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Victor 6000: Design, Utilization and First Improvements

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ABSTRACT

Following the needs of a widening community of end users the modular deep Remotely Operated Vehicle *Victor 6000* of the Institut Français d'Exploitation de la Mer, Ifremer, is evolving using new technologies. A deep record dive at high latitude (79°north) was reached in the Molloy Deep at 5550 metres in 1999. The performance obtained till 2002 during 2600 hours of work/survey near the seafloor are contributing significantly to the observation and the monitoring of the deep benthic ecosystems in various environments of the mid-oceanic ridges and the continental margins.

KEY WORDS: ROV ; underwater technology ; marine ecosystems, biodiversity ; continental margin ; mid-oceanic ridge ; polar deep sea.

INTRODUCTION

The purpose of this paper is to give technical and scientific background leading to the successful operation and results of the 6000-m depth-rated Remotely Operated Vehicle (ROV), *Victor 6000*, during the past 4 years. The industrial and technical context, that favored the development by Ifremer of a ROV dedicated to scientific users, is summarized. First you will find a general view of the context of the operational dives carried out from 1999 to 2002, then summaries on several scientific missions covering results at long term Arctic benthic station, mid-Atlantic ridge ecosystems and continental margin ecosystems off west Africa and the northern North Atlantic. Those experiences conduct to list and select new improvements to take into account reliability and operability improvements, obsolescence, new ideas and requirements, several of them being allowed or caused by the technical progress. Some perspectives are defined before the conclusion.

THE *VICTOR 6000* DEVELOPMENT

In the 90s the offshore oil industry increased its use of large, work class ROV, with depth capacities evolving from 1000 to 3000 meters at the end of this decade.

In a first phase, Ifremer designers and users evaluated in cooperation at sea several existing ROVs in the early 90s:

- the Hysub 5000 built by International Submarine Engineering (ISE) for the Deep Water Survey Company (DWS)
- the experimented Ventana built by ISE for the Monterey Bay Research Aquarium Institute (MBARI),
- the experimented Dolphin 3K (3000 meters) from the Japan Marine Technology Center (JAMSTEC),
- the specialized torpedo catcher Errato from the French Navy.

Following these evaluations and a feasibility study, the Ifremer decided to invest in the development of a ROV dedicated to the scientific utilization in coherence with the 6000-metre depth capabilities of the Ifremer deep-sea fleet.

The former accrued experiences in deep-sea technologies, developed and operated on the manned submersibles (*Nautile/Robin and Cyana*) as on several towed vehicles and robots (*Epaulard, Sar, Scampi*), made Ifremer sub-sea systems designers able to take in charge this development. A biologist and a geophysicist, as representatives of the scientific-end users, accompanied the project from the early beginning. The main breakthrough of this new ROV, called *Victor 6000*, was foreseen as coming from its capacities:

- to collect a large quantity of data in real time, by using fiber optics in the umbilical,
- to allow long duration dives, lasting for up to 72 hours, supported by the constant power supply delivered by the surface vessel,
- with its modular design concerning the scientific payload section, which offers flexible mission planning for different scientific disciplines.

The basis of the requirements were:

- 6000-m depth for an access to 97% of the sea areas and compatibility with the Ifremer manned submersible le *Nautile*,
- vehicle fitted with broadcast TV and high level manipulation using the *Maestro* computer-assisted hydraulic arm,
- positioning by the ultra short base line system *Posidonia 6000*,
- large and modular multidisciplinary scientific payload section,
- efficient and light electrical power supply,
- ability to be supported by the Research Vessel *L'Atalante* and other deep ROV support vessels including *Thalassa*.

After the comparison of several concept candidates including cage and top hat, the deployment with a flexible arch was chosen as well suited to Ifremer oceanographic requirements, means and know-how.

The critical technologies of the umbilical and its coherence with the electrical power supply were first tackled before starting the development of the system. The achievement of this system, weighing about 100 tons including the 4.6-ton vehicle, was followed by progressive sea trials starting in 1997 (Fig. 1).

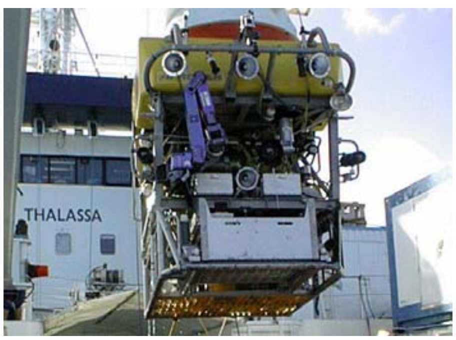


Fig. 1: 1997 and 1998 first cruises of the *Victor 6000* on *Thalassa*.

Fig. 2: the 4.6 tons vehicle measuring 3.2 L., 2.2 l., and 2.3 m high includes its large 600 kg sampling module at the inferior part.

The first 600-kg payload, the "basic sampling module", is fitted to the vehicle (Fig. 2) with a working environment design derived from the long experience acquired with the previous equipment used on the Ifremer manned submersibles (Michel et al., 1990).

THE CONTEXT OF THE FIRST SCIENTIFIC UTILIZATION OF *VICTOR 6000* FROM 1999 TO 2002

The first fully scientific operation took place in 1999 on the German icebreaking Research Vessel Polarstern (Fig. 5) headed by a team of the Alfred Wegener Institute for Polar and Marine Research, Germany (Soltwedel et al, 2000).
A team of Ifremer sub-sea systems design engineers was involved in this first deployment from the RV Polarstern accompanied by a team of Genavir operating the *Victor 6000*.

The scientific missions following the first use of the system expanded remarkably the *Victor 6000* utilization in latitudes ranging from:

- the continental margin off Angola, Congo and Gabon by Ifremer in cooperation with TotalFinaElf, (France);
- through the studies of hydrothermal vents in the Mid-Atlantic Ridge in cooperation with the Departamento de Geologia, Fac. de Ciências de Lisboa (Portugal) or in the East Pacific Rise;
- to the Arctic and the northern North Atlantic by the Alfred Wegener Institute for Polar and Marine Research (Germany) in cooperation with Ifremer scientists.

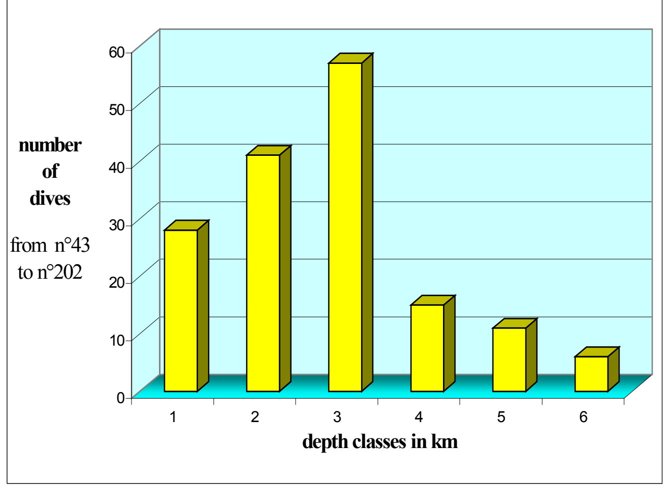
From the record of each dive characteristics collected by Genavir, in charge of the operations of the *Victor 6000*, we present (Table 1), the dive profile averaged from the last 160 dives that followed the 42 test and evaluation dives.

Table 1: Mean dive profile for the last 160 dives:

Parameter	Mean profile for the last 160 dives
Total dive duration	19 hours
Time near the sea floor	16 hours
Depth	2300 meters

More details on the number of dives per depth interval are illustrated (Fig. 3) which shows that 57 dives were accomplished in the 3 km class from depth of 2000 to 3000-meters.

Fig. 3: *Victor 6000* dive/depth histograms



Presently the *Victor 6000* has a track record of 3200 hours of diving time including 2600 hours of work near the seafloor for scientific purposes. The mobility of the system allows it to be operated from three different ships by the Genavir operational teams. Those ships were the Research Vessels *Thalassa* (Fig. 1), *L'Atalante* (Fig. 4) and Polarstern (Fig.5).

Fig. 4: the *Victor 6000* on *L'Atalante* in 2000, 2001 and 2002.

THE USE OF *VICTOR 6000* AT LONG-TERM ARCTIC STATIONS

The aim of the project was to identify key factors governing functional benthic biodiversity in the polar deep sea. There, fluxes of organic matter fueling the benthos are strongly seasonal, influenced by ice cover and thus vulnerable to the ice regime changes. Besides, organic matter flux, bottom currents, substrate properties, and natural disturbances are also important for the interactions between deep-sea organisms and their environment. The 1999 work conducted at long-term stations (Klages et al., 2001) in the Fram Strait, focussed on the zone between the lower bottom water and upper sediment. From a biological, geological and geochemical perspective, this complex system acts as a filter for burial of particles and as a source and sink for dissolved and gaseous components affecting bottom water chemistry.

Fig. 5: the Polarstern operated the *Victor 6000* in 1999.

The *Victor 6000* system was used for: - targeted sampling - installation of simulation experiments - deploying and activation of an *in situ* microprofiler unit - large scale video mosaicking for habitat mapping.

Moreover during this Polarstern (Fig. 5) 1999 cruise the *Victor 6000*, already tested at full depth, made a deep record dive at high latitude (79° north) reaching the bottom of the Molloy Deep in the Fram Strait at 5550 meters.

THE USE OF *VICTOR 6000* FOR THE MID-ATLANTIC RIDGE ECOSYSTEMS

The *Victor 6000* was successfully used for scientific operations on the Mid-Atlantic Ridge south of the Azores during two geological cruises IRIS (2001) and Seahma-1 (2002).

During these cruises five hydrothermal fields were studied at various depths between 764 and 3156 m. The *Victor 6000* was used in several technical configurations for:

- geochemical exploration,
- geophysical explorations and local surveys,
- sampling of sulfide chimneys and hot fluids.

The recent *Victor 6000* Iris and Seahma-1 cruises in the Azores area stems from two past European research contracts (MARFLUX, AMORES), relates to a continuing European research contract (VENTOX) in the same area and prepares the site selection for an ODP drilling leg already proposed by our team. The French program Dorsales supported the project.

The IRIS cruise in may-june 2001 was a continuation of research conducted on the Mid-Atlantic Ridge south of the Azores since 1992. Previous cruises in the area show the presence of four hydrothermal fields of contrasting characteristics in four segments of the ridge. These fields enable the study of the influence of depth, the nature of footwall rocks, tectonic activity and volcanic activity on hydrothermal processes. The Lucky Strike and Menez Gwen fields, on top of neovolcanic edifices, are located at moderate depths and are associated with basaltic lava making up the oceanic crust. On the contrary, the Rainbow and Saldanha fields lie on faults at the edge of segments and are associated with mantle rocks (Fouquet et al., 1997; Fouquet et al., 1998; Fouquet et al., 1999a&b). The Saldanha site (discovered in 1998) is attributed to fluids directly related with serpentinisation (as the 30ºN Lost City site discovered in 2000) throttled by a sediment cover (Barriga F.J.A.S., 1998; Barriga F.J.A.S., 1999).

The purpose of the *Victor 6000* IRIS cruise was to conduct detailed work on the Rainbow field and continue the exploration of the ridge south of the Azores.

The data obtained demonstrate that the Rainbow field is unique in several ways. Because of its setting on mantle lithologies the composition of fluids and hydrothermal precipitates is different from those of the other fields. Rainbow enables the study of hydration and chemical exchange between the ocean and the terrestrial mantle. One of the fundamental aspects underscored by our team is the abundant production of hydrogen as a by-product of the hydration of mantle rocks, strongly enriched in the hydrothermal fluids. Hydrogen is the initial building stone for the production of organic compounds by way of purely inorganic reactions. Metals present in various ways in mantle rocks and hydrothermal precipitates may catalyze such reactions. These phenomena can potentially lead to the formation of prebiotic molecules. The organic molecules produced are also the basis of a bacterial population specific of such environments. Our interdisciplinary project involving geologists, chemists, geophysicists and microbiologists is inserted in this research. Other themes for the mission focused on the characterization of massive sulfide bodies formed by hydrothermal springs.

During the IRIS cruise 16 dives were conducted and a distance of 121 km was covered on the seafloor during 195 hours. The *Victor 6000* was used in three different ways: sampling, exploration and geophysical survey. During the sampling operations hot hydrothermal fluids, sediment cores, chimneys and rocks were collected. Compared to the *Nautile* the *Victor 6000* was particularly efficient for exploration and survey. The *Victor 6000* allowed us to conduct a specific strategy to explore new targets and locate and map methane discharge on large surfaces of mantle outcrops. Mapping (Fig. 6) of the methane concentration near the floor was made using *Victor*'s water sampling capabilities (19 samples during each dive). Other specific equipment was coupled to a CTD for in situ iron and manganese analyses and methane measurement.

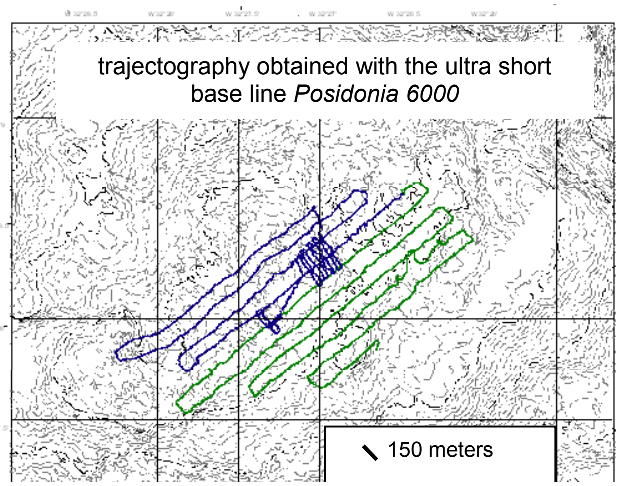


Fig. 6: example of the long exploration survey made on the Menez Hom mound (1900m) during the IRIS cruise to map chemical anomalies. Two 13-hour dives covered 30 km in this area. The spacing of the lines is about 150 m. More detailed surveys with a 30-m spacing were carried out at the center of the area.

A precise magnetic map of the hydrothermal field was also obtained from a 29-hour dive during which a 27-km long grid of 15 profiles, centered on the hydrothermal field, was covered. This was done to investigate the geometry of the system and prepare an ODP drilling strategy in this area. All data gathered during the IRIS cruise enable a better knowledge of the 3 dimensions of the metallogenic, chemical and microbiological processes in the Rainbow hydrothermal reactor.

In 2002, the Seahma-1 cruise was conducted in the same area with the benefit of the accumulated experience on the use of the *Victor 6000.* Between July 31 and August 14, the *Victor 6000* stayed more than 170 hours near the sea floor (Table 2), on various targets along a 270-km line, SW of the Azores.

Table 2: Dive duration/distribution of 2002 Seahma-1 cruise

Dive number	Bottom Depths	Hours on sea floor	Hours to next dive*
179 - Menez Gwen	792-850	15,5	15
180 - Menez Gwen	764-1020	24,5	18
181 - Saldanha	2196-2698	32,5	13
182 - Saldanha	2093-3156	17	7,5
183 - Rainbow	2284-2495	7	8
184 - Rainbow	2238-2429	12	8
185 - Saldanha	2188-2322	14	21
186 - Menez Hom	1783-1905	11	4
187 - Lucky Strike	1609-1752	36,5	-

(*) – with *Victor 6000* on deck

We had few technical problems:

- one of the dives (No. 183) had to be interrupted due to malfunction in Victor's arm that was solved by the operational team before the following dive (No. 184),
- we had additional but minor trouble with *Victor 6000* equipment for temperature measurement (Fig.7) and fluid sampling. Our main causes of delay were 3 unsuccessful attempts to use the shuttle for the transfer of equipment and rock samples on the sea floor, requiring high skill and training. This led to the preparation by the designers of part of the first evolutions conducted in 2003.

Fig. 7: Seahma-1 (2002) cruise: *Maestro* manipulator operator is performing precise temperature measurements in a black smoker (Rainbow hydrothermal field, venting temperature up to 364ºC).

Many operations (sampling, measurements, positioning over a non-planned target) are slower with the *Victor 6000* than with the *Nautile*, but the much greater times permissible on the bottom compensate for this disadvantage. Long dives create a payload conflict, as sample collection (especially geological) becomes limited by the weight that Victor can support. The elevator concept has merit and becomes a necessity at times. Additionally, it should be mentioned that direct observation (such as in the *Nautile*) is superior to remote observation (e.g. with the *Victor 6000*) given the tridimensional capability of humans and also a greater sensitivity/quality of the human eye image over the video camera. However, this difference does not exist in recorded images. In spite of these less favorable aspects, the *Victor 6000* is an extremely powerful vehicle, fitted with an impressive array of useful instruments, which produces observations and data beyond the capabilities of manned submersibles in many circumstances.

The Seahma-1 (2002) cruise was aimed at surveying the Menez Gwen, Lucky Strike, Saldanha and Rainbow hydrothermal fields, with an additional dive over Menez Hom mound (near Lucky Strike) trying to find hydrothermal activity there (given the presence of a large methane anomaly in the water over Menez Hom mound). Operations with *Victor 6000* consisted on observations and recordings on video (including hours of Betacam recordings), mapping (geological and biological), observations and sampling for certification of geophysical data from previous cruises, and extensive sampling. The cruise was eminently multidisciplinary, in a successful attempt to create synergies and scale economies in a sophisticated operation at sea.

The approach had proved well with *Nautile* (Saldanha cruise, 1998) and produced even better results with *Victor 6000*. The *Victor 6000* gives the possibility of much greater time spans on the sea floor and the possibility of participation of many more scientists in the real time observations/decisions, inside and outside *Victor*'s control container (Fig. 14). Thus we collected hundreds of rocks, hydrothermal minerals such as chimney fragments, sediments (Fig. 8), animals (including fish, crustaceans, gastropods, microbes and many others) and a variety of hot and cold fluids. Very accurate navigation, on most occasions, permitted visiting sites of previous operations, such as dredges, for precise knowledge of the original position of the materials collected by dredging.

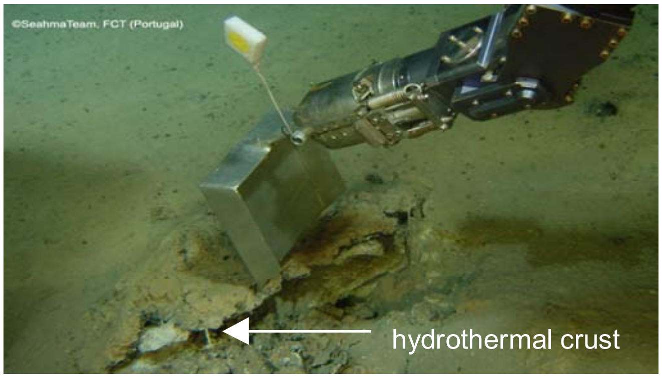


Fig. 8: Seahma-1 (2002) cruise: *Maestro* manipulator operator is shoveling delicately a hydrothermal crust deposited within the sediment, to recover both into a tightly sealed box.

Seahma-1 results include indisputable evidence for sub-sea floor precipitation of metal rich minerals (massive sulphides) at Rainbow (and Lucky Strike), observation and sampling of increased life associated with the Saldanha site, extensive mapping on and around Mount Saldanha (geological and biological). The presence of several animals was recorded for the first time and there is new information on population distributions and abundance. Several probably new species of animals were collected.

THE USE OF *VICTOR 6000* FOR THE CONTINENTAL MARGIN ECOSYSTEMS OFF WEST AFRICA

The pluridisciplinary studies of the Atlantic continental margin ecosystems off Angola, Congo and Gabon, involved investigations with the *Victor 6000* during two cruises in cooperation with TotalFinaElf : Biozaïre-1 in January 2001 (Sarradin, 2002) and Biozaïre-2 in December 2001, reaching the depth of 4059 meters.

The scientific objectives were combined with a new interest of TotalFinaElf in the understanding of both detritus and chemosynthetic-based ecosystems. The goal of these studies was to improve our understanding of how biological communities can be affected by anthropogenic factors and to identify which benthic processes control abyssal life before any impact of oil industry affect the extreme environment of the deep sea. Sediment and fauna have been sampled near old exploration wells on drilling cuttings and sediments, in order to analyze *in situ* colonization.

The exploration and diving strategy of *Victor 6000* was adapted after the discovery of rich cold seep communities (Fig. 9) located on pockmarks. The *Victor 6000* was used to perform observations (photo, video, mosaics), sediment, fluid and faunal samplings as well as *in situ* measurements. The aim of these dives was to identify the relationships between the geochemical features (methane and sulfur rich fluids), the biodiversity and microbial activities found in cold seep ecosystems. During the Biozaire-2 (dec. 2001) cruise, two extremely long dives were performed, for a total of 38 and 22 hours respectively near the sea floor. The carrying capacity of Victor basket was insufficient during long dives. To overcome this limitation, two shuttle deployments were performed during each dive to carry extra tools such as sediment blade and tube corers as well as experimental devices. The addition of this simple shuttle, developed for the manned submersible *Nautile*, greatly improved bottom-sampling efficiency. The need for replicates and several core samples on a same site is essential for the achievement of ecological studies. This shuttle has to be further improved, in view of its use with the *Victor 6000*, to increase its sampling capacity. The blade corer modified at Ifremer was extremely performant to collect sediments and macrofaunal samples in the vicinity of drilling wells and allowed the identification of faunal assemblages that recolonized the disrupted area.

An ecological systemic approach was conducted for the first time in a pockmark area discovered near the Zaire subsea channel. Each faunal assemblage was sampled using this approach and included:

- 3 measures of temperature,
- 3 measures with a new methane sensor,
- 3 water samples by pumping (called *PEP* device),
- 3 tube corer samples,
- 3 box corer samples,
- megafauna samples collected with *Victor's Maestro* arm.

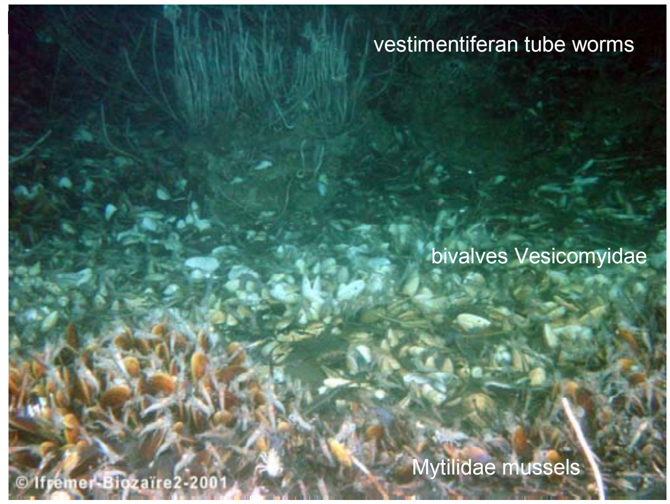


Fig. 9: Three types of faunal assemblages were discovered and were dominated by either Mytilidae mussels -foreground-, bivalves Vesicomyidae -center- and vestimentiferan tube worms – background (picture from the *Victor 6000* electronic still camera).

In addition to the identification of distinct faunal assemblages, two original observations were made:

- frozen gas hydrates (Fig. 10) rising to the surface of the sea floor near carbonated concretions,
- bubbles of methane emerging from the sediments captured with a Niskin water-sampling bottle to analyze methane concentrations. The use of a benthic chamber (Fig. 11) for measuring fluid flow rate was unsuccessful due to transition from gas to snow.

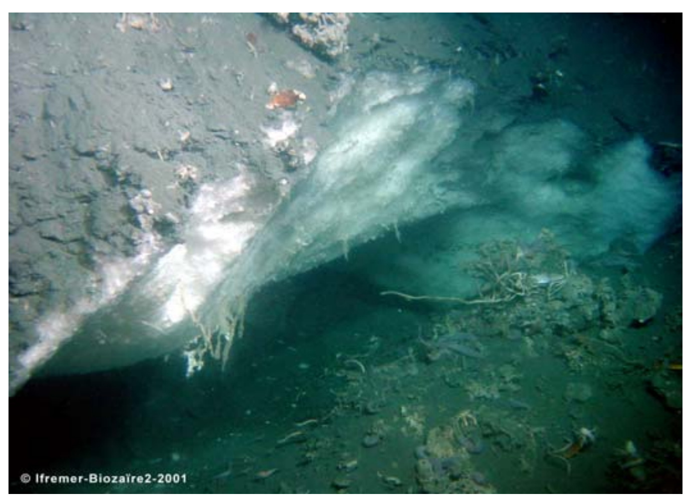


Fig. 10: Frozen gas hydrates outcrop (picture from the *Victor 6000* electronic still camera).

Fig. 11: Bubbles of methane rising through a benthic chamber disposed by the *Victor 6000.*

The observations and precise operations conducted during the Biozaïre cruise show the capacity of *Victor 6000* to carry out a sampling strategy that allows an integrated study of faunal distribution and related environmental factors.

THE USE OF *VICTOR 6000* IN STUDYING A COLD SEEP AT THE CONTINENTAL MARGIN OF NORWAY

For the northern North Atlantic, the Håkon Mosby Mud Volcano (HMMV) at about 72° N 14° E is the only mud volcano that has been studied in greater detail by photo and video camera observations. The HMMV is situated on the continental slope north-west of Norway at a water depth of 1250 meters. It has a diameter of about 2-km, with an outer rim populated with methane-depending, chemosynthetic communities and an inner center of about 500 m in diameter where fresh mud baths are expelled. Between the central plain and the outer rim, a complex topography of hills and depressions was found that is derived from the transport of young sediments. The setting studied in this investigation represents a point source of methane at a passive continental margin.

For the purpose of this study, a few selected key locations were sampled with the *Victor 6000* in 2001 during an expedition with the French RV *L'Atalante (*Klages et al., 2002). The major aim of this study was the investigation of microbial sulphate reduction (SRR) and anaerobic methane oxidation (AOM) in methane-enriched surface sediments of the HMMV. Samples were obtained from the center of the HMMV crater, the south and south-east of the crater and the surrounding area from sediment cores which were retrieved by the *Victor 6000* and by multiple corer hauls. To obtain large additional quantities of bottom water at these sites, a rosette and a newly developed horizontal bottom water sampler were used. Different types of methanotrophic communities were detected which seem to efficiently consume methane despite the extremely low temperatures measured with the temperature probe of *Victor 6000*.

THE SCIENTIFIC RETURNS AND THE FIRST 2003 IMPROVEMENTS OF *VICTOR 6000*

The French ROV *Victor 6000* demonstrated during these first 4 years of intensive scientific use its ability to:

- ►work at the microhabitat scale (due to its high handling quality) to study the ecology or ethology of benthic invertebrates,
- ►perform large exploration or survey instrumented operations for the knowledge of the benthic environments.

Even though it is efficient for long dives, it was also proven efficient for short dives combining video observations, in situ analysis and deployment of moorings. On account of the last 202 dives experience, the designers are now conducting a main overhaul of the *Victor 6000* with yet significant improvements extending the system capacities (Sarradin and all, 2002). In answer to scientific requirements, and taking advantage of fast evolving technologies, new improvements are presently integrated, particularly in fibre optic communications and in digital photo & video fields.

The first important change is the increase of transmission abilities by the use of a new optical telemetry (Fig. 12) using Coarse Wavelengh Division Multiplexer (CWDM). The potential flow of data from the vehicle to the surface has been increased extending the vehicle capacity to be implemented with more observing video systems (up to 12) and analysis or sensor devices (up to 30 serial links) and 3 Ethernet links.

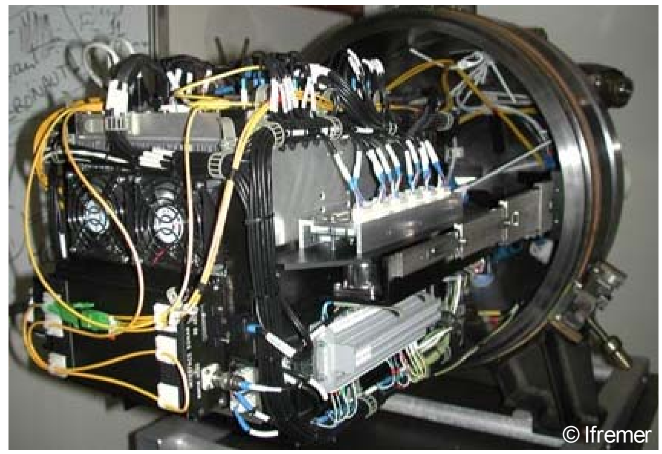


Fig. 12: Subsea part of the telemetry used on one fiber of the electro-optical umbilical of the *Victor 6000*.

The second improvement concerns the integration of a high-resolution digital still camera (3 Mpixels, autofocus, 3X optical zoom). Selected by the engineer in charge of the optical program, the prototype camera named VSPN 3000 was used successfully as illustrated by all the subsea photos presented above. This camera is presently modified to be used to 6000 meters and to communicate with an Ethernet link. This adapted electronic still camera VSPN 6000 will be mounted on the central pan & tilt system (Fig. 13) moving the main 3CCD TV camera. A video link allows the scientist and pilot to have a real time view of the pictures. Pictures are stored in the still camera flash memory and transferred to the surface via the Ethernet link during the dive. Four parallel laser beams were integrated to the main 3CCD TV camera to perform size estimation on the TV images.

Fig. 13: *Victor 6000* central pan & tilt unit handles the 3CCD TV with the 4 parallel lasers (left). The future electronic still camera VSPN (right) in its 6000m option will be placed on its right side.

To increase the quality of the video recorded, the durability of the records and the easy access for scientific user, the recording process has been changed from conventional analog VHS standard to a digital standard on DVD. The scientific station has been entirely modified so far as the software and hardware are concerned. The positioning is carried out by an ultra short baseline system called *Posidonia 6000*. Three modes are now possible to increase the performance of the navigation: - ultra short base line (*Posidonia 6000*), - dead reckoning using a fiber optic gyro compass associated with a bottom track doppler log - hybrid mode associating both modes.

Finally, the ergonomy of the software and interfaces used by the pilot and scientist in the control room (Fig. 14) has been improved as well as the whole system reliability.

Fig. 14: The decisive role of the photonics in the control room.

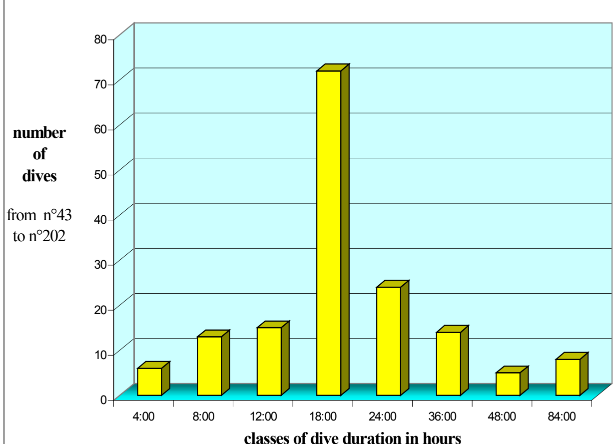
The main objectives of the 2003 evolutions are thus:

- to increase the reliability according to the acquired experience,
- to increase the flux of data coming from the sea floor,
- to improve the quality of the images (photos and video) produced by the *Victor 6000* (Fig. 14) during either survey studies or site work at a microscale.

THE *VICTOR 6000* PERSPECTIVES

The *Victor 6000* has the possibility to be operated till three days on end. This option to make long duration dives is studied through the following statistics. The dive/duration histogram (Fig. 15) shows an important concentration of the dive duration in the 12 to 18-hour class for the last 160 dives performed since 1999. We also observe that 53 dives among those 160 dives have duration over 18 hours.

Fig. 15: *Victor 6000* nb of dives/duration

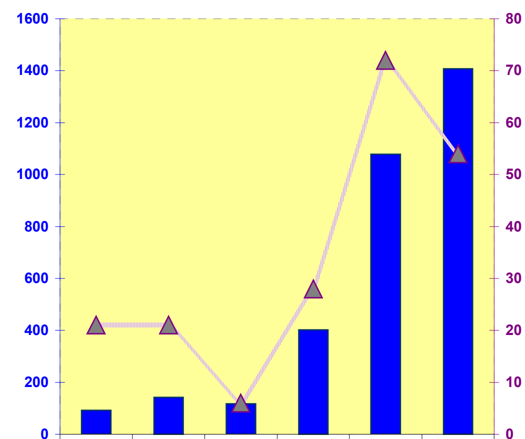


The annual performance, based on the number of dives and their total duration, illustrate the two periods during the first 6 years of use of the *Victor 6000*:

- 1997/1998: 2 years of evaluations at sea for designers, operators and users reaching for the first time 5917 meters depth on the 2nd of October 1998,
- 1999/2002: 4 years of operations with increasing scientific use.

During the last 4 years the annual diving time (Fig. 16) increased significantly. In 2002, the mean time per dive reached 26 hours as long dives were largely performed using systematically optical or acoustical sensors.

Fig. 16: *Victor 6000* annual performance



	1997	1998	1999	2000	2001	2002
diving time in hours	92	142	117	402	1079	1407
nb of dives	21	21	6	28	72	54

At present, feasibility studies are in progress to prepare the future achievement of a second scientific payload module supporting survey instrumentation.

The first sensor tested for survey is a multibeam echosounder that was used on an experimentally basis during several scientific cruises in order to have a common georeference based on a "micro" bathymetric map for scientific observation and monitoring. Other sensors are either tested or under development to obtain optical mosaics at several ranges up to 10 meters above the seafloor in clear deep waters. It is envisaged that this payload package will contribute to the perspective of deep-sea "remote sensing" at long survey transects.

We suppose that, as surveys will become more repetitive, new generations of autonomous vehicles will occupy some niches in this field of activities (Michel et al., 1984; Renard et al., 1993).

These last four years of intensive and increasing use enhanced our operational and scientific experience, which directed the first major technical overhaul of the system. The *Victor 6000* is now situated in the French deep underwater intervention plan amongst the top of exploration submarine vehicles, that cover a large range of measuring and sampling scales in time and space. The *Victor 6000* central place is shared with manned submersibles towed vehicles, AUVs and deep-sea observatories.

In this context, the *Victor 6000* use will generate a dynamic prospective vision of future needs and technological progress, taking account of the experience gained during sea campaigns.

In view of this demand, short technical overhauls, more frequent than for ships and manned vehicles, are required to take into consideration the equipment technical nature and to go on making the system reliable following a gradual replacement policy for obsolete equipment. Successively all the on-board instruments: geophysical measurements, video observations, in situ measurements for water, sediment and living samples have to be periodically improved. Shuttles will be elaborated in stages to overcome the inherent small payload of the vehicle as it has been done successfully with the manned submersibles.

A concerted, coordinated or shared investment and management process must be progressively developed on a European scale to give the scientists easier access to a complete range of modern vehicles. This broadening to Europe is taken into account to define the national priorities.

A new effort will be made for training the users, preparing the missions and testing ashore the future developments with the necessary installations in the Ifremer Mediterranean Center of Toulon.

CONCLUSION

After the commissioning of the 6000-m depth-rated Remotely Operated Vehicle *Victor 6000* by the Ifremer in 1999, this system became a highly appreciated instrument. A large community of end users performed successful cruises in the Arctic deep sea, mid-oceanic ridge ecosystems and continental margin ecosystems off west Africa and in the northern North Atlantic.

At the end of 2002 the *Victor 6000* has a total of 3200 hours of diving time at latitudes ranging from the continental margin off Angola to the deep dive record at high northern latitude (79°north) reaching the seafloor of the Molloy Deep at 5550 meters.

Among the new technologies the progresses in photonics (Fig. 12,13,14) are particularly at the origin of the development of the *Victor 6000* and also of its continuous improvements. A permanent effort is conducted to increase its overall reliability.

The transfer of the accrued experiences at Ifremer, resulting from the use of the manned submersibles, to this Remotely Operated Vehicle led to a renewed experience on the modularity of the vehicle payload with a first module dedicated to basic sampling able to handle several scientific tools and instruments.

A major step in further improvement of the *Victor 6000* concerns its ability to operate continuously for several days, which offers many future perspectives of the system for long surveys.

Shuttles and seafloor observatories are axes of development that will have to be more intimately associated with the deployment from subsea intervention systems as the *Victor 6000*.

With these capacities the *Victor 6000* system is able to play a major role as a mobile observatory for the monitoring of the marine ecosystems in their deep environment.

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