# MARINE RESEARCH REVIEW 4

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# INTELLIGENT CONTROL OF ROVS AND MANIPULATORS





#### MARINE RESEARCH REVIEWS

The aim of this new series of short reviews is to disseminate the results of MTD research programmes beyond the immediate circle of the researchers and their sponsors to a wider readership in the offshore and other marine industries. Results that are innovative and have practical potential will be presented in a form that will be accessible to the technically literate non-specialist. The aim is to encourage industry to participate in further development needed to convert research results into products or services that can reach the industrial marketplace.

The Offshore Supplies Office (OSO) of the Department of Trade and Industry has supported the establishment of the series. OSO has chosen the first five topics from MTD research programmes in underwater technology undertaken with the support of the OSO and the UK Science and Engineering Research Council. The series is published by MTD.

#### About OSO

As part of its work within DTI to assist the development of the offshore supplies industry, the research and development branch of OSO:

- gives financial assistance to support R&D projects and stimulate private sector support
- encourages oil companies to support R&D in their suppliers
- assists companies to obtain support from European Community programmes
- encourages links in offshore technology between universities, research establishments and industry.

#### About MTD

MTD is a UK-based association with an international membership. The Members have significant interests and capabilities in ocean-related technology, and come from industry, Government, research establishments, academic institutions, the UK Science and Engineering Research Council, and the Royal Academy of Engineering.

MTD operates programmes with a total value of £8 million a year in three broad areas:

- research and development
- education and training
- publications and information services.

## Intelligent Control of ROVs and Manipulators

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#### Acknowledgments

This report is based on three projects. The first two were part of the third phase of the Automation of Subsea Tasks (AST) managed programme, and the third was part of the Enhancement Technologies for Underwater Vehicles (ENTEC) managed programme. Both programmes were funded by the Science and Engineering Research Council through MTD and a number of industrial sponsors (see p.19). The AST Managing Agent was Prof G T Russell of Heriot-Watt University. The ENTEC Managing Agent was Mr D Spagni of Marinetech Research, and Prof J Lucas of the University of Liverpool was its Research Director.

#### The projects considered are:

Distributed knowledge-based system architecture for subsea sensor interpretation and manipulator co-ordination

The researchers were Dr D M Lane and Mr M J Chantler of the Dept. of Computing and Electrical Engineering at Heriot-Watt University.

Co-operation and planning for collaborating subsea manipulators using a distributed KBS architecture

The researchers were Prof G T Russell, Dr D M Lane, Mr M J Chantler and Mr M W Dunnigan of the Dept. of Computing and Electrical Engineering at Heriot-Watt University.

#### Intelligent adaptive control of subsea vehicles

The researchers were Prof J Lucas and Dr D W Shimmin of the Dept. of Electrical Engineering and Electronics at the University of Liverpool.

Members of MTD may consult the full research reports in the MTD library. Anyone interested in taking up the described techniques should contact the appropriate programme manager.

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This review was orginally written for MTD by Jeff Crook. The series editor is Judith Mirzoeff.

#### Summary

This review summarises the work of three research projects directed towards increasing the autonomy of underwater vehicles through the use of 'intelligent' control systems. A central theme is the use of machine learning techniques to develop advanced control systems. The projects formed part of the *Automation of Subsea Tasks* (AST) programme and the *Enhancement Technologies for Underwater Vehicles* (ENTEC) programme. These were focused on the development of underwater vehicles capable of advanced robotic operation, which is a challenging task given the unstructured nature of the subsea environment. The ultimate aim of these programmes was to improve the utility of remotely operated vehicles (ROVs) and thereby increase their use in comparison with divers.

The projects described here concentrated on enabling technologies for interpretation, manipulation and task control. Researchers developed state of the art control methods which were tested on practical equipment and evaluated for their suitability in 'real world' situations. Potential applications identified for some of the control methods and software extend beyond the underwater industry. Work is continuing on the most promising systems under the current MTD Managed Programme, Technology for Unmanned Underwater Vehicles (TUUV).

### Background

#### Market potential for underwater vehicles

Remotely operated vehicles have been used successfully by the oil and gas industry in the North Sea for many years, but their use has often been confined to simple tasks such as opening or closing subsea valves and routine inspection. More complex tasks are generally undertaken by divers, who have greater dexterity and manipulative skills than ROVs at present.

The role of the ROV is, however, becoming increasingly important as oil production moves into deeper waters where intervention by saturation divers presents greater problems. The Norwegian Government has recently introduced legislation limiting saturation diving to 180 metres or less on grounds of safety. In practice, saturation diving in water deeper than 250 m would be prohibitively expensive.

Both the United States and Brazil are exploiting deep water developments. In the Gulf of Mexico a reservoir of one billion barrels of oil equivalent was discovered in deep water in 1991. It was described as 'one of the best remaining domestic opportunities available to the (USA) oil industry'. Exxon has recently installed a

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10-slot manifold in 450 m in the Gulf of Mexico. This installation was notable because the pipelines were pulled in by an ROV without diver assistance. In addition the manifold is designed to allow all its components, including electrical harnesses, to be retrieved by ROVs.

In Brazil deep water production is vital for future oil field development. While only 8% of oil production currently comes from depths greater than 400 m, this is anticipated to increase to 61% by the year 2001. Petrobras is currently funding a programme called Procap 2000, which includes a study of subsea intervention problems.

The Russians have also shown an interest in subsea robotics for development of the Shoktman Field 375 miles north of Murmansk. This field contains an estimated 300 billion cubic metres of gas. A recent newspaper report stated that Boris Yeltsin has approved a plan that could involve converting nuclear submarine technology for development of the field.

Clearly there is a significant demand in the offshore oil and gas industry for improvements to the utility of ROVs.

#### **Current operational difficulties**

Currently, ROVs are deployed from the surface and controlled by ROV operators (pilots) via a control umbilical. The underwater environment is extremely unstructured, and the pilot cannot predict what the ROV will find when it arrives at its destination. Tasks are approached in two ways, by the use of either one or more manipulators fitted to the ROV, or a dedicated tooling system that allows the ROV to dock on to standard interfaces on the work site. In the North Sea environment the second approach is preferred, but has disadvantages. Tooling packages are expensive to develop and can only be used for preplanned tasks on systems which have been specifically designed for intervention by ROVs. This approach does however provide a stable platform from which ROVs can mate electrical connectors, manipulate valves and change seals on production systems on the seabed.

Successful deployment of ROVs with manipulators requires highly skilled operators to perform even the simplest tasks. As well as piloting the ROV and talking to the ship's captain, operators must co-ordinate the position of the vehicle with the movement of the manipulators, by working and reading a variety of sensors: video cameras, sonars and other instrumentation (heading, depth and attitude). Video cameras provide a patchwork of narrowly focused pictures with no complete view of the work site. Additionally the view is often obscured by suspended particles or by the manipulator arms themselves. The sonar information provides coverage over