Project contract no. 036851
ESONET European Seas Observatory Network

Instrument: Network of Excellence (NoE)
Thematic Priority: 1.1.6.3 – Climate Change and Ecosystems
Sub Priority: III – Global Change and Ecosystems

Project Deliverable D75

COMPILATION OF DEPLOYMENT PROCEDURES OF THE DEMONSTRATION MISSIONS AND CONCLUSIONS FROM THE RECOMMENDED PRACTICES

Due date of deliverable: month 4
Actual submission date of report: May 2010

Start of project: **March 2007** Duration: **48 months**
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Work Package 2
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Revision [31st May 2011]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	x
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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EXECUTIVE SUMMARY

The FP6 project *European Seas Observatory NETwork (ESONET)* has launched six demonstration missions on 7 sites and one test experiment on 4 sites. The selected demonstrations missions have been performed by skilled teams having a large experience of sea operations. They used existing procedures and innovated on others in order to face the specific matters of subsea observatories.

Various ships were used, mostly from the oceanographic fleet. Their schedule was very difficult to set up. The use of dynamic positioning for the vessel and ultra-short base line for the sea-bed equipement are recommended for optimized use of ship time.

Several designs of subsea observatories were demonstrated. The differences come either from former decisions of the institutes, or from specific requirement of each Esonet site.

Four standalone designs were demonstrated, three innovative moorings were tested. This brings several recommendations for the future: energy saving, redundancy, acoustic data transmissions, buoy design, ...

Deployment procedures are evolving from free fall to cable lowering. The positionings during the demonstration missions and test esperiment have been very accurate. The experience of Esonet allows the duration estimation for the deployment of subsea observatories (see table 2).

ROVs operations were prepared by WP2 of Esonet. Recommendations have been issued, especially regarding connection/disconnection procedures.

Tens of sensors were implemented on the seafloor. The procedures include installation, tuning, *in situ* calibration. Few cases of recovery and exchange were performed, as most sensors are still operating at the end of Esonet NoE.

Several of the recommendations of this report are included in the Esonet Label and will be updated with the Esonet Label document in the future (Esonet VI and EMSO). It is very valuable to share at sea experience, either good or bad.

1 - INTRODUCTION

1.1 Activity at sea

The main objective of ESONET NoE is the long term deployment of subsea observatories on fixed sites of interest. As the target sites are in the deep sea, the sea intervention means are crucial.
The most innovative and specific aspects have been addressed by ESONET NoE as a major standardisation issue in WP2. Nevertheless, most of the necessary ships, ROVs, equipments and associated methods are the result of decades of oceanographic efforts, funding and establishment of associated human professional skills. This large knowledge and know-how has been intensely used but not directly addressed by ESONET NoE.

This deliverable compiles corresponding achievements and opens a discussion on the practices. The tentative recommendations issued from the ESONET Experience (six demonstration missions on 7 sites – Deliverables D45 - and one test experiment on 4 sites – Deliverable D59) are either directed to ESONET Label activity or to input for EUROFLEETS, OFEG and similar oceanographic fleet initiatives.

1.2 High seas and coastal

The depth is an important parameter for ship and underwater intervention. Two coastal cabled observatories have been used for ESONET Test experiments: Koljofjord in Sweden (45m water depth) and OBSEA in Spain (20m waterdepth). They were serviced by diver and to many respect, the sea intervention methods are not relevant for comparison. They were very useful for the ESONET Community to experiment cabled observatory technologies. Some results are also valid for deeper sites.

The Koeri seismic cabled observatory has been deployed by two ESONET NoE partners, KOERI and GURALP in the Marmara Sea. They have not used ESONET budget for that purpose but this experience, although not multidisciplinary, is worth being examined.

1.3 Demonstration Missions organization

Two Calls for Demonstration Missions were opened during the ESONET project. The first one was launched in May 2007 and closed in October 2007 and the second one was launched in September 2008 and closed in November 2008.
Four proposals were selected during the first call and two proposals during the second call.

The sea operation capabilities were a criteria for the choice between the competing proposals which were submitted to international experts, most of them experienced in subsea observatories.

Call	DM Name	Coordinator	Start date	End date Planned/actual	Partners involved
First Call	LIDO	Universitat Politècnica de Catalunya (E) Michel Andrè	01.09.2008	31.08.2010 28 02 2011	KDM-UniHB, INGV, ISMAR, INFN, Tecnomare, FFCUL, CSIC, UPC, BHT-Berlin, DBSCALE
	LOOME	Max Planck Institute -MM (D) Dirk de Beer	01.02.2008	31.12.2010 28 02 2011	KDM-AWI, KDM-IFM-GEOMAR, KDM-UniHB, KDM-MPIMM, Ifremer, UIT
	MARMARA-DM	Ifremer (F) Luis Geli	01.04.2008	30.09.2010 28 02 2011	Ifremer, CNRS-Cerege, INGV, ISMAR, ITU, DEU-IMST
	MOMAR-D	Ifremer (F) Pierre-Marie Sarradin	01.09.2008	31.08.2010 28 02 2011	Ifremer, UAC, FFCUL, IPGP, NOCS, CNRS-LMTG, CNRS-IUEM, KDM-UniHB, SOPAB
Second Call	AOEM	National Oceanographic Center Southampton (UK) Ian Wright	01.07.09	31.10.2010 28 02 2011	KDM-AWI, KDM-IFM-GEOMAR, FORTH, NERSC, NOCS, UIT
	MODOO	IFM-GEOMAR (D) Johannes Karstensen	01.05.09	30.09.2010 28 02 2011	KDM-IFM-GEOMAR, NOCS, IMI, NIOZ, UniABDN, KDM-AWI

Table 1 - Demonstation Missions

All the Demonstration Missions had very accurate sea intervention plans. But the practice in this field is difficult and all of them suffered (and overwhelmed) deviations. This will be addressed topic by topic in the present document.

2 - SHIP AND CRUISES MATTERS

2.1 Ship requirements

Several ships have been used in ESONET Demonstrations Missions.

- Cable ship from MECMA consortium, have been used by INFN for the LIDO and the SN1 site test experiment. They were used also at Capo Passero

Ship: C/L Certamen

- A working vessel was used at the Antares test experiment site for site preparation

Ship : Castor

- Most experiments used Oceanographic vessels

R/V Maria S. Merian
R/V Pourquoi Pas?
R/V Le Suroit
R/V Sarmiento De Gamboa
R/V Poseidon
R/V Urania
R/V Jan Maien
R/V James Ross
R/V Polarstern

- A fishing vessel was used by Kolofjord

The dynamic positioning is needed for an efficient work on the sea bed. When available, ultra-short baseline enabled a very precise positioning on the seafloor.

As a matter of fact, the cruise of deployment and the cruise of recovery are excellent opportunities to refine the survey.
In MARMARA DM, each cruise brought additional soil and sediment mapping. The capability of gas mapping was increased at each cruise. A specific data processing is now available and will continue on a 2011 dedicated cruise.

In LOOME, the additional survey by the AUV Sentry of Woods Hole Oceanographic Institute brought additional insight to the investigation of the mud volcano, especially with the exceptional methane mapping.

2.2 Ship availability

As the problem of ship availability is well known from the experienced ESONET members, a special concern was forseen, it has been one of the reasons of the initial constitution of a “Test and Operation” council.
Nevertheless, ship planning has been a major difficulty.

MoMAR-D
The visit by oceanographic vessels is very regular at MoMAR site. It makes it a very attractive hydrothermal vent study site, extremely well surveyed. It was a good argument, in addition to science for the success of the Demonstration Mission proposal for the first call with an excellent rating . Anyway, after the success of the benthic station deployments of EXOCET/D FP5 funded project, the ship planning has not allowed a MoMAR-D deployment with Victor6000 ROV during the first year of the DM in 2009. ESONET committed partners had to wait until end of 2010. The recovery was planned inside the DM, it will be performed instead in mid 2011.

Cadiz site of LIDO
The first cruises were part and followed the Nearest project operations. The recovery cruise planned in 2010 could not be performed. Even if there were no data coming from the sea floor, data is most probably acquired and stored ; it means that partners are eager to download but the planning of the cruise could not be advanced before June 2011.

Marmara DM
The access to ships suffered some limited delays of planned national vessels from France and Italy. It was compensated by cruises with Turkish vessels.

LOOME
The ship time for LOOME was available as planned. For the recovery, the oceanographic ROVs were not available. An ROV had to be rented, involving more expenses than planned.

AOEM
Ship time allocation postponed also the AOEM completion. A cruise proposal was submitted to Norwegian agencies for the 2010 lander deployment, but was unsuccessful. Due to changes in the safety regulations aboard a research vessel, the work plan was adjusted so that a lander systems was modified for use in MASOX and this system was deployed by NOCS staff and their partners in Fall 2010. The system will be recovered in summer 2011 and analyses of the data and system performance will follow.

Safety requirements
Due to a fire induced by a lander on board a Norwegian ship, the AOEM operations had to be changed.

2.3 Recommendation

The experience of INFN during the last 4 years at SN-1 and Capo Passero sites and the repair of Antares in 2007 are showing the interest of agreement with MECMA or ACMA for the access to cable ships.

The possibility to use either MECMA Vessel or oceanographic vessel at NEMO site (LIDO DM) and either working ship Castor and oceanographic vessel at Antares site (Test Experiment) provide more operation opportunities.

The access to Oceanographic vessels is restricted by the tenders issued each year for the national oceanographic fleet programming. OFEG consortium helps the sharing of ship time and EUROFLEETS I3 project is building the conditions of a large integration of the European oceanographic fleets . The ESONET consortium should establish agreements with ship owners to program periodic visits of subsea observatory sites. This might be a mandate of EMSO ERIC.

Dynamic positioning and accurate positioning such as ultra short baseline are needed to operate subsea observatories.

The ship capacities must be checked such as the height of the A Frame (see LIDO with MODUS) or crane size and capacities. Security rules must be fulfilled on board, they need to be documented and explained during the cruise preparation.

3 - DESIGN OF SUBSEA EQUIPMENTS

3.1 Architectures

Several architectures have been demonstrated during ESONET. As the project has not provided funds for new equipments, most of them had been designed beforehand.
Stand alone concepts were demonstrated at MoMAR, MODOO,
Landers were used at LOOME (ROV positionned) and AOEM.
Cabled observatories were demonstrated in LIDO and at test experiment sites (OBSEA, SN-1, Antares and Koljofjord).

3.2 Technical choices due to specifications

- Underwater protections are used against trawling and ship anchors.

The choice of Koeri and Guralp was to protect by a concrete cap. The deployment was performed by a working ship in the Marmara sea.

In the Arctic, an antitrawling protection is used by AOEM Demonstration Mission.

Concrete cap protecting the Guralp seismometer

AOEM steel trawl protection of the subsea node. The cap is also concentrating fluid fluxes, holes are allowing current measurement.

- Electronic architectures are more or less modular.

Some manufacturers are providing dataloggers with sensors already interfaced.
The choice of modularity was experienced in LOOME and MoMAR with “Costof” electronics using an internal Can bus. It was also experienced in LIDO and MARMARA DM with the “DACS” of SN1 and SN4.

The Devologics technology, in MODOO, also associates the acoustic Modem with the datalogger. It led to a long checking and debugging procedure during the deployment.

3.3 Ship and ROV logistic requirement

The requirements are not the same for all subsea observatory operation, but the principle of check list is similar.

Exemple – SN1 GEOSTAR (*ref. LIDO Deliverable D1.4*)

a) manage deployment operation
b) manage all operations on deck , involving lifting , positioning and handling of the whole observatory (with or without MODUS) and parts of it
c) provide adequate space on deck for the final integration of GEOSTAR (*stand alone observatory*)(24kN –3.584 m x 3.584 m) and MODUS (*mobile docker*)
d) provide adequate internal space to install and operate MODUS control unit
e) provide adequate storage area for boxes , crates etc .
f) carry out a detailed survey of the area identified for GEOSTAR deployment, to determine exact bathymetry and characteristics of the seafloor (slope, absence of obstacles)”

3.4 Buoyancy

The lander systems used buoyancy.
Glass sphere buoyancy was used by MODOO. The implosion of one glass sphere has probably induced the implosion of several of them, the lander was lost. The spheres were rated for more than 6000 m water depth. The energy of the shock wave transmitted to the neighbouring equipment is large at 4000 m water depth at Porcupine site. Experimental studies were performed by Antares consortium and under KM3Net Design Study project.

The deployment of syntactic foam buoyancy equipments during the Demonstration Missions brings no comment. Previous experience for instance on NEMO site show that a preliminary test of the floats is needed.

During MoMAR DM, all the buoyancies were syntactic foam. The buoyancy floats are grouped on structures, moored to the benthic station, they are used to constitute neutraly buoyant lines easy to position by the ROV. When the position is reached, the buoyancy is released. The release was performed by VICTOR 6000 during MoMARSAT cruise during its last dive.

The BOB (Bubble OBservatory Module) deployed in Marmara Demonstration Missions has a syntactic foam buoyancy integrated in the lander.

3.5 Recommendation

The Demonstration Missions provided input to several topics of the ESONET Label such as: limitation of the use of glass spheres, need of tests on buoyancy floats,...

The relations with subsea equipment providers is easier in a modular design where functions are separated (exemple of data logger and acoustic modem). It is easier for debugging and spare part management. This must be balanced with the drawback of having more containers and more connectors.

Stand alone observatories rely much on batteries. A best practice exchange of data is recommended between users of battery packs. MoMAR DM is probably limited (SEAMON EAST node) by a battery problem. Such a problem is reported during the LIDO recovery in 2009, it was due to a capacity derating induced by lower temperature (2°C) in Gulf of Cadiz waters than in the Mediterranean Sea (13°C).

4 - MOORINGS AND BUOYS

4.1 *Mooring deployments*

The moorings participating to the multidisciplinary subsea observatory experiments have to be extremely well positioned. They must not interfere with the seafloor equipments and need to support an acoustic telemetry. The best way to deploy was discussed in several Demonstration Missions.

The mooring is inserted in the subsea observatory system referenced from the seabed. The positioning of the line and of the deadweight must not interfere with other equipment. This is true:

- for the mooring of the relay buoy of an acoustic stand alone observatory (LIDO Cadiz, MoMAR),
- for the mooring ensuring the upper segment of observation near a seafloor based bottom station and line (MODOO concept),
- for the mooring line extending the capacities of a cabled observatory (Albatross line extending Antares earth-sea science extension).

This question was perfectly analysed by the MODOO team as expressed in the text below (*See MODOO deliverable D2.2*).

The primary concern of all those present was to deploy and test equipment in a phased manner, ensuring that the risk of damage to either the mooring or the BOBO lander was minimized. The deployment of the Met Office buoy presented a challenge in itself in that the water depth at the PAP site is 4800m, the deepest water a UK Met Office buoy has been deployed to date. There were issues around how to test communications between the lander and the mooring and the synchronization of deployments between the two. The distance between the lander and the location of the anchor of the PAP mooring was also critical to ensure efficient communications between the two.
The National Geographic team also had a number of requirements regarding timing and order of deployments as they planned to place a drop camera on the BOBO lander.

Deployment Scenario 1

1. Place the buoy into the water first, then the frame, feed out the rope and chain and add the anchor last.
2. Then the lander can be deployed.

Problem: The acoustic receiver will be located within the instrument frame on the mooring – therefore no communications testing or adjustments can be made to either system if the lander is deployed after the mooring.

Deployment Scenario 2

1. Deploy the lander (freefall) to the seafloor (takes ~2 hours).
2. Test the acoustics by hanging the modem over the side of the vessel on a platform. In this case, the megacorer is being used as a platform for the modem receiver to give stability and weight to the system. Testing can take place while the lander is descending.
3. Triangulate the position of the lander using the landers release units. During triangulation the modem can also be used to define the distance the mooring needs to be from the lander for efficient data transfer. Modem testing is expected to take an additional 2 hours.
4. If the system works, place the receiver in the mooring and deploy the buoy, mooring and anchor as per deployment scenario 1 above.

Problem: Potential risk to the lander by deploying the mooring and anchor after the lander. Also the distance between the two may not be optimal for communications purposes. It will need to be tested.

Deployment Scenario 3

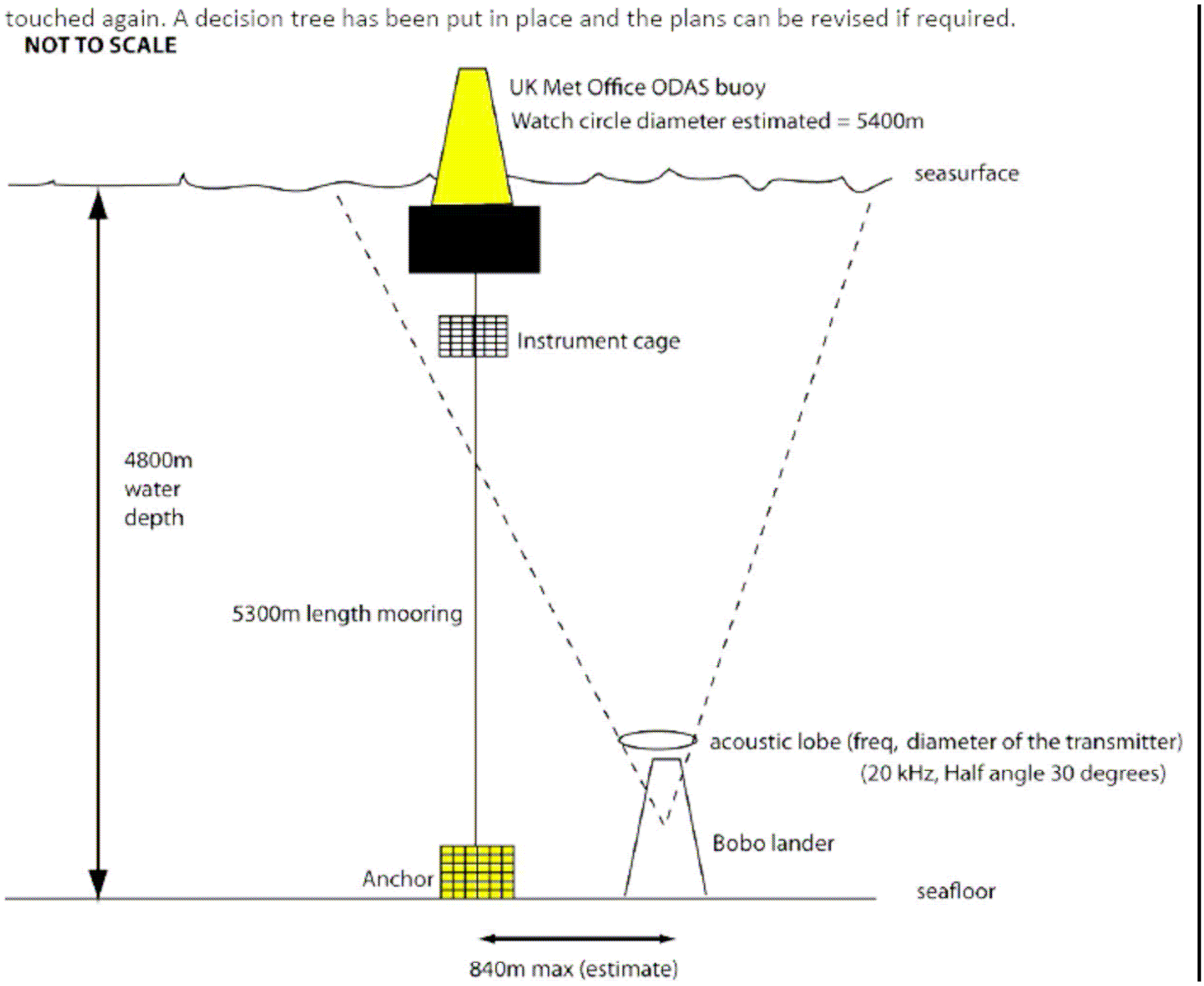
1. Deploy the BoBo lander on a wire with a USBL and hang the acoustic receiver on another winch over the side. If communications are not confirmed, then it is a very straight forward matter to recover the lander quickly for additional modifications.
2. Deploy buoy, mooring and anchor as per deployment scenario 1.
3. Deploy the lander again.

Problem: Two wires are out. The final lander communication cannot be tested.

The decision was taken to try deployment scenario 2 as it appears to provide the most flexibility. After the lander with the LDCD node (lander modem) has been deployed the MDCD node (Mooring) is still on board – and can be used to test the lander modem and instruments performance. If initial testing is not successful, possible lander recovery permits more detailed investigations to take place.

In particular determining the maximum distance to which one can go away from the lander is of importance as it determines the maximum distance at which the mooring can be deployed later. The watch circle of the mooring has been estimated to be 2700m - that is 5400m diameter, water depth 4800m - that is 7225m maximum distance if lander is placed at the anchors position.

In case all systems working fine, and that the mooring deployment is in the vicinity, the lander need not be



touched again. A decision tree has been put in place and the plans can be revised if required.

Schematic of MODOO installation – UK Met Office ODAS buoy (PAP observatory)

During the MODOO Azores deployment (Poseidon Cruise), the precise deployment of the two mooring lines was achieved thanks to a “deadweight(anchor)-first” procedure. When all the subsea components were in the water, the deep sea wire of one winch was connected to the top float with an acoustic release so that the mooring could be lowered very close to the seabed. At a distance of 50 m between the anchor and the seabed, and with the vessel being precisely at the deployment site, the upper release was opened, thus allowing the mooring to sink to the seabed. Subsequently, the actual mooring location was determined precisely by acoustic triangulation.

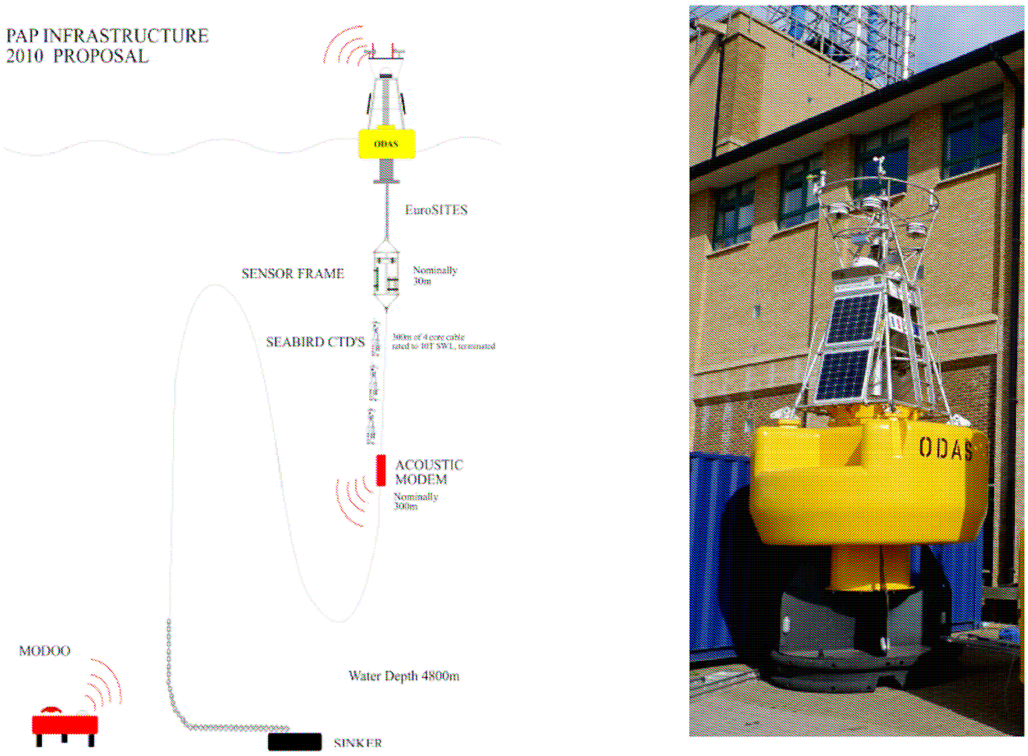
The accuracy of positioning depends on the method of deployment andof the ship positioning system. R/V Sarmiento de Gamboa positionned SN1 in the Gulf of Cadiz, on 6th November 2009,with an uncertainty of 258 X 128 m, the water depth was 3187 m.

4.2 Buoys

Buoys have been used during the Demonstration Missions (MoMAR, LIDO and MODOO).

- When operating in the Gulf of Cadiz, the LIDO buoy failed. This sad experience of LIDO in the Gulf of Cadiz in 2009 has been analysed in the TECNOMARE report (See *LIDO deliverable D4.1*). It comes from a lack of bending stiffener at the intersection between the buoy and the umbilical. Such devices must be designed and manufactured by skilled designers and manufacturers.

- The "PAP mooring" deployed by MODOO



Sketch of the PAP mooring as planned for the MODOO deployment(left). The PAP surface telemetry buoy at the NOC,S yard (right).

The position of the Acoustic modem is rather low along the line (–300 m). The EuroSITES oriented upper level of the mooring line is using inductive link. It hosts CTDs communicating with the surface logger in the ODAS type of buoy.

- The Borel buoy is transmitting data from MoMAR site.

The Borel buoy was moored North of the lava lake. © Ifremer MoMARSAT2010

The Borel buoy was deployed at mid cruise, within acoustic range of the 2 nodes. The position of the buoy was chosen to optimize the acoustic transmission and to minimize the constraints for the ROV dives.

Two deployment procedures are usually applied (discussed in the MoMAR context)

1. Classical procedure

The ship is positionned 1.5 miles leeward from the targetted point. The buoy is launched at sea by A-Frame. The line is paid out while the ship slowly directs to the target point. The speeds are tuned in such a way that the target point is passed shortly (15 mn) after the end of the line pay out (1712 m). When the whole line is out, the deadweight is craned by the A-Frame, ready for release by cutting a rope. When the ship passes 280 m after the target, the release order is given. The ship stays in the vicinity to observe the route of the buoy during descent and then its position is noted once stabilized.

2. Procedure bringing possibly more precision to the deadweight positionning.

The deadweight is hung to the deep sea line by an accessory line of 15 m, followed by an ultrashort baseline (BUC) release.

Deadweight ----------- BUC Release--- … ----- SHIP

The ship moves 2.5 miles leeward of targetted point. Le navire se rend à 2,5 milles sous le vent du point cible. The buoy is launched at sea by A-Frame. The line is paid out while the ship slowly directs towards the target point. The speed of the ship and the pay out speed are tuned in such a way to reach 1 lie leeward distance from target point when all the line is paid. Launching of the dead weight, of the 15 m line and of the ultra short baseline (BUC) release. Pay out of the Oceano line at low speed, checking the position in x,y,z of the release. Tune the ship speed and pay out speed in order to bring the deadweight at 30 m altitude (45 altitude of BUC release) before the target point is reached.
Stop pay out when the deadweight has reached 30m altitude. Keep on at low speed and give the order of acoustic release when the deadweight is at the vertical position of target point. Note the position.

4.3 Acoustic transmissions

MODOO DM performed acoustic transmission tests in August 2010, as a compensation to the lack of transmission after the loss of BOBO lander in May.

AOEM ARCOONE made an overview of the potential manufacturers of acoustic modems (See *AOEM Deliverable D9*). The field test conducted in 2010 are following previous experiments performed since 2007. It addresses the **horizontal** data transmission between mooring lines. The modems, positioned at 800 m water depth, are moored across the FRAM straight at water depth ranging from 1400 m to 2400 m. The range between moorings is 30 km. The HAM.NODE (modems from Devologics GmBH) are using n-mFSK (multiple frequency-shift keying frequency hopping) , 2.5-5 kHz carrier frequency with 150 bps/handshake, 1800 Wh battery/12 months between service. The results of 19% transfer success based on sent and received packets is expected to be enhanced.

In ESONET, a dedicated intercomparison and selection for **vertical** acoustic telemetry was performed . After a first selection of modems by considering their technical specification, five modems were deployed for short term trial at 2200 m for 2 weeks. Then the best two modems (Evologic and Sercel) were deployed off Nice for testing the acoustic link between the seafloor and surface buoys. This is reported in deliverable D57 and conclusions participate to the recommendations stated in the ESONET Label Document (D68). The conclusions of D57 were used by Ifremer for the MoMAR-D demonstration mission.
These conclusions are:

- Vertical communications (max angle = +/- 45°)
- Bi-directional comms, mainly from bottom to surface
- Working duration without human intervention = 2 years
- Max sleep mode power * = 30 mW
- Max transmit power = 70 W
- 12 V < Power supply voltage < 30 V

A maximum energy efficiency (bits / J) is sought:

$$\text{Energy efficiency (bits / J)} = \frac{\text{quantity of correctly transmitted information (to the surface)}}{\text{spent energy (on the sea bottom)}}$$

On the hydrothermal sites, the experience of vertical data transmission is a quite ancient practice of Ifremer (SAMO in the 90’s), it was then a transmission to the ship from the benthic stations. The MoMAR Demonstration Mission experienced a stand alone acoustic system on the Lucky Strike site.

Less than 20mJ per bit is achievable for 2500 m waterdepth (45° angle). For a specific distance, this energy efficiency must be the major criteria towards the acoustic modem manufacturer. (conclusion for ESONET Label)

4.4 Recommendation

Deployment and recovery of buoy deep mooring can be implemented by medium size multi-purpose vessels that have sufficient space on deck, handling system with high clearance and lifting capabilities up to several tons for the buoy and its mooring, and dynamic positioning possibilities. There are no standards for this operation. A good positioning of the deadweight on the seafloor is mandatory.

Recommendations on the acoustic telemetry are addressed by the ESONET Label document.

5 - POSITIONING AND DEPLOYMENT ON THE SEA FLOOR

5.1 Cable

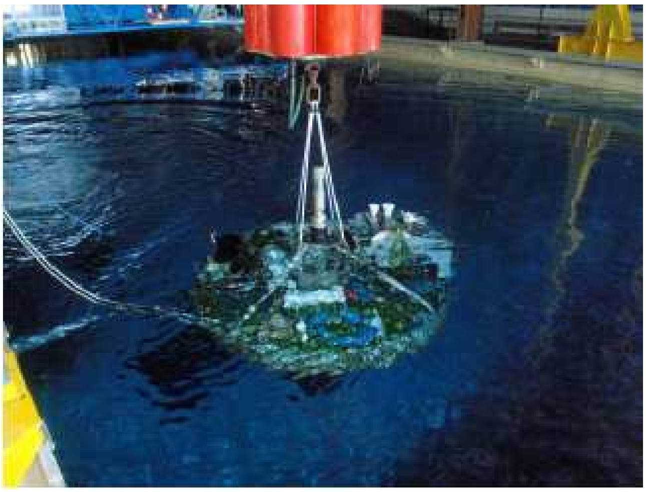
With the positioning precision of the latest generation of large Oceanographic vessels, it is possible to deploy from a crane or A-Frame directly with a cable.

In AOEM, the observatory (modified FluSO – fluid flow seabed observatory) was deployed with the starboard crane on RV Jan Mayen at 389 m waterdepth.

Launch of AOEM observatory from RV Jan Mayen of the University of Tromsø

In the future, all the methods and procedures planned for the equipment deployment should be completely presented and detailed in a ***Deployment document*** ; although they exist under a form or another, all the ESONET DMs have not reported on such document.

While Ifremer is used to launch its benthic equipments by free fall with synthacic foam buoyancy, in the MoMARSAT cruise (MoMAR DM), it was decided to approach the seafloor by hanging to a cable, the structure with attached buoyancy. The buoyancy was released during the last dive of VICTOR 6000.



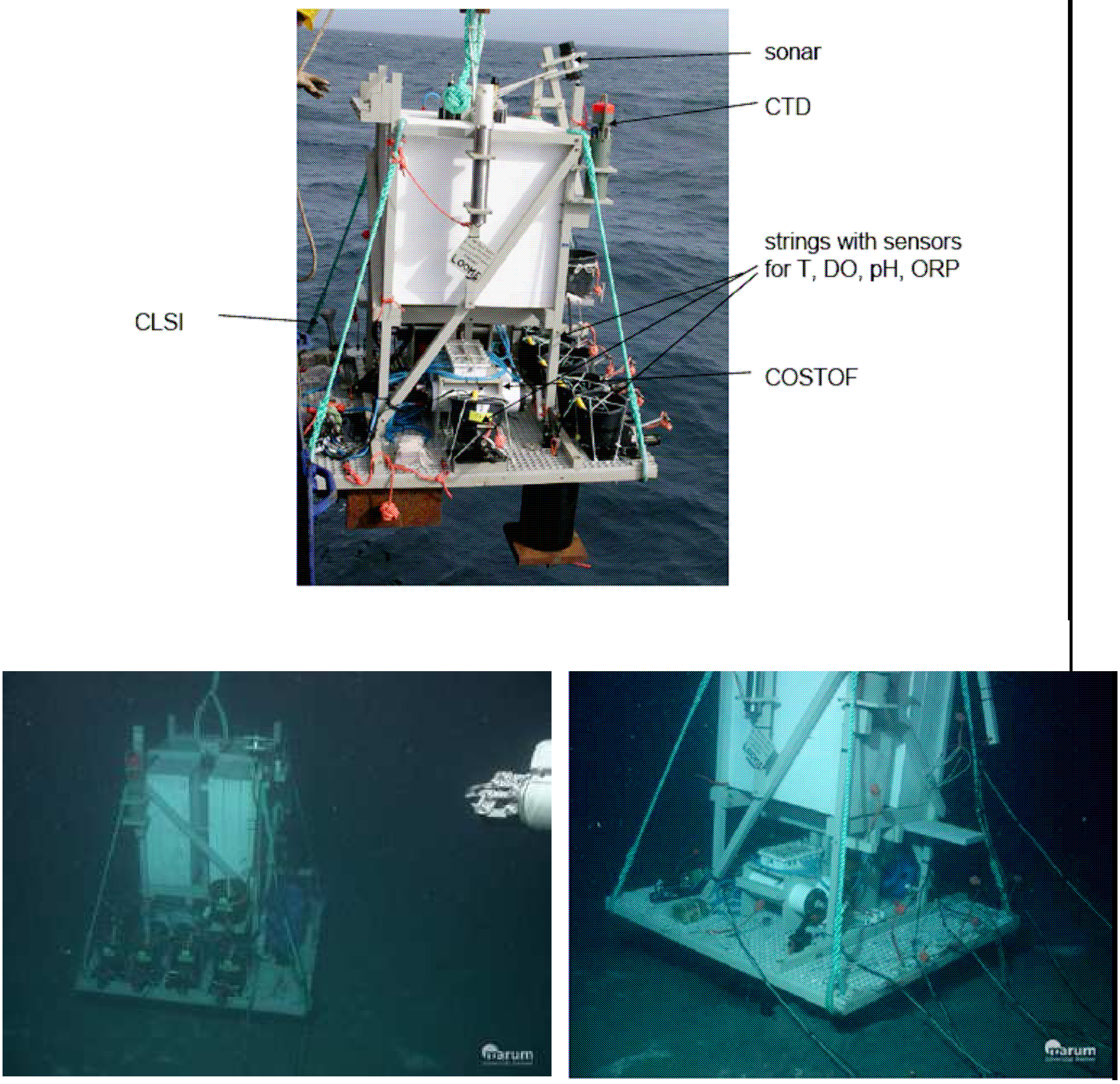
Basin test of SEAMON station with associated buoyancy pack. This pack is released when the station is positioned by the ROV.

The first result of the cruise was the validation of the deployment procedure used to deploy the different components of the observatory. The 2 SEAMON nodes and the geophysics module were moored using the cable of the vessel. They were equipped with an additional buoyancy to reach a weight of ca 40 kg in water. On the bottom, Victor performed the precise deployment and connection operations.

For Marama DM, a similar deployment approach was used for the BOB (Bubble OBservatory module) lander . A cable was used to hang the BOB over the targeted site. It was released from that position and had a free falling course of 15 m.

In the LOOME deployment cruise, the procedure was also to release at a reduced distance from the seafloor the hanging lander. It was absolutely necessary in order to position the prototype observatory at the verge of the soft part of the mud volcano.
report:

- The central frame of the LOOME prototype observatory was ballasted with an additional weight of 100 kg to allow for a deployment by winch from board POLARSTERN. The overall weight in water was brought up to 175 kg.
- 20 m above the seafloor the frame was released by an acoustic releaser
- The frame reached the seafloor at about 60 m distance north from the actual planned position
- The QUEST ROV from UniHB/MARUM was deployed to relocate the frame
- With the aid of an acoustic beacon the frame could be localized by the ROV
- The 100 kg ballast weight was removed
- After the that the ROV relocated the frame to the desired position within +/-1 m
- The frame was rotated so that the attached scanning sonar was aiming at the hot spot
- After that 8 sensor strings were laid out by the ROV which implemented also the other sensors (*see paragraph 8).*



LOOME DM prototype observatory

5.2 Free fall (launching and recovery)

Free Fall Mode (FFM) of neutral or almost neutral equipment

The following recommendations are kept as ESONET Label item:
The deployment of a neutral equipment could be done in free falling mode (FFM). Because the landing point is not precise, it could be necessary to use a ROV in order to horizontally translate the equipment to the right position afterwards. This technique is well adapted when the weight and displacement in water are moderate, typically less than 50 daN (depending on the vehicle).

In this case, a "two cables operation", when ship captain agrees, may induce shorter intervention time.

Acoustic positioning system, sonar and by end optical means are highly recommended for these operations.

For small equipment, a direct deployment by ROV or dynamically positioned power pod is also possible.

BOB lander was recovered by free buoyancy release.
Free fall is used by several operators. Ifremer uses to send equipment to the deep sea prior to their use or positioning by the ROV. We see from ESONET Demonstration Mission that this method is less used when a precise positioning is needed or when a risk exist of touching another equipment (reference to "busy" MoMAR site).

5.3 Mobile docker (MODUS)

The MODUS mobile docker, designed by the University of Berlin has been the reference technique of the GEOSTAR I II and ORION projects. The comparison with ROV operation was discussed in the technical deliverable of ESONET CA. The procedures are very precise and well established, especially from R/V Urania.

The recovery operation of the NEMO-OnDE and SN1 station in April 2007 is the reference experiment of the whole procedure of LIDO on cabled site (*ref. LIDO Deliverable 1.1*). It required an ARGUS light work ROV class Deep Sea ROV, the MODUS and the GEOSTAR-class observatory with the auxiliary cable and winch.

Left - The ARGUS ROV on board of the C/L Certamen ; right –MODUS vehicle.

5.4 Downlink cable laying

Concerning long cables deployment (>some tens of metres) between an equipment and some remote instrument sites, scientific institutions have now developed tools and procedures for first operational experiences. They are based on two generic solutions:

- deployment of a special drum sent from the surface in FFM and manipulated by a ROV (ESONET Test experiment on Antares site);
- direct use of a dedicated toolsled on the ROV.Examples can be found in documents describing MBARI *Mars* installation (Tibuton), Neptune Canada undersea observatory (Ropos) or Donet Japan (Hyper Dolphin). For more details, please see presentations during Esonet meetings.

5.5 Training and standards

(from ESONET Label document)

- Prior to deployment, rehearsal in dry conditions are recommended (*reference to D51 Training and simulation manual*).

ESONET Deliverable D51 provides the scientific users and operators with design recommendations for training, simulation and testing.

Two existing dry manipulator testing facilities may be used for the design and training courses :

- Ifremer, Toulon:
    - existing Cybernetix 7P proportional electro-hydraulic arm test setup and positioning and control software simulator;

    - ROV simulation Platform (Victor).

- Marum, Bremen: existing Schilling Orion 7PE proportional electro-hydraulic arm training setup with 2 proportional pan/tilt camera heads.

It is recommended that Deployment and maintenance plans benefit from these facilities in order to check the procedures.

- Written procedures are mandatory.

A **maintenance plan** will be established to describe **periodic maintenance** operations that have to be carried out (mandatory). It will deal with:

- Maintenance procedures available for ROVs to replace modules or subsystem. Standard procedures would allow to use any opportunity ROV for these operation and would, so, minimize operational costs;
- Planning at European level, would allow to refit and calibrate sensors for redeployment on different nodes.

The management plan will also take into account **exceptional maintenance** operations:

- Protocols to be studied for the major components, for example extra length of cable for retrieval, additional connectors…
- Existing agreements with ROV operators to maintenance operation under a short delay.
- Agreement on cable ships operation (Ex: MECMA / ACMA interval activity,…).
- Existing spare component stock related to a failure analysis study (reliability, redundancy, availability). They could be stored at the manufacturer’s shop or at regional level.

All the maintenance operations should be budgeted initially.

N.B. Maintenance cruises are also scientific cruises during a learning phase of a few years and consequently operate short time instruments complementary to the ESONET-EMSO connected ones.

- Standards that can be applied for deployment or maintenance

API RP 2D..............	Recommended practice for the operation and maintenance of offshore cranes

BS 7121-11	British code of practice for safe use of offshore cranes
ISO 13628-1	Guidelines on proper maintenance planning and tooling design
ISO 13628-5	Design and installation of subsea umbilicals
ISO 13628-8	Functional requirements and guidelines for ROV interfaces
NORSOK U-102	Remotely Operated Vehicles (ROV) services.

5.6 Recommendation

Regular meetings on deployment and recovery practices would be very useful. It does not mean any competition but more opportunities to build collaboration, train seagoing personnel and improve procedures.

The anticipation of operating cost is crucial for subsea observatory cost analysis. The data base of experiences is valuable for EMSO.

5.7 Operations during Demonstration Missions

Demo Mission	Ship-ROV	Observatory/site	Duration	Depth	Date	Type of operation
Pre-LIDO	Certamen-Argus-Modus	SN1-GEOSTAR	22 h	2200m	April 2007	Recovery
Pre-LIDO	Certamen-Argus-Modus	NEMO-OnDE	11 h	2200m	April 2007	Recovery
Post-LIDO	Certamen-PEGASO-ROV	SN1-GEOSTAR	72 h	2200m	Planned	Deployment
MODOO	RSS James Clark Ross	Porcupine Abyssal Plain	8 h (BOBO lander alone)	4850 m	May 2010	Checking Deployment
MODOO	RSS James Clark Ross	Porcupine Abyssal Plain	14 h (Lander and moored buoy)	4850 m	May 2010	Deployment (Lander failure)
MODOO	Celtic Explorer	Porcupine Abyssal Plain		4850 m	September 2010	Moored buoy recovery and redeployment
MODOO	RV Poseidon	MoMAR site		2140 m	August 2010	Transmission test on mooring
AOEM	RV Jan Mayen	Prins Karl Foreland (Svalbard)	Few hours	389 m	October 2010	Deployment
MoMAR	Pourquoi	Lucky Strike	10 h	1740 m	October	Deployment

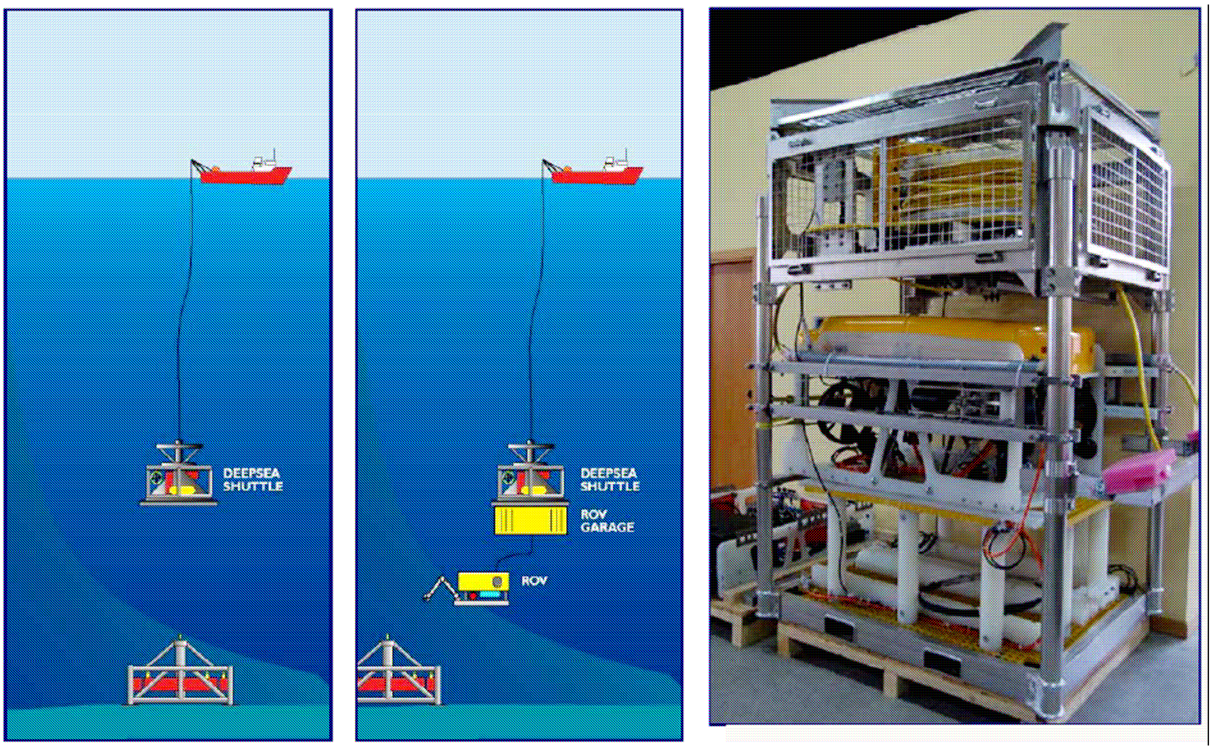
	Pas? – Victor 6000	MoMAR			2010	SEAMON W
MoMAR	Pourquoi Pas? – Victor 6000	Lucky Strike MoMAR	10 h	1696 m	October 2010	Deployment SEAMON E
MARMARA	R/V Le Suroit	Çinarçik basin - Marmara	4 h	1250 m	November 2009	Deployment BOB
MARMARA	R/V Le Suroît	Çinarçik basin - Marmara	2 h	1250 m	December 2009	BOB recovery
MARMARA	R/V Urania	Izmit Gulf - Marmara	-	-	October 2009	Deployment SN4
MARMARA	R/V Yunuz	Izmit Gulf - Marmar	-	-	March 2010	Deployment and Recovery SN4
MARMARA	R/V Urania	Izmit Gulf - Marmara	-	-	October 2010	Recovery SN4
LOOME	R/V Polarstern-QUEST ROV	Haakon Mosby Mud Volcano	7 h (prototype observatory + instruments + video reporting)	1250 m	July 2009	Deployment Prototype Observatory
LOOME	R/V Maria S.Merian-CHEROKEE ROV	Haakon Mosby Mud Volcano	6 h overall	1250 m	September 2010	Recovery Prototype observatory
Test Experiment TEXREX	R/V Pourquoi Pas? – VICTOR 6000 ROV	Ligurian Sea - Antares			November 2010	Deployment Junction Box (BJS) and MII instruments

Table 2 - Deployment / Recovery cruises

6 - ROV OPERATIONS

6.1 ROV used in the DEMO MISSIONS

- LIDO and NEMO Test Experiment are using PEGASO ROV on Sicily sites.



Left - The PEGASO Deep Sea Shuttle (DSS) deploys the station on the seabed. Middle – The PEGASO ROV, driven by means of an interface by the DSS, connects the e.o. jumper from the structure to
the frame. Right – The PEGASO ROV and its garage.

- Victor 6000 was used for MOMARSAT (Lucky Strike site) and TEXREX (Antares site) cruises.

- QUEST ROV from Marum was used during LOOME deployment cruise (*see paragraph 5*)

- CHEROKEE ROV was used during LOOME recovery cruise in November 2010. (See *Deliverable D10 of LOOME DM*):

LOOME design is using the ROV capabilities . The observatory was designed from light, flexible and non-corrosive material, easy to deploy and recover by winch and ROV.

ROVs allow to position above described instruments precisely and are today used extensively in oceansciences. To a certain degree they replaced other technical approaches due to the fact that they carry sensors that allow for-• Determining the exact position of the region under investigation• Positioning instruments and frames with the help of manipulator arms with handling capabilities of ~ 100 kg of load • Online observation and documentation of all manipulation steps using multiple video camera systems
• Interrogating instruments through a dedicated communication link to check for proper operation or programming a mission.

6.2 Discussion

Several types or ROVs are available, few of them capable of intervention in the deep sea under 3000 m. The Demonstration Missions took benefit from the sharing of experience between oceanographic institution who are ROV operators (Marum, Ifremer,…), sessions of Best Practices Workshops were devoted to this topic. The number of operations was not sufficient to cover all cases, especially, with private sector ROVs. An idea in the future would be to check ROV capacities in relation with the ESONET sites needs ; in USA it led to the definition of OOI class ROVs.

It is liable that a manned submersible such as Nautile (Ifremer), Thetys (HCMR) or private submersibles such as Remora (Comex) are used on European ESONET sites as they represent a diving capacity complementary to the ROVs. The Demonstration Missions have not experienced such subsea intervention vehicles. They may require modifications of the procedures for safety reasons (distance from glass spheres, from hanging cable ,…).

The ESONET Label states:

> *Note that the cases when a manned submersible is liable to operate the subsea equipment, special rules must be applied (mandatory) such as those issued by the ASME Safety Standard for Pressure Vessel for Human Occupancy – PVHO 2007 .*

6.3 Recommendation

In the future, it might be useful to define specifications of ESONET class ROVs.

The following recommendations are included in the ESONET Label.

7 - CONNECTION AND DISCONNECTION

7.1 Connectors

Connectors are the weak point of subsea systems. Prior to ESONET, the first European pluggings on subsea observatories suffered from poor experiences such as connector damage during the mating operation.

ODI is the leading manufacturer of deep-sea wet mateable electrical and electro-optical connectors. Some improvements had been issued before the demonstration missions. INFN, CNRS, IN2P3 and Ifremer worked on enhanced plugging methodologies. They were ready for the test experiment. Ifremer's design of the BJS interface with the Antares infrastructure included:
- optimized position with respect to ROV Victor 6000 operation,
- specific holder for ODI bulkhead part of the connector, providing self centering before mating.

The enhancements proved their efficiency during the tests experiment.

CDC
For MoMAR DM, the connection of the sensors to the nodes was validated using the two methods tried during the cruise. The geophysics module was successfully connected in situ to SEAMON West using a wet mateable connector (CDC). This underwater connection is particularly valuable when the parcels are large. The second alternative used on SEAMON East is an onboard connection of the sensors.

7.2 Procedures

The ISO 13628-8 lists the key elements that should be considered during the design of a submarine system to ensure future intervention by ROV.

For example, connectors would be ROV friendly designed, by adding T-type handles on top of their flying part. Guide cones must be sited around the point where a connector is inserted. Their face upwards should be open-ended or equipped with a suitable debris cap. Grasping devices on the structure may also make the operation easier for the ROV. Docking and interface points should be a minimum of 1,5 m above the clear local seabed. Interface shall be accessible to standard 7 functions manipulators.

7.3 Recommendation

At the end of deployment operations, it’s mandatory to check that all the sensors, connections and data processing are working well on the subsea observatory before the ROV leaves.
Check all transmission before leaving the site.
Cleaning devices are necessary to sweep sediment from the connectors before plugging or unplugging.
When connectors are not used, it is mandatory to position a dummy connector in place.

8 - SENSOR INSTALLATION

8.1 Examples

The installation by ROV allows to deploy many connected instruments on the seafloor. Sensors deployed on the frame of the subsea station are covering less volume. The limitation of anti-trawling must be of course taken into account (reference to AOEM).

The QUEST ROV during the LOOME deployment first positioned the prototype observatory, then :

- 8 sensor strings were laid out by the ROV (followed paragraph)
- It started with a 100 m long temperature string
- A string of chemical sensors including pH, dissolved oxygen, and redox with a length of 100m was laid out
- Two more strings of chemical sensors were laid out one with a length of 84 m and the other with a length of 67 m
- The temperature lance then was deployed. The system was attached to a 50 m long cable that ended in the COSTOFS module. By employing a contact less inductive link it was possible to check the proper operation of the module (CLSI, Contact Less Serial Inductive Link, NKE/*Ifremer)*
- Another 3 chemical sensor strings were laid out by the ROV where the cable lengths were 50 m, 35 m, and 17 m.
- The cable drum of the temperature string was then placed into the LOOME frame
- A final test of the temperature string employing again the CLSI proved the proper operation of the system
- After that, an autonomous temperature lance and an OBS has been positioned on the seafloor.
- Finally a video camera has been placed in front of the hot spot that takes video footage of 10 minutes length of the bubble streams emanating from the seafloor every 12 hours. Again the proper operation has been checked with the CLSI.

During the MoMAR deployment, Victor 6000 ROV laid cables and connected 4 different groups of sensors on their own frame.

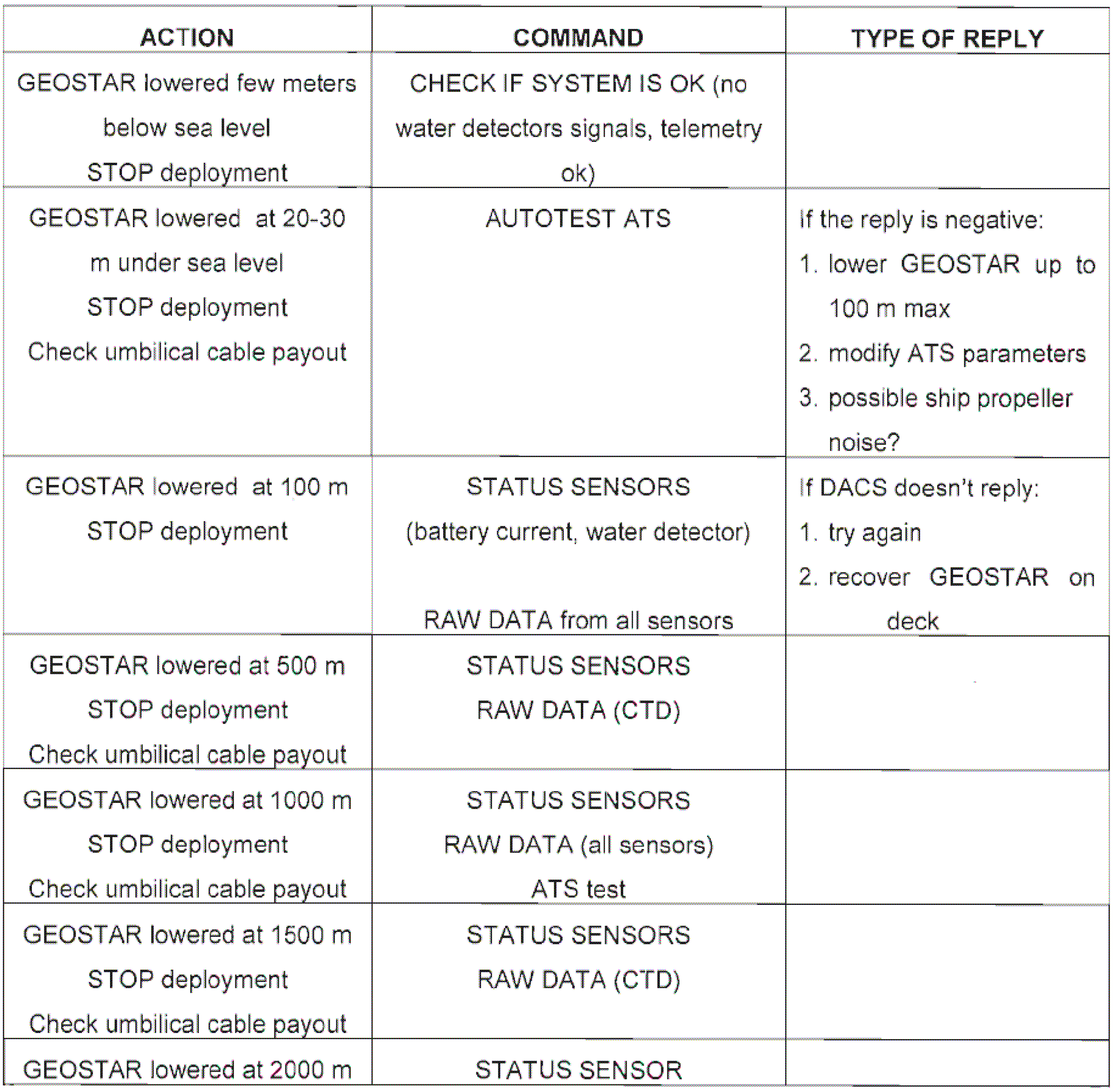
8.2 Recommendation

The LIDO experience shows the need to deploy magnetometers far from the observatory (10 m to 15 m).

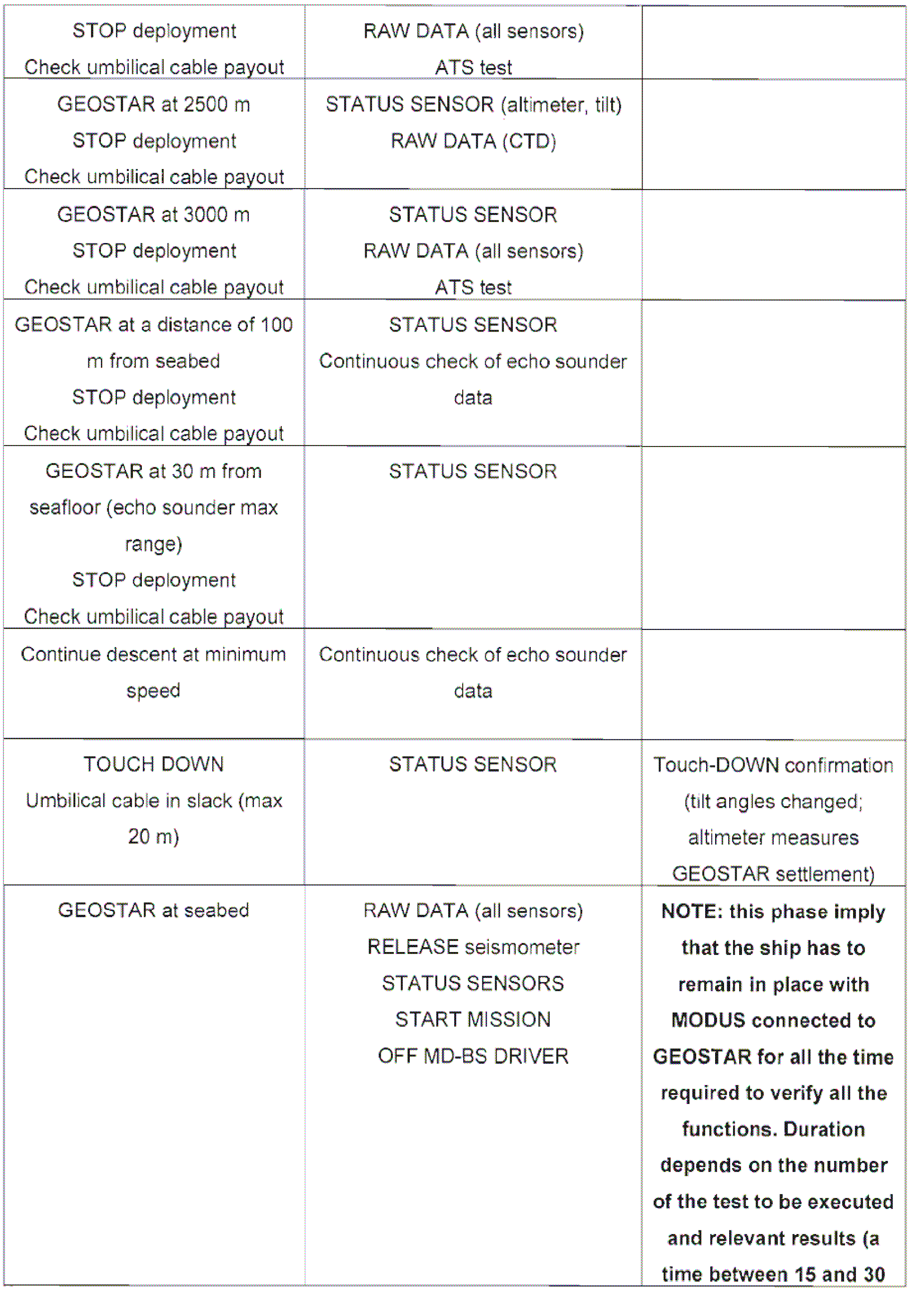
9 - SENSOR TUNING AND *IN SITU* CALIBRATION

9.1 Checking procedures

- The procedure of all GEOSTAR family stand alone observatories (SN1 and SN4) requires a permanent link with the observatory during launching. Several checkings are performed. It was especially designed using the MODUS and its connection for 3000 m water depth.



ACTION	COMMAND	TYPE OF REPLY
GEOSTAR lowered few meters below sea level STOP deployment	CHECK IF SYSTEM IS OK (no water detectors signals, telemetry ok)	
GEOSTAR lowered at 20-30 m under sea level STOP deployment Check umbilical cable payout	AUTOTEST ATS	If the reply is negative: 1. lower GEOSTAR up to 100 m max 2. modify ATS parameters 3. possible ship propeller noise?
GEOSTAR lowered at 100 m STOP deployment	STATUS SENSORS (battery current, water detector) RAW DATA from all sensors	If DACS doesn't reply: 1. try again 2. recover GEOSTAR on deck
GEOSTAR lowered at 500 m STOP deployment Check umbilical cable payout	STATUS SENSORS RAW DATA (CTD)	
GEOSTAR lowered at 1000 m STOP deployment Check umbilical cable payout	STATUS SENSORS RAW DATA (all sensors) ATS test	
GEOSTAR lowered at 1500 m STOP deployment Check umbilical cable payout	STATUS SENSORS RAW DATA (CTD)	
GEOSTAR lowered at 2000 m	STATUS SENSOR	



STOP deployment Check umbilical cable payout	RAW DATA (all sensors) ATS test	
GEOSTAR at 2500 m STOP deployment Check umbilical cable payout	STATUS SENSOR (altimeter, tilt) RAW DATA (CTD)	
GEOSTAR at 3000 m STOP deployment Check umbilical cable payout	STATUS SENSOR RAW DATA (all sensors) ATS test	
GEOSTAR at a distance of 100 m from seabed STOP deployment Check umbilical cable payout	STATUS SENSOR Continuous check of echo sounder data	
GEOSTAR at 30 m from seafloor (echo sounder max range) STOP deployment Check umbilical cable payout	STATUS SENSOR	
Continue descent at minimum speed	Continuous check of echo sounder data	
TOUCH DOWN Umbilical cable in slack (max 20 m)	STATUS SENSOR	Touch-DOWN confirmation (tilt angles changed; altimeter measures GEOSTAR settlement)
GEOSTAR at seabed	RAW DATA (all sensors) RELEASE seismometer STATUS SENSORS START MISSION OFF MD-BS DRIVER	**NOTE: this phase imply that the ship has to remain in place with MODUS connected to GEOSTAR for all the time required to verify all the functions. Duration depends on the number of the test to be executed and relevant results (a time between 15 and 30**

Table 3 - Geostar deployment procedure

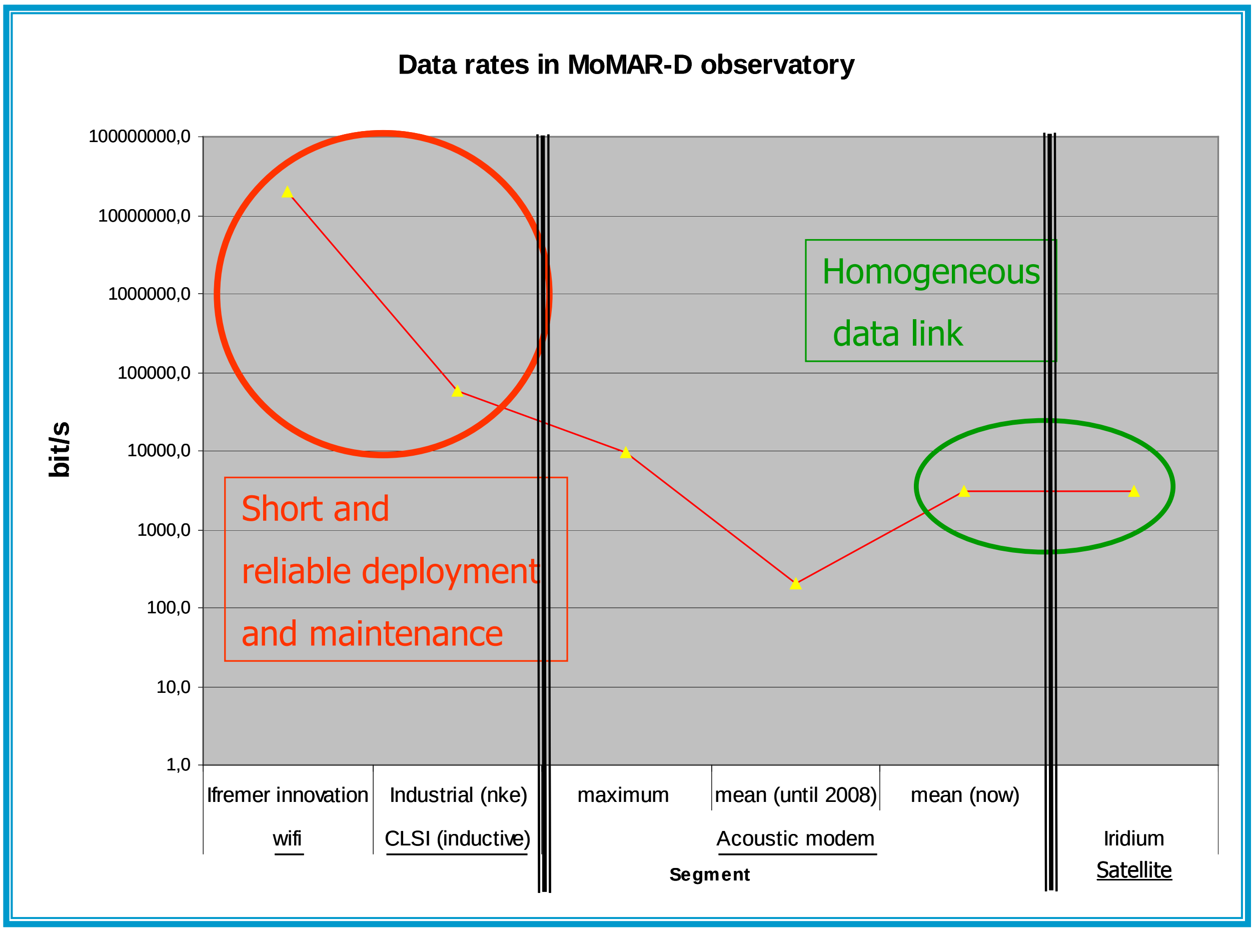
- LIDO experienced procedures for validation of the seismometer and magnetometer stabilisation during the first hours. Typically:

After LIDO Cadiz mission start , GEOSTAR status can be checked via Acoustic telemetry .
After deployment, it is necessary to check GEOSTAR status at least two times
a) few hours (2 -3) after mission start
b) after 24 hours after mission start
During every check at least a DATA MESSAGE and a STATUS MESSAGE (for example , the ones relevant to the last completed hour of mission) shall be recovered .

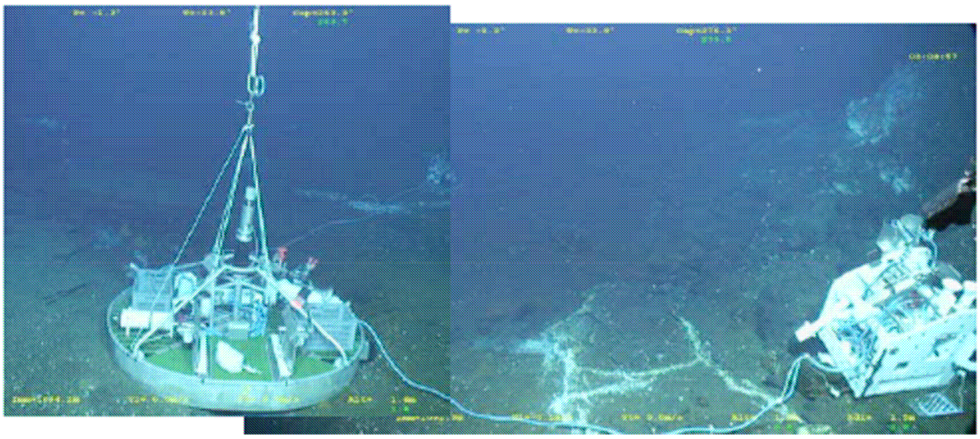
Although not strictly necessary , it is also recommended to carry out a check every time the ship is in the vicinity of the deployment site .

- On MoMAR

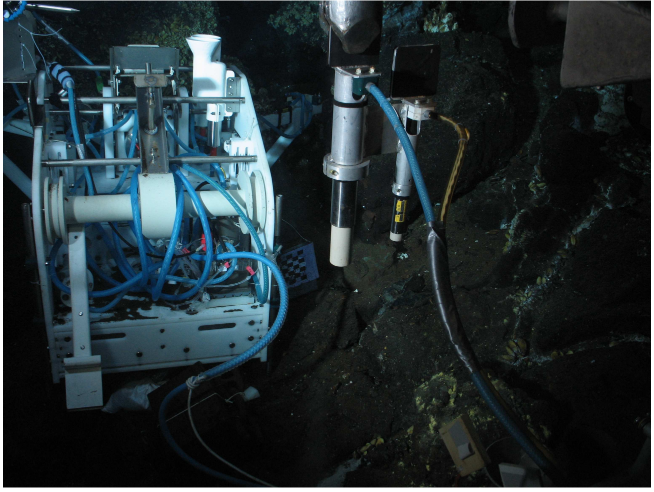
During MOMARSAT, the deployment of the sensor was validated using 2 different communication links. The ROV Victor 6000 is used for a bi-directional dialogue with the SEAMON nodes. A CLSI (Contac Less Serial Link – inductive connection) link was installed on both SEAMON nodes allowing checking the functioning of the sensors. A WIFI link was adapted to the Tempo camera to transmit the images acquired in real time to the ROV during the deployment. These 2 communication systems were essential tools during the deployment. All the connected nodes and the Costof electronics were checked. The orientation of the camera is only possible with a data link able to transmit images quickly. The innovative Wifi link brings this capacity.



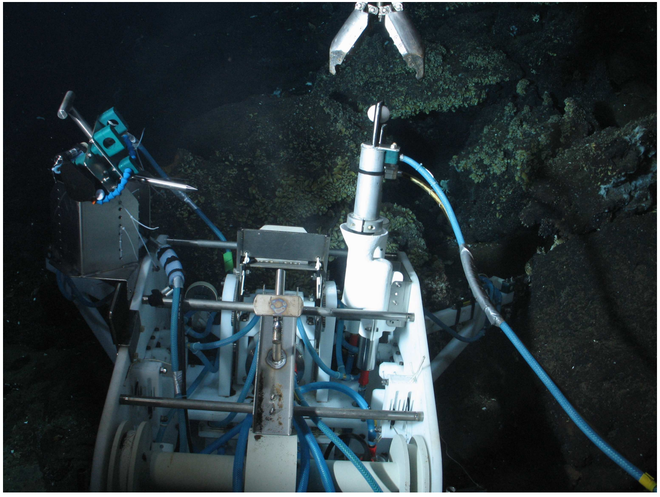
Comparison of data links. The acoustics and Iridium have limitations. Final observatory checking needs higher rates, provided by short distance electromagnetic devices.



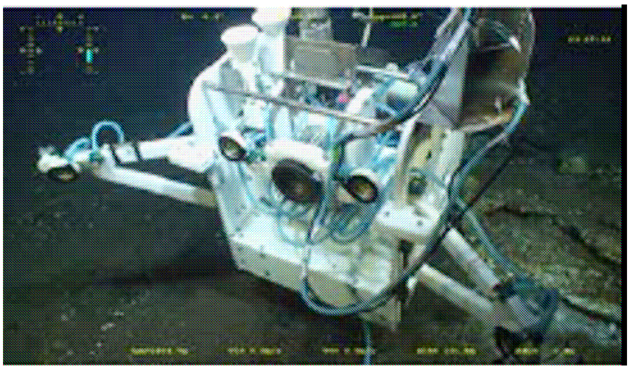
Seamon West was deployed at the base of the Tour Eiffel active edifice. The Tempo ecological module on the right is nearer. It includes a camera and lights, chemical analysers, oxygen optode,…



WIFI and inductive tools approached from Tempo module



Tools inserted



Tempo ecological module (Ifremer-MoMAR).

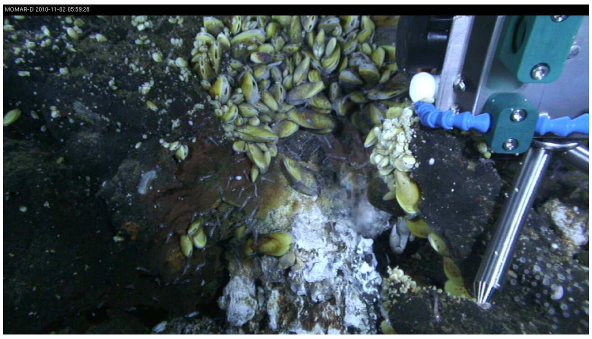


Image checked at the end of the deployment and transmitted daily afterward through the acoustic-buoy-Iridium channel (Ifremer-MoMAR).

-

9.2 Recommendation

Seismometers and magnetometers must be checked before the end of the installation cruise.

Checking of the good functionning of instrumentation is necessary before leaving the site. If the ROV can do it, it is a more efficient process as technical investigations and mitigating actions can still be performed.

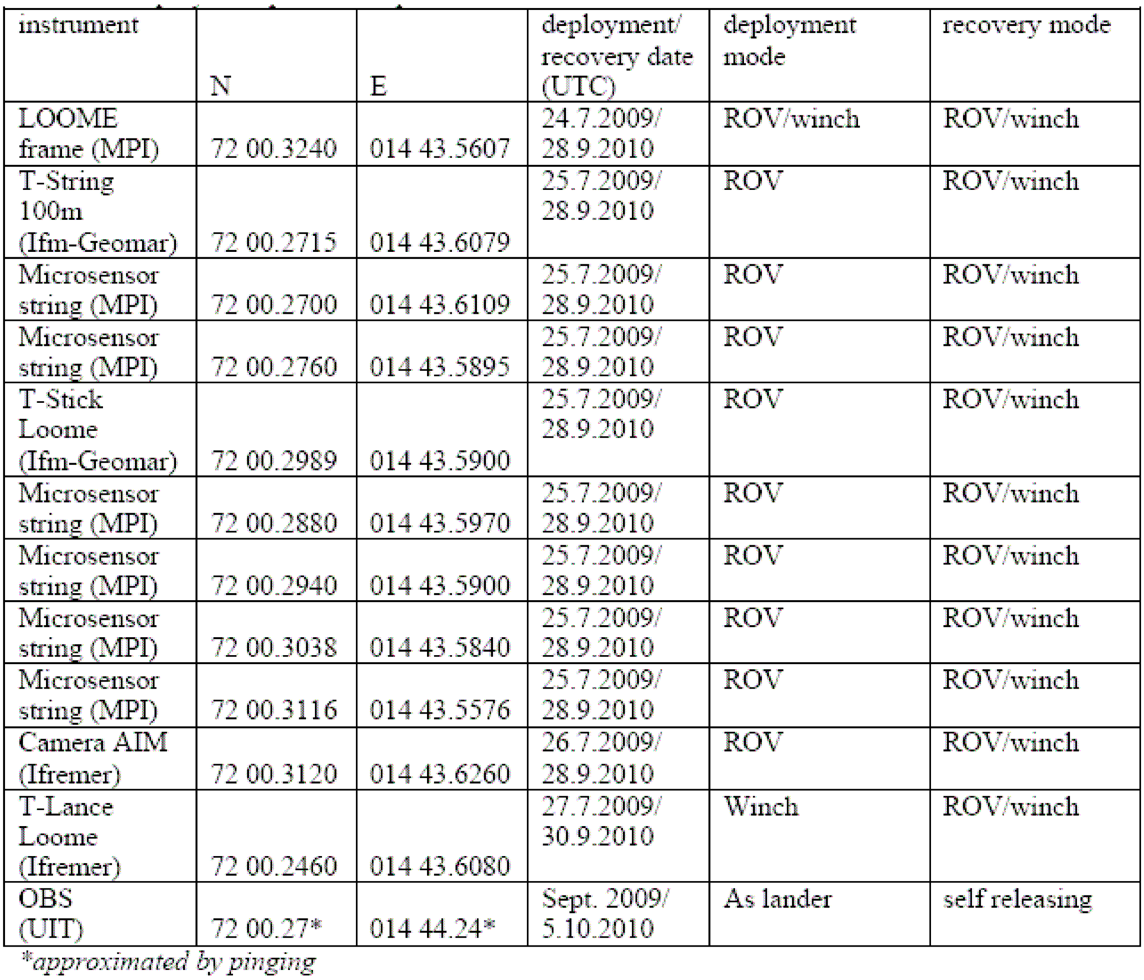
10 - SENSOR RECOVERY AND EXCHANGE

Few recoveries were performed

LOOME .

In the *Deliverable D10 of LOOME DM*,the recovery is described:

> In 2010 the frame with sensors was recovered. A first reconnaissance learned that the frame remained at position, and that all sensors were visible. The T-strings and chemical sensors were pulled away from the frame by moving mud, but remained connected, although the cables were stretched. All cables were pulled in south-eastern direction. The sensors made trails in the mud, as the sediment had moved under them, while they stayed in place due to the cable connection. The T-lance, of 15 m length and 1500 kg, was found after a long search about 160 m south of the deployment position. Thus sediment has flowed at least 160 m. The camera was placed on the edge of the hydrates and had stayed in position. The OBS was located approximately by pinging, but not observed by the ROV. It was located on gas hydrates in the south eastern region of the HMMV. It has probably hardly moved during the year of deployment.
>
> The camera, LOOME frame, and T-lance were recovered by the ship winch, the hook was connected to the equipment by the ROV. The strings and loggers remained connected, were very entangled but intact, and were after surfacing pulled on deck by hand. The OBS was recovered via acoustic release. The recoveries were without problems. The temperature, pressure and chemosensor data learned that several eruptive events occurred.



instrument	N	E	deployment/ recovery date (UTC)	deployment mode	recovery mode
LOOME frame (MPI)	72 00.3240	014 43.5607	24.7.2009/ 28.9.2010	ROV/winch	ROV/winch
T-String 100m (Ifm-Geomar)	72 00.2715	014 43.6079	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.2700	014 43.6109	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.2760	014 43.5895	25.7.2009/ 28.9.2010	ROV	ROV/winch
T-Stick Loome (Ifm-Geomar)	72 00.2989	014 43.5900	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.2880	014 43.5970	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.2940	014 43.5900	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.3038	014 43.5840	25.7.2009/ 28.9.2010	ROV	ROV/winch
Microsensor string (MPI)	72 00.3116	014 43.5576	25.7.2009/ 28.9.2010	ROV	ROV/winch
Camera AIM (Ifremer)	72 00.3120	014 43.6260	26.7.2009/ 28.9.2010	ROV	ROV/winch
T-Lance Loome (Ifremer)	72 00.2460	014 43.6080	27.7.2009/ 30.9.2010	Winch	ROV/winch
OBS (UIT)	72 00.27*	014 44.24*	Sept. 2009/ 5.10.2010	As lander	self releasing

**approximated by pinging*

Table 4 - Loome deployment period and positions of instruments