# SUCCESSFUL TECHNIQUES FOR SUPPORTING MULTIDISCIPLINARY SCIENCE PROGRAMS WITH 'ROPOS'

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Abstract:

The ROPOS scientific ROV has successfully achieved the multidisciplinary objectives of up to thirty scientists on a single research cruise. These have included fine scale terrain mapping with a scanning downward looking sonar and video; collection of rock samples up to 2000kg, including drilled cores; video observations of the behavior of animals down to centimetre size; collection of animals from bacteria to crabs, fluid samples; positioning of probes within millimetres, real-time chemical analysis with an on-board scanner; and deployment and recovery of a range of equipment.

This success is partly due to versatility and adaptability of the system. ROPOS has two configurations, a 'caged' system for operations up to 5000m depths, and a 'live-boating' system for shallow waters. The system is supplied with a set of 'core tools' including long-base-line navigation, two manipulators, 3-CCD Video, forward-looking scanning sonar, suction sampler, 'PacMan' grab, sample tray and bio-box. ROPOS readily accepts user-provided tools. Its hydraulic power packs can provide up to eight separate functions for the users' scientific tools. Its scientific telemetry system, independent of the vehicle telemetry, can multiplex up to seven bi-directional RS-232 channels for realtime communication with, and control of many instruments. Analog and digital input and output are available through an external junction box. User provided tools have included a hot-fluid sampler, chemical scanner, ODP borehole data link, tubeworm stainer, rock-coring drill, rock-cutting chain saw, and downward looking scanning sonar.

Operational procedures developed through experience have also had a big impact on effectiveness. Dive flexibility is maintained by carrying as many tools as possible at all times, which also minimizes changeovers on deck. The long dive times possible with an unmanned vehicle allow both survey and sampling on the same dive. This in turn allows the shipboard scientists to work efficiently.

## I. Scientists need versatility.

The Canadian Scientific Submersible Facilities ROPOS operation supports leading-edge scientific research and similar engineering and technical tasks. Each expedition has multiple objectives, often involving several scientific disciplines. The submersible must be able to conduct a wide variety of operations within a single expedition, and often within a single dive. These may be unique to the expedition, or may involve unique tools and equipment developed by individual scientists.

The 1998 NeMO expedition aboard the US NOAA vessel Ron Brown is a good example of a typical expedition. A detailed record of the cruise can be found at the website: ***http://newport.pmel.noaa.gov/nemo_cruise98/ report98.html.*** The science team included 7 geologists, 9 chemists, and 10 biologists. The cruise objectives included

- Document relationships between volcanic activity, tectonic setting and temporal evolution of hydrothermal systems
- Measure effects of diking on horizontal strain field and hydrothermal system
- Define geochemical niches in different hydrothermal vent sites.
- Look for relationships between seismicity and temperature changes at hydrothermal vents
- Look for evidence of chemical reaction or metabolism by microorganisms within hydrothermal fluid samples.
- Measure low-temperature microbial abundance and diversity
- Culture microbes from well-characterized environments.
- Assess diversity and population structure by genetic techniques.
- Relate chemistry and microbiology to geological structure and plumbing system.
- Mineral, chemical, and microbial characterization of oxide mounds around ASHES
- Characterize biological diversity of the Axial Seamount vent communities:
- Relate community structure to water parameters:
- Document habitat conditions and behaviour of sulphide worms

As shown in Table 1. these scientists brought with them an array of instruments to augment ROPOS's own suite of equipment or to be deployed onto the sea floor or recovered from it

Table 1. Equipment used with ROPOS on the NeMO '98 expedition

| NeMO '98 |
| --- |
| User supplied equipment installed on ROPOS |
| Imagenex scanning sonar |
| Digital still camera |
| 35mm still camera |
| 28 mm stereo camera |
| SUAVE Chemical Scanner |
| Hot Fluid Sampler |
| 2 gas tight water sample bottles |
| 5L Niskin bottle |
| User supplied equipment carried for deployment on sea floor: |
| Markers |
| glass wool bacteria traps |
| Osmosampler |
| Portable biobox |
| High-temperature probe |
| Low temperature probe |
| ROPOS standard equipment: |
| Navigation |
| Black and White SIT camera |
| Sony 3 chip video camera |
| Mesotech scanning sonar |
| Suction sampler |
| Rotating sample tray |
| Biobox |
| 5 function arm: Standard jaw |
| 5 function arm: Pacman |
| 7 function arm: standard jaw |

## II. Creating a versatile vehicle:

ROPOS and the CSSF operation are continually evolving in collaboration with the users. The operations team has many years experience supporting science with both manned scientific submersibles and ROV's. The current ROPOS vehicle, delivered in 1997, incorporates extensive modifications based on a decade of experience with the first ROPOS. Other components of the system have been continuously modified since 1986, in dose collaboration with the scientific user community and in response to specialized sampling and imaging requirements and new developments in scientific instrumentation.

The new ROPOS is a powerful (30/40-horsepower) electro-hydraulic, tethered ROV designed and built by International Submarine Engineering to operate at depths up to 5000 meters. The design was based on the ISE Hysub series of successful industrial vehicles (Shepherd and Juniper, 1997) The vehicle (2.6m x 1.7m x 1.45m) has fore-aft, vertical, and lateral thrusters. A Mesotech colour imaging sonar, colour (3-CCD) and low-light silicon intensified (SIT) video cameras, and seven- and five-function manipulators are mounted on the front of the vehicle. For deepwater operations (>500m; 30-horse-power) ROPOS is launched and recovered in a 4.2m X 2.7m X 2.1m cage containing a winch with a 300m tether. The cage is linked to the support vessel by up to 5000m of electrical-opticall cable mounted on a large winch. This arrangement provides decoupling of the vehicle from the ship's motion while operating at depth. In live-boat, shallow water operations, the vehicle is deployed directly from the ship on a 500m tether and the hydraulic power pack provides 40-horsepower.

The whole system is portable, and can be shipped to meet the support vessel in a convenient port. ROPOS has operated from seven different support vessels belonging to four countries, and has mobilized as far afield as Capetown, South Africa.

The hydraulic power packs on the new vehicle provide eight separate hydraulic functions for scientific tools. The modification was undertaken in response to the increasing number of hydraulically actuated scientific tools being used on ROPOS and frequent requirements to use several tools during a single dive. Hydraulically driven tools successfully used on ROPOS include a rock coring drill and rockcutting chainsaw.

The Scientific Telemetry System is completely independent of the vehicle telemetry system. It multiplexes up to seven bi-directional RS-232 channels together, permitting real time communication with, and control of many instruments. An external junction box is provided for the user interface, providing analog and digital input and output, DC power and access to the RS-232 ports. A very wide variety of equipment has been successfully interfaced with the Scientific Telemetry System, including an Imagenex downward looking scanning sonar, a chemical 'scanner, and the datalogger in a seafloor drill hole.

Many operations need high-quality visual information. This is provided by a Sony DXC-950 broadcast quality video camera with a 16x zoom lens and highpower lights on the front of the vehicle. The camera's RGB signal travels via the fibre optic link to the surface where it is recorded in Betacam SP and S-VHS video formats.

Scientific instrument deployment and sampling operations demand a great deal of manipulative dexterity and the ability to grasp small to medium sized objects. The five and seven function manipulators have had their jaws replaced with smaller double-sided jaws constructed of stainless steel. This allows better manipulation of small samples and instruments. The double-sided jaw has a much larger opening so that larger objects can be grasped when necessary. Also, it is easier for the operator to see around the double-sided jaw during sampling of small and often fragile objects on the sea floor. Another option is the "Pacman" sampler, a clamshell shaped sampler that replaces the jaw end effector of the manipulator. It can bolt directly onto either the seven or five function arm and excels at sampling soft or fragile items.

The manipulators are very strong, rated for 600 lb. lift at full extension. Manipulator feedback has been upgraded to use solid state, Hall effect sensors instead of potentiometers. This gives better reliability with fewer seals and no moving parts. A two axis sensor for the ROPOS manipulators provides better linearity ad more consistent feedback.

Several other devices have been developed to meet common needs. One of these is the suction sampler, an original design. The suction pump is variable speed and reversible, so it can also be used for jetting. The suction inlet is attached to the end of the manipulator in such a way that the manipulator can still perform other simple tasks. The samples are collected in eight, two litre jars that have a filter mesh on the outflow. The mesh can be changed on each jar, allowing for the collection of a wide array of specimens such as water, bacterial mat, tube worms, clams, small fish and crabs, sediments and small rocks.

Storage of larger or more robust samples is a common requirement. A large rotary sample tray incorporates four to eight compartments for collecting geological and biological samples. It extends into, and retracts from the work envelope for easy sample stowage. A hydraulically-actuated Lexan "biobox" can be substituted for the sample tray in the same mount. The thick Lexan walls of the biobox provide thermal insulation for temperature-sensitive organisms sampled in deep water, and its larger compartments permit the collection of specimens that would be damaged by forcing them into the sample tray.

## III. Operational procedures contribute to versatility.

Scientists use ROVs in a fundamentally different way from manned submersibles. Manned submersibles descend to the seafloor with a pilot and one or two scientists. Information exchange with the surface is limited: the submersible and those aboard are in their own little world. The planned objectives of any given dive are either focussed on the interests of the scientists in the submersible, or constrained by their expertise. This picture is completely changed by the high level of real-time information available at the surface from a tethered ROV. Every scientist on the support vessel can participate in every dive. Dives can be longer, and dive planning can be based on making the most efficient and effective use of vehicle and support vessel time.

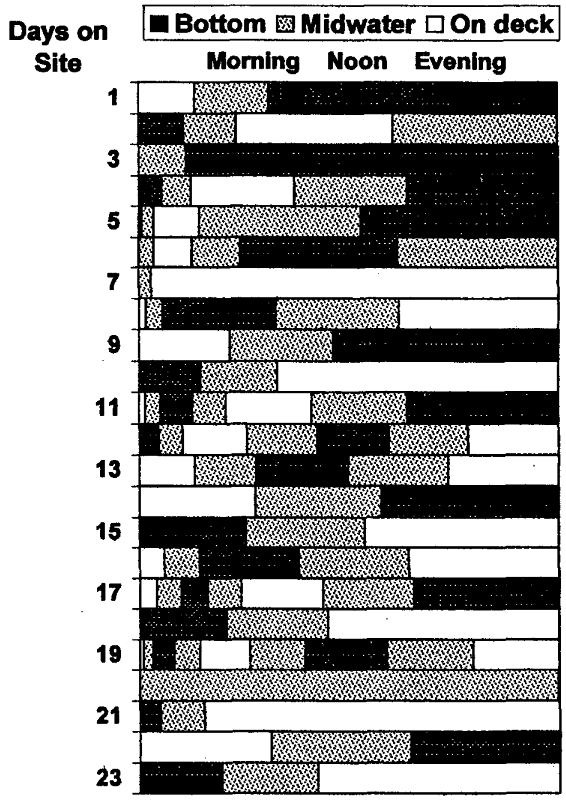


Fig. 1 ROPOS Dive History during NeMO '98

ROPOS produces a large amount of varied information during a dive, such as locations of sample collections, instrument deployments and observations, survey tracks and imagery of important features. Real-time text and video logging of dive operations uses an HTML-based system (MacDonald and Juniper, 1997). Sea floor features, sample collections and other interventions are recorded as captured video frames, in addition to being recorded in the continuous video tape archive. Real-time text logs are prepared in hypertext format and include hot links to corresponding video frames. At the end of an expedition the entire dive log series is transferred to CD-ROM and copies supplied to the scientists involved, who can be quite numerous.

One way to increase the efficiency of the vehicle is to minimize travel time between sites on the sea floor and between the surface and the sea floor. It is more efficient to complete all the scientific tasks on one dive at a particular site before either moving on to another site or returning to the surface. This leads to a demand to carry on every dive as much of the equipment needed for every scientific task planned for the expedition as is possible. This demand is exacerbated by the time lost involved in changing equipment on deck.

| | Dive Number → | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navigation | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Black and White SIT camera | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Sony 3 chip video camera | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Mesotech scanning sonar | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Suction sampler | | | X | X | X | | | | | | | X | X | X | X | X | X | | | X | |
| SUAVE Chemical Scanner | X | X | | | | X | X | X | X | X | | | | | | | | X | X | | X |
| Rotating sample tray | | | | | | | | | | | | | | | | | | | | | |
| Biobox | X | X | X | X | X | X | X | X | | | X | X | X | | X | X | X | X | X | | X |
| Hot Fluid Sampler | | | | | | | | | X | X | | | | X | | | | | | X | |
| 5 function arm: Standard jaw | | | | | | | | X | | | X | X | | | X | | | | X | X | X |
| 5 function arm: Pacman | X | X | X | X | X | X | X | | X | X | | | X | X | | X | X | X | | | |
| 7 function arm: standard jaw | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Imagenex scanning sonar | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Digital still camera | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 35mm still camera | X | X | | | X | X | | X | X | X | X | X | | X | | | | X | | | |
| 28 mm stereo camera | | | X | X | | | | | | | | | | | X | X | X | | X | X | X |
| Gas tight sample bottles | | X | X | | | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X |
| 5L Niskin bottle | | | X | | X | X | X | X | X | X | | X | X | X | X | X | X | X | | | |

Fig 2 Configuration of ROPOS for NeMO'98 dives: equipment competing for the same space is grouped together in the shaded boxes. The number of changeovers is minimized to reduce time on deck.

As described above, the configuration of ROPOS has evolved to meet this demand by increasing the number of controllable hydraulic functions and communications ports available for scientific equipment.

Balancing the desire to load the vehicle with every imaginable piece of equipment is the impact of each item on payload, space, power, maneuverability, dexterity and communications bandwidth. Too much equipment, greatly reduces the effectiveness of the ROV. How to optimize the effectiveness has had to be learned.

## References


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