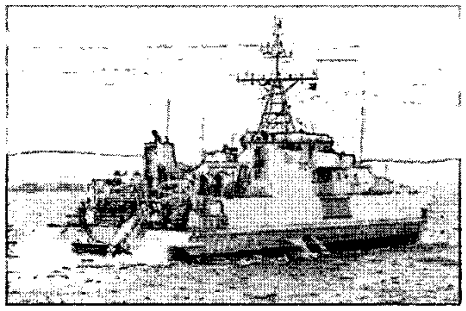


Figure: The Norwegian Navy mine hunting vessel KNM Karmøy with HUGIN I AUV.

V. WHAT'S NEXT ?

What are the future applications and market prospects – offshore, naval, research/environmental monitoring?

What new technology developments are required for existing and future applications of AUVs?

These subjects will be briefly commented on during the presentation.

REFERENCES

[1] N. Størkersen, J. Kristensen, A. Indreeide, J. Seim and T. Glancy, HUGIN - UUV for seabed surveying, Sea Technology, vol. 39 no. 2, February 1998.

[2] K. Vestgård, R. A. Klepaker, N. Størkersen, High Resolution Mapping with the HUGIN UUV,UUVS98, Southampton UK,September 1998.

[3] J. Kristensen and K. Vestgård, HUGIN - An Untethered Underwater Vehicle for Seabed Surveying, Oceans 98, September 1998, Nice, France.

[4] B. Jalving and K. Gade, Positioning Accuracy for the HUGIN Seabed Surveying Untethered Underwater Vehicle, Oceans 98, September 1998, Nice, France.

[5] B. Jalving: "Depth Accuracy in Seabed Mapping with Underwater Vehicles". *Proc. Oceans 99*, Seattle, WA, USA, 1999.

[6] K. Vestgård, R. A. Klepaker, N. Stoerkersen, HUGIN 3000 AUV For Deep Water Surveying, OTC 2000, May 2000.

[7] J. G. Northcutt, A. A. Kleiner and T. C. Chance. A High-Resolution Survey AUV. OTC 2000, May 2000.

[8] K.Vestgård, R. Hansen, B. Jalving and O. A. Pedersen. The HUGIN 3000 survey AUV – design and field results, UI 2001.

[9] B. Jalving, K. Vestgård, Nils Størkersen. Technology and Applications of Autonomous Underwater Vehicles. To be published by Taylor & Francis in their series Ocean Science and Technology.

[10] P E Hagen, N Størkersen, K Vestgård (2001): "The HUGIN Autonomous Underwater Vehicle for Forward Mine Hunting Operations". *Proc. UDT Europe 2001*, Hamburg, Germany, June 2001.

[11] P E Hagen, R E Hansen, B Jalving, E Hammerstad (2001): "SENSOTEK – Synthetic Aperture Sonar for AUV Based Mine Hunting". *Proc. Unmanned Systems 2001*, Baltimore, MD, USA, July-August 2001.

[12] P E Hagen, J Kristensen (2002): "The HUGIN AUV Plug and Play Payload System". Submitted to *Oceans 2002*, Biloxi, MS, USA, November 2002.