

Evaluation of the first year of scientific use of the French ROV Victor 6000

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Abstract - The evaluation of the first year of intensive scientific use of the French deep sea Remotely Operated Vehicle (ROV) "VICTOR 6000" is presented.

VICTOR was used in 2001 during five cruises on continental margins. **ZAIROV 1 & 2**, **BIOZAIRE 1 & 2** cruises were conducted offshore Western Africa and **CARACOLE** cruise along the North East Atlantic margins (Porcupine and Rockall bank). Cold seep settings (up to 3000m depth), coral mounds (400-1000m), oil exploration rigs (1300m) and the Zaire channel (about 4000m) were explored. VICTOR carried out on site work during two cruises (**IRIS & ATOS**) on the hydrothermal vent areas in the Mid Atlantic Ridge (Menez Gwen 850m, Lucky Strike 1650m and Rainbow 2350m). Finally, VICTOR was used by Alfred Wegener Institute, through a French-German co-operation in arctic deep sea, to study high diversity of species in the deep sea, in high latitude (**AWI** leg).

Different strategies were tested during those cruises like survey and exploration or experimental work on small areas. The dives duration ranged between 8 to 28 hours on the bottom. The high potential of Victor was confirmed in both strategies with a high ability for manipulation and the trials of varied instrumentation. The status and recent evolutions of the VICTOR 6000 are presented showing the essential role of a dynamic technical support oriented toward the satisfaction of the scientific objectives and operability.

1. Victor 6000

1.1- Technical specifications (Table 1)

VICTOR 6000 is a modular remote-controlled system made up of two sub-systems. The vehicle itself includes servicing equipment: propulsion, video survey, lighting, remote control, navigation and miscellaneous services. The scientific module (Basic Sampling Toolsled) is composed of a 0.7m high structure placed under the vehicle in which the majority of scientific equipment, specific to the mission, is located. The positioning is carried out by an ultra short baseline system called POSIDONIA.

The "Basic Sampling Toolsled" holds all necessary tools to collect samples (sediments, water, organisms, rocks,...), to perform temperature measurements and to release passive markers on the sea floor for future investigations. Specific

instrumentation can be connected to the toolsled using power connectors and serial links.

Table 1: Vehicle and sampling module specifications

Vehicle	
Depth rating	6000 m
Dimensions L*W*H, (m)	3,1 *1,8 *2
Mass in air (kg)	4000
Thrust	200 kg in all directions
Main video camera	3CCD on pan & tilt with zoom lens
Others cameras	5 additional cameras
Lights	5 kW, 8 units
Sensors	gyro laser, depth, altitude, doppler log
Main manipulator	7 fct M/S, 100 kg lift
Grabber	5 fct, 100 kg lift
Buoyancy system	70 l, 2 l/mn at 600 bars
Sampling module	
Dimensions L*W*H, (m)	2,5*1,9*0,7
Weight (kg)	170 in water, 600 max in air
Hydraulic power	3 kW, 210 bars max
Electric power	500W - 240V, 200W-48V
Data communications	3 serial links
Basket dim. L*W*H, (m)	1,1*0,9*0,6
Temperature sensors	3 sensors
Fauna sampling	carousel with 8 bottles
Site marking	6 passive markers
Water sampling	19*200ml

1.2- Evolutions for 2001 scientific missions

The first recommendations made by users during the last scientific cruises in late 1999 have lead to first evolutions concerning mainly the quality of the images and the positioning. A high-resolution vertical camera has been installed, forward facing lights have been fixed on the bottom of the ROV to enhance optical contrast. A high-resolution digital still camera (HYTEC VSPN3000, 3 Mpixels, autofocus, 3-t optic zoom) has been associated to the main video camera to be tested during 2001. Finally, four laser beams have been integrated to the main video camera to perform size estimation on the images. The navigation system has been improved by the addition of accurate position reckoning sensors -optic fibre gyro and doppler log-. Performances of these sensors (drift <10 m/ph) combined with the precision of the

POSIDONIA positioning system (0.5% of water depth in standard acoustic environment), make it possible to obtain the sensor's trajectory measuring data suitable for map drawing. The production of on-profile optic images from successive shots is now possible. As part of a research project, a detailed bathymetric survey carried out using a multi-beam echosounder (Reson Seabat 8101/240 khz) have been tested on the vehicle and assessed during the Caracole cruise. Concerning handling and sampling operations, the MAESTRO slave/master arm has been improved with regard to both robotics and manoeuvring. A second grasping arm has been installed. A first prototype of the lifting shuttle in its simplest version has been tested and used to transfer equipment and samples from the seabed to the surface (and conversely) during a dive.



Victor 1° cruise, Ifremer©

2. Scientific evaluation of the 2001 cruises

VICTOR 6000 onboard the French research vessel "L'Atalante" was used in 2001 during eight cruises on continental margins (offshore Western Africa and North East Atlantic), hydrothermal vents (Mid Atlantic Ridge) and northern North Atlantic. Different strategies were applied during those cruises like survey and exploration or experimental work on small areas. The dives duration ranged between 8 to 28 hours on the bottom. Preliminary results obtained during that cruises are presented thereafter.

2.1- The Zairov-Fluids cruises

Chief scientists: Hélène Ondréas and Bruno Savoye.

The Zairov cruise was carried out in december 2000, on the Angola and Congo margins. It was the last part of the joined research project ZAIANGO which links IFREMER and TotalFinaElf in a scientific and technical collaboration from 1998 to 2002. The main goal of the cruise was to study in situ active geological processes of fluids migration (water, hydrocarbon or gas) occurring through the

sedimentary cover and resulting in cold seeps and pockmarks on the bottom. These fluids are coming from high depths and are bringing information's on deep margin structure or on nature of hydrocarbons present in the substratum. These studies are also conducted to assess geohazards related to fluid migration processes. The use of ROV VICTOR 6000 technology during the Zairov cruise allow conducting in situ observations of morphology and repartition of pockmarks but also physical and chemical studies of fluids escapes by water sampling and continuous measurements. Observations and sampling have also been carried out in order to study fauna associated to the cold seeps. Eight dives were carried out with VICTOR for 85 hours and 55 kilometres on the bottom.

Exploring surveys of several kilometres were carried out to search and localise the more active sites. On these sites, visual accurate surveys for videos mosaics and chemical detailed surveys were conducted by regular profile covering. Concretions and fauna samples were taken with tongs, sediment sampling by tube-cores of 40 cm long and 6 cm in diameter. Water sampling were conducted using the Victor's water samplers. The continuous measurements of conductivity, temperature and pressure were possible using a CTD-SEABIRD SBE 25 equipped with a nephelometric sensor LSS600 and a methane sensor. Real time data of methane and nephelometry were recorded near the bottom on some pockmarks. An in situ analyser of manganese was also used in order to map the chemical cartography of some pockmarks.

The works conducted during the Zairov cruise show different types of fluids escapes linked to scale, to deep structures or to fauna associations. Circular depressions are few meters or few decimetres large, sometimes gathered on cluster of several hundred meters in diameter. An abundant fauna of Vesicomidae, Mytilidae and Pogonophora typical of cold seeps is present at some areas. Chemosynthetic processes are involved to explain the genesis of carbonate crusts and fauna association of these environment. The analysis of methane and nephelometry in the water column show the existence of a methane plume in the majority of studied areas with variable value from one site to the others. Comparing to the background of deep ocean waters, these near-bottom abnormal methane concentrations in the water column are the result of a intense methane flux in the area but with preferential escapes. Gas hydrates have been collected in the vicinity of a giant pockmark.

The use of ROV VICTOR 6000 as exploration tool or as on site work tool during the ZAIROV-Fluids cruise was a success, showing great diversity and complexity in fluids circulation. In situ observations, samples and measurements carried out with ROV VICTOR 6000 in the gulf of Guinea fully answer scientific expectations.

2.2- BIOZAIRE cruises

Chief scientist Myriam Sibuet

A new program on deep sea ecology of the continental margin in the Gulf of Guinea was initiated with the BIOZAIRE 1 cruise in January 2001 followed by the cruise BIOZAIRE 2 in November. The use of the ROV Victor

6000 with a great variety of tools has been designed for the study of the benthic fauna, the physical and chemical characteristics of the environment at a local and regional scale. The general objectives were to establish for the first time the diversity of the ecosystems and to propose sampling and experimental strategies before oil exploitation, in the framework of a scientific and technical cooperation between Total Fina Elf and Ifremer.

Scientific questions on which the programme was focussed and which need particularly a submersible are : i) Are there chemosynthetic ecosystems linked to hydrocarbon seeps in this passive margin ? ii) Are the small mounds related to deep corals and eventually hydrocarbon seeps? iii) What are the potential of the benthic ecosystems to recover equilibrium conditions after physical and chemical disturbances of the environment linked to oil drillings?

Several sites were selected for the Victor 6000 m dives from 400 m to 4000m depth allowing to 1) describe the structure (diversity and biomass) of the benthic communities near exploration well heads , 2) to understand the formation of topographic mounds which are in fact deep coral structures, 3) to observe the variation of biological activity influenced by the terrigenous input through the Zaïre canyon, and 4) to study the original communities living on pockmarks in relation with the chemical and physical substrates.



Sediment sampling for fauna analysis close to a well head. Biozaire cruise, Ifremer©

The cruises allowed to realised successively 14 dives on precise localities: a total of 7 successful dives during Biozaire 1 and a total of 11 (with only 7 successful) dives during Biozaire 2. The ROV Victor 6000 deployed several tools developed by the scientists (of the Ifremer Deep sea Environment department, DRO/EP) in collaboration with engineers of Ifremer – Technology Direction :TMSI and DNIS) in order to sample the sediment for microbial and chemical analyses with tube cores and the macrofauna with blade corers. Both equipment have been adapted to be used with the ROV Victor 6000 from the prototype described by Sibuet, Floury et al 1988; to sample water near the chemosynthetic fauna with a 19 bottles array (PEP) fixed on the vehicle; and to sample megafauna; organism for taxonomic and biological studies

The discovery of chemosynthetic communities on active pockmarks with the ROV Victor on the Equatorial African margin revealed the co –existence of two types of benthic ecosystems based on trophic input originated from the photosynthetic production within the surface layers of the ocean and the other depending on local chemosynthetic production based on methane rich fluid emission and secondary sulfide production in the sediment.

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2.3- IRIS Cruise: Sampling and exploration on hydrothermal fields along the Mid Atlantic.

Chief scientist Y. Fouquet

The IRIS cruise was a continuation of research conducted on the Mid-Atlantic Ridge south of the Azores since 1992. Previous cruises in the area have shown 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. The purpose of the IRIS cruise was to conduct detailed work on the Rainbow field and continue the exploration of the ridge south of the Azores. 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 evidenced 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. Such reactions may be catalyzed by metals present in various ways in mantle rocks and hydrothermal precipitates. These phenomena can potentially lead to the formation of prebiotic molecules. The organic molecules produced are also the base 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 had bearing on the characterization of massive sulfide bodies formed by hydrothermal springs. The project 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 project was supported by the French program Dorsales.

During the cruise 16 dives were conducted and a distance of 121 km was covered on the seafloor during 195 hours. Victor 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 Nautilie the ROV was particularly efficient for exploration and survey. Victor allowed us to conduct a specific strategy to explore new targets and locate and map methane discharge on large surfaces of mantle outcrops. Mapping 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 with a CTD for in situ iron and manganese analyses and methane measurement. A 30 Km long survey (9 profiles with a spacing of 150m) was completed in two dives totaling 27 hours on the seafloor to map near seafloor chemical anomalies. A precise magnetic map of the hydrothermal field was also obtained during a 29 hours long dive during which a 27 km long grid (15 profiles) centered on the hydrothermal field were 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 three dimensions of the metallogenic, chemical and microbiological processes in the Rainbow hydrothermal reactor.

2.4- ATOS: Deep sea hydrothermal vents : a natural pollution laboratory

Chief scientist Pierre-Marie Sarradin

ATOS is the single oceanographic cruise of the European project VENTOX (EVK3-CT1999-00003) co-ordinated by David Dixon (SOC, UK) and gathering 10 English, Portuguese and French partners.

The aim of this interdisciplinary project is to carry innovative research into the specialised adaptations and processes found in representatives of the mid-Atlantic deep-sea hydrothermal vent fauna and its associated microbial populations under a potentially toxic environment. During this cruise, the French ROV Victor performed 19 dives (from 8 to 20 h on the bottom) on the hydrothermal fields Menez Gwen (37°51'N, 31°31'W, 850 m), Lucky Strike (37°17'N, 32°16'W, 1650 m) and Rainbow (36°13'N, 33°54'W, 2350m).

The cruise has combined in an integrated multidisciplinary approach : video observation, imaging and mosaicking, in situ analysis (using the in situ chemical analyser ALCHIMIST.), sampling for on board or on shore analysis

(organisms, water, substrate, particles using autonomous particle traps), in vivo experiments at atmospheric pressure or in situ simulated conditions. The strategy adopted was identical on the 3 studied fields presenting different depth, geological, geochemical and biological characteristics. The video recognition of known sites allowed to choose the working spots. These study spots were implemented with autonomous probes (temperature and pH) and subjected to small scale video imaging to determine the main faunal assemblages constituting the ecosystem. The chemical characterisation of the ecosystem at the micro habitat scale, in order to quantify the rates of exposure to various "toxic" compounds (sulfide, metals, CO₂, ...), was carried out using in situ analysis (*in situ* analyser ALCHIMIST, T/pH probe) and discrete water sampling. Finally, the organisms which environment was described were sampled and preserved for later analysis particularly to determine their temperature adaptation ability or metal bioaccumulation.

Concurrently, in vivo experimentations at ambient pressure or in situ simulated conditions (using IPOCAMP flow through pressure chamber associated to the chemical regulation device SYRENE) represented an important part of the on board work. The bivalve *Bathymodiolus azoricus*, present on the 3 fields studied, was the preferred experimental model. Experiments have been conducted on a variety of biological endpoints including blood physiology, animal behaviour and growth, DNA damage, and heavy metal bioaccumulation and toxicity.



In situ analysis using ALCHIMIST in a clumps of *Bathymodiolus azoricus*. Menez Gwen, ATOS, Ifremer©

A specific set of samples (water, organisms and substrates) was collected to isolate new extremophilic micro organisms or extremophiles able to act bio-transformations potentially useful for bio-remediation.

The mooring and displacement by Victor during the cruise on the Menez Gwen vent field of 6 acoustically retrievable cages filled with mussels allowed to carry on the experiments on alive organisms yet after the cruise in the land-based laboratory settled at Horta on the island of Faial (LABHORTA).

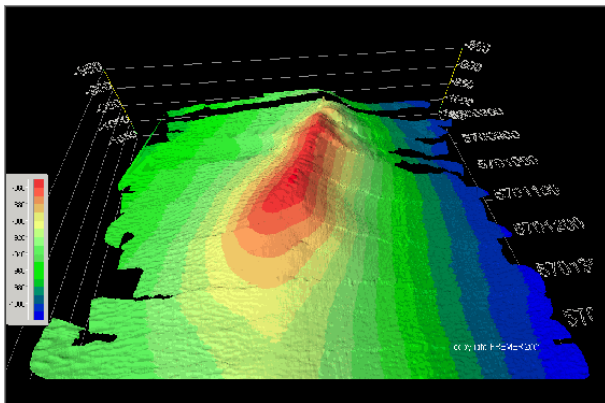
The French ROV Victor demonstrated during this campaign devoted to the study of the hydrothermal ecosystem an important working potential both speaking of its ability to work at the microhabitat scale to study the

mixing zone of hydrothermal fluid and seawater or the ecology or ethology of benthic invertebrates. Even though it has been designed for longer dives, it was proven efficient for short dives (12 hours) combining video observations, in situ analysis and sampling of fresh organisms for subsequent in vivo experiments.

2.5-CARACOLE Cruise

Chief scientist Karine Olu Leroy

Carbonate mounds and deep coral communities were explored during the CARACOLE cruise in the Porcupine Seabight and Rockall Trough, west of Ireland, following the last few years series of discoveries of spectacular underwater mounds (up to 300 m in height and 2-3 km in diameter) on the Irish Continental Margin. The European (France, Ireland, Belgium, Netherlands and Germany) and inter-disciplinary scientific team (biology, geology, microbiology and chemistry) included people working on mounds in several European projects (ACES, GEOMOUND, ECOMOUND). The objectives of the CARACOLE cruise were: i) to perform the first submersible exploration of these mounds and estimation of the extent, biodiversity, and spatial variability of these spectacular biological communities, ii) to understand the sedimentary environment and the genesis of the mound and their possible links with hydrocarbon seepage, iii) to compare these mounds and coral communities with those discovered off Angola (Biozaire cruise), and iv) to promote technique for video data to facilitate comparative studies. Finally the CARACOLE cruise had the opportunity to carry out trials of micro-bathymetry and sonar imagery by using SEABAT multibeam settled on VICTOR, and real-time video mosaicking systems.



Micro-bathymetry realised with the multibeam sonar SEABAT 8101.

Contact : Jan Opperbecke, Ifremer DNIS-SM-RNV.

Ten dives were performed at depths from 380 to 1000 m in order to explore different « geo- and bio-types » selected from surface data. 162 hours at the seafloor (mean of 16h/dive, from 8 to 32h) has provided video data (using a vertical colour camera) over more than 100 km tracks, and fauna, water and sediment samples. Observations during dives revealed exceptionally dense and rich biological communities dominated by corals (*Lophelia pertuasa* and

Madrepora oculata) and filter feeding species especially sponges and gorgonians. Motile fauna comprises echinoderms, and numerous fishes. An unexpected observation is that coral associated fauna differs largely between mounds. The communities cover large areas at some sites (mounds up to 500-1000 m in diameter) while they show much more patchy distribution on restricted area at other sites. These differences in fauna composition and coral community extent, as well as differences in mound topography could be explained by hydrodynamics. Indeed, active mound and intense coral development have been observed in regions of strong currents while inactive mounds are found in areas of enhanced sedimentation. Another result is that, contrary to the Angola margin, no seafloor (chemical, biological or geological) evidence of hydrocarbon seepage has been observed in the surveyed sites. Our observations suggest that mound formation could be rather explained by biological colonisation of the dropstones released by icebergs (observed on the seafloor), and active growth of corals by hydrodynamics. An important fact is that framework-constructing corals appear essential for the formation of mounds.

Trials of a new “module” on Victor including the multibeam sonar Reson Seabat 8101 (for microbathymetry and acoustic imagery) and a vertical camera with two HMI lights were realised during two long-time dives during the cruise by two engineers of Ifremer. Very accurate bathymetric maps have been obtained on two mounds on areas of 600*700m and 1000*700m with a metric horizontal and a decimetric vertical accuracy (Figure). Sub-metric horizontal accuracy was obtained on 50*50m areas, together with colour optical imagery. These maps evidenced for example ripple marks along some flanks of the mounds related to higher faunal abundance, and at some places trawls impacts between corals. Acoustic sonar images were recorded simultaneously to bathymetry over several km profiles. Optic mosaics were obtained using the MATISSE software developed at Ifremer and geo-referenced with Arcview GIS on three small areas of 50*50m in order to study micro-distribution and density of the different species.

2.6- Arctic deep sea biodiversity and methane seepage at a high latitude mud volcano

Chief scientist: Michael Klages

During the cruise leg "AWI", two areas of scientific interest were investigated in the northern North Atlantic. The first site was a deep sea observatory (79 ° N 004 ° E; 2500 m water depth) where long-term programmes were initiated in 1999 to identify factors and processes governing high biodiversity in Arctic deep sea sediments. The second area was the Håkon Mosby Mud Volcano (72 ° N 14 ° E; 1300 m water depth) northwest of Norway. The Håkon Mosby Mud Volcano (HMMV) of the Barents Sea continental margin is one of the deepest and coldest sites of the world ocean where methane seepage takes place. Microbiological sampling, microbial methane turnover rate measurements and complementary geochemical investigations were performed on surface sediments and

bottom water. Access on the ROV "VICTOR 6000" was the basis for most of the intended work at both sites.

Advanced techniques of the "VICTOR 6000" system like the mosaicking of digital video signals were used, for example, estimating deep sea demersal fish abundances along transects. Sediment samples were taken with the manipulator arms of the ROV at defined locations of the long-term station, e.g. areas with high degree of biogenic structures versus less structured areas. Samples for geochemical characterisation were also taken to investigate the geochemical milieu within the surface sediments. This information is valuable to understand faunal species composition, distribution and abundances in the deep sea environment. For this purpose an *in situ* microprofiler was deployed by means of "VICTOR". This microprofiler was newly designed to be (re)placed and activated by the ROV, after having been transported to the sea floor by the shuttle lander (ascenseur). The system consisting of a profiler unit (vertical resolution up to 0.1 mm) which can be equipped with up to 8 microsensors for O₂, H₂S, pH, and resistivity, a deep-sea power supply and syntactic foam blocks for weight compensation. By a special switch "VICTOR" can initiate a profile measurement. After the measurement has been finished, the profiler unit can be transferred to another place and re-activated by the ROV for further measurements.



The sediment surface is covered with white mats of sulfide oxidizing bacteria (probably *Beggiatoa*) sampled with a tube corer. HMMV, .AWI cruise, Ifremer©

At the HMMV, having a diameter of about 2 km, with an outer rim populated by methane-depending, chemosynthetic communities and an inner centre of about 500 m diameter where fresh muds are expelled, video transects were carried out first to get an impression about the topography and the distribution of benthic communities. Between the central plain and the outer rim, a complex topography of hills and depressions was found which is derived from the transport of young sediments. For the purpose of the studies in 2001, some key locations (centre of the HMMV crater, the south and southeast of the crater and the surrounding area) were selected and sampled with nearly all instruments and techniques available at the ROV as well as with the multiple corer.

3. Victor 6000 scientific evaluation and future outlook

The French ROV Victor demonstrated during this first year of intensive use an important working potential both speaking of its ability to work at the microhabitat scale to study the ecology or ethology of benthic invertebrates and its performances in exploration or survey operations. Even though it has been designed for longer dives, it was proven efficient for short dives (12 to 28 hours) combining video observations, *in situ* analysis, sampling and deployment of moorings.

The trials of the new "module" including the multibeam sonar Reson Seabat 8101 (for microbathymetry and acoustic imagery) and a vertical camera with two HMI lights allowed the obtention of very accurate bathymetric maps obtained on two mounds on areas of 600*700m and 1000*700m with a metric horizontal and a decimetric vertical accuracy .

In the next decade, the VICTOR 6000 will remain a major element of French equipment dedicated to deep underwater intervention. In this context, its use will generate a dynamic prospective vision of future needs and technological progress, taking into account the experience gained during sea campaigns.

VICTOR operations will be stopped for a maintenance check up at the end of 2002. As a complement to current maintenance work and small evolutionary changes, it is planned to open transmission abilities, essential for future developments. This important modification will allow to increase significantly the system capacities, and in that way, answer to already identified needs (video and sensors) as well as future needs. A particular effort will be made to improve VICTOR's potential in the imaging field, integrating digital mode and technical progress (digital colour photography, black & white vertical imaging, direction towards high-definition television, image measuring tools for quantitative analysis and surveys).

Today, VICTOR is proposed to users with a "basic sampling module" efficient for local interventions on the seabed. It can also carry out survey missions to an altitude of 3 or 4 metres. A second module called "on-path measuring module" may be developed and dedicated to automatic on-profile data acquisition at a scale ranging from one acre to one square metre. This module, staying also a platform receiving optional measuring and sampling instruments, would integrate functions as microbathymetric data acquisition, long-range optical data acquisition, basic physical and chemical parameters acquisition.