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MULTIBEAM SONARS FOR MAPPING THE SEABED WITH THE HUGIN UUV

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ABSTRACT

The HUGIN UUV was developed for the purpose of precision mapping of the seabed. In its first version, it was equipped with a special version of the 300 kHz multi beam sonar EM 3000. The next system generation which is presently under development, will have a wider range of acoustic equipment, including the EM 2000 multi beam sonar which is operating at a center frequency of 200 kHz. The paper describes the 2 versions of the HUGIN UUV system. Particular attention is given to the multi beam sonars which are used to map the seabed. Some examples of survey results are given.

INTRODUCTION

There is an increasing market demand for system solutions to do mapping and inspection of the seabed with a higher resolution and accuracy than that which can be obtained with hull-mounted sonars on surface survey vessels. Typical applications are cable and pipeline route mapping and inspection.
Traditionally such work was performed using either deep towed vehicles or remote operated vehicles (ROV's). Both these types of platforms are connected to a mother vessel by an umbilical cable. The high drag force of pulling the cable through the water is the main problem associated with both these methods, limiting the effective survey speed which can be obtained. Accurate navigation is an additional problem for the deep towed vehicles, because of the long horizontal distance between mother vessel and survey platform.
These problems are the main motivating factors for developing autonomous, free swimming sensor platforms which can survey at a speed which is higher and independent of water depth. The typical survey speed of an AUV/UUV is 3-4 knots.

Additional benefits which can be offered by untethered underwater vehicles are:

High payload sensor data quality. The properties making an AUV/UUV to an ideal payload sensor carrier platform coincide with the requirements crucial to obtaining high quality survey data, i.e. low acoustic self noise, hydrodynamic stability and effective control of optimal height above the seafloor.

High positioning accuracy. The freedom in positioning an AUV/UUV relative to the support vessel allows the support vessel being directly above the vehicle during survey operations. Consequently, this will minimise the effects of acoustic ray-bending errors on the acoustic positioning accuracy. Additionally, influence by errors in heading sensor and acoustic positioning system alignment onboard the support vessel will be reduced to a minimum.

Curvature changes and line turns. The advantage also applies for heading changes along a survey line and turns from one survey line and onto the next, which can be accomplished within minutes opposed to hours for alternative tools.

Portability. An AUV/UUV system can be maintained in two 20-foot cargo containers, which may be airfreighted throughout the world. One container holds the vehicle and the launch-and-retrieval system. The second container acts as a combined maintenance shop and battery service facility.

1. THE HUGIN UUV

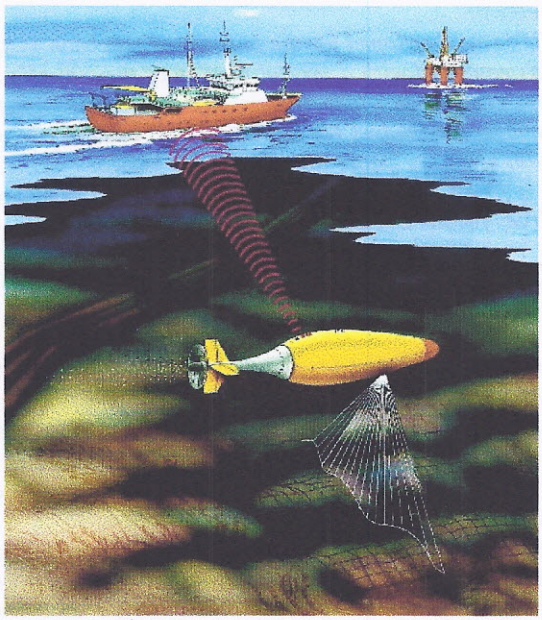

Fig.1. The HUGIN UUV operation concept

The HUGIN UUV development is a co-operation between the Norwegian Defence Research Establishment, Statoil, NUI, and Kongsberg Simrad. At the present time 2 vehicles have been produced (HUGIN I and II for max 600m water depth), and a new version is in production (HUGIN 3000) for max 3000m water he operating concept is illustrated in figure 1. HUGIN is a battery operated free swimming vehicle. It is linked to its mother vehicle by 4 acoustic connections:

- an acoustic control link
- a fast uplink for transfer of a subset of the data collected

- an emergency command link
- an acoustic transponder for navigation purposes.

The vehicle has built-in autopilot as well as a survey control according to preplanned lines. The height control is either relative to the seafloor or relative to the water surface.

While HUGIN I and II were equipped with the EM 3000 multi beam sonar as the only survey instrument, the HUGIN 3000 will have a wider suite of instruments including side scan sonar, sub bottom profiler and a multi beam sonar. The workload package is a separate, replaceable unit, and a central payload processor is designed so that it can record data from a multitude of sensors.

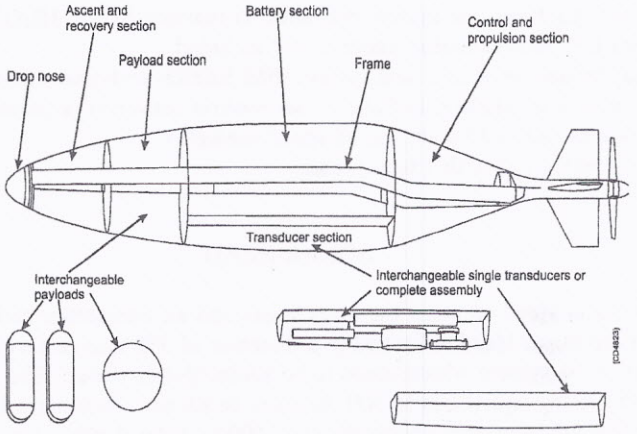

Figure 2. HUGIN 3000 vehicle structure

Vehicle navigation and positionin.

Vehicle position in surface co-ordinates is established by combining position data from the HiPAP acoustic position tracking system and DGPS navigation system. In addition HUGIN is equipped with an Aided Inertial Navigation system, integrating IMU (Inertial Measurement Unit) data, combined HiPAP/DGPS position data, DVL data, pressure transmitter data and gyrocompass heading in a mathematical optimal way. The navigation system provides an accurate real-time position solution allowing the vehicle to be run in autonomous mode and the mission plan to be based on waypoint navigation.

The vehicle guidance functions can interchangeably be used with guidance functionality implemented in the Payload Processor System.

2. MULTI BEAM ECHO SOUNDERS FOR THE HUGIN UUV

While the HUGIN I/II model only operates the EM 3000 multi beam sonar, the HUGIN 3000 can use either EM 3000 or EM 2000, and will also be able to use future instrument designs.

2.1.EM 3000 SYSTEM CHARACTERISTICS OVERVIEW

The Kongsberg Simrad EM 3000 multibeam echo sounder consists of three units:

- Sonar Head
- Processing Unit
- Operator Station

In a HUGIN configuration, the system operation is handled by the HUGIN operator station, and the standard EM 3000 operator station is not included.
The system may be delivered as a dual system (EM 3000D) with two sonar heads. A complete mapping system will in addition include vessel motion sensor(s), a positioning system, plus usually a postprocessing system and sound speed sensor(s).
The HUGIN I/II version is with 1 sonar head.

SONAR HEAD

The EM 3000 Sonar Head contains the transducers and all transmitter and receiver electronics. The size of the Sonar Head is limited to a diameter of 332 mm and a height of 119 mm. It is the only part of the system which needs to be submerged in water. The standard Sonar Head has a pressure rating equivalent to 500 m water depth and a submersed weight of 15 kg. A Sonar Head with a pressure rating equivalent to 1500 m water depth is also available.
A single cable with an underwater plug connects the Sonar Head to the EM 3000 Processing Unit. Fibre optic converters for use with an ROV or towed body telemetry link may be delivered with the Sonar Head.

PROCESSING UNIT

The EM 3000 Processing Unit performs the beamforming, bottom detection and controls the sonar head with respect to gain, ping rate and transmit angle. It contains all interfaces for time-critical external sensors such as vessel attitude (roll, pitch, heading and heave), vessel position, and external clock. For the HUGIN I/II application, the processing unit is packed in a pressure housing, and extended with functionality for recording data to a replaceable disk. The disk contents are transferred to the HUGIN operator station after each mission, while a subset of the data is transferred to the mother vessel in real time by acoustic link, so that it is possible for the system operator to verify that the survey is proceeding as planned.

OVERALL SPECIFICATIONS FOR THE EM 3000 SONAR

Frequency	300 kHz
Maximum ping rate	25 Hz
Number of beams per ping	127
Beamwidth	1.5° x 1.5°
Beam spacing	0.9°
Coverage sector	130°
Transmit beam steering	±25° in 0.5° steps
Depth resolution	1 cm
Pulse length	150 αS
Range sampling rate	15 kHz (5 cm)
Beamforming method	FFT

Frequencies of 293 and 307 kHz are also available, and are used in dual Sonar Head systems
Both beam width and beam spacing are inversely proportional with the cosine of the beam pointing angle with respect to the Sonar Head (i.e. beam width is 2.1° at ±45° beam pointing angle and 3.0° at ±60°, and beam spacing is 1.3° at ±45° and 1.8° at ±60°)

2.2. EM 2000 SYSTEM CHARACTERISTICS
OVERVIEW

The Kongsberg Simrad EM 2000 multi beam echo sounder is equivalent to the EM 3000 system, except for a different sonar head which is pressure rated for 3000m and uses a lower frequency. It comes in 2 models, both using curved receiver arrays. One is for a 150 degree swath, the other is for a 120 degree swath, with narrower beamwidths.

OVERALL SPECIFICATIONS FOR EM 2000 SONAR HEAD

Frequency	200 kHz
Maximum ping rate	10 Hz
Number of beams per ping	111
Beamwidth	1.5° x 2° or 1.5° x 4°
Beam spacing	Equidistant or equiangular
Coverage sector	150° or 120°
Roll stabilisation	Within ±15°
Depth resolution	1 cm
Pulse length	150 (mu)S
Range sampling rate	14 kHz (5 cm)
Beamforming method	Phase shift

3. SURVEY RESULTS

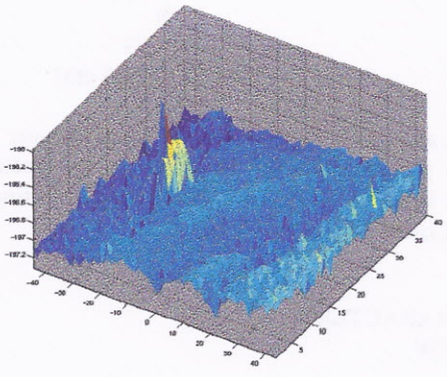

Figure 3. A 3D plot of a manta mine

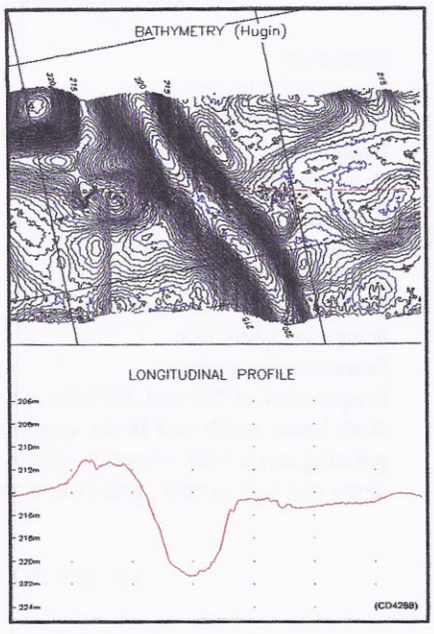

Figure 4. A detailed bottom map

4. CONCLUSIONS

Autonomous underwater vehicles, such as HUGIN, is a technology that offers new and very interesting opportunities for surveying the seabed, as well as oceanographic and biomass investigations. The survey speed is higher than alternative approaches, and makes the application economically attractive.

HUGIN is well suited as a platform for seabed mapping, due to good navigation capability combined with high motion stability and low acoustic noise signature. The modern multi beam sonars EM 3000 and EM 2000 can be fitted to HUGIN without major problems, due to low power consumption and small physical dimensions. The seabed mapping results are clearly better than anything seen before. For all these reasons it seems probable that the combination of AUV's and multi beam sonars will play an increasing role in the future scenario of seabed mapping and inspecton.

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