

[Next](#)[Previous](#)[Contents](#)

Chapter 2 : [Mechanics](#)

- [Mechanics: an overview](#)
 - [Technical constraints](#)
 - Main object descriptions
 - PBS 1.1 [Junction Box](#): mechanics
 - PBS 1.2 [Bottom String Socket](#):
 - PBS 1.3 [Storey](#)
 - PBS 1.4 [Cables](#)
 - PBS 1.5 [Buoy](#)
-

Mechanics overview

A description of the detector is given in the introduction, and in this chapter, mechanical aspects of each of the components are detailed.

The AC voltage transmitted from the shore is converted inside a [Junction Box \(JB\)](#), which distributes the power to each line. The JB is positioned inside a [JB Frame](#) to allow deployment and recovery operations. The JB is a critical component of the system and is the first object to be deployed. Mechanical aspects of the JB are described in this chapter; [electronics](#) and [electrical power](#) issues will be considered in the appropriate chapters.

Each detector **string** (or **line**), is anchored on the sea bottom and maintained vertical by its buoyancy. Between the buoy and the anchor, the active detector part of the string is made up of an assembly of standardised elementary segments. The components of the line will be described in turn:

- an anchor, made of a dead weight and a recoverable structure, the [Bottom String Socket \(BSS\)](#)
- 30 elementary [storeys](#), each with an [Optical Module Frame \(OMF\)](#), which supports 3 Optical Modules, a [Local Control Module \(LCM\)](#), 10 metres of [Electro Mechanical Cable \(EMC\)](#) with penetrators in the LCM containers, giving a total distance of 12 metres between storeys. Some storeys support a [hydrophone](#) dedicated to positioning or a specific light source ([LED Optical Beacon](#))
- 100 metres of [Electro Mechanical Cable \(EMC\)](#) and their penetrators.
- the top of the line is maintained by a syntactic foam [Buoy](#)

The connections from the strings to the JB are made using a remotely operated submarine vehicle (ROV). The [Interconnecting Link \(IL\) cable](#) (also called EOC) with penetrators on both ends, ensures both data communication and proper power transmission.

A schematic view of the main objects found in the line can be seen by clicking [here](#).

Technical constraints

This section contains descriptions of the main mechanical design criteria, including specific constraints relating to the environmental conditions in which the detector must operate.

- [Materials](#)
 - [Water tightness](#)
 - [Pressure tests](#)
 - [Corrosion and stress](#)
 - [Environmental constraints](#)
 - [Objects handling](#)
 - [Maintenance](#)
-

Materials used in the detector

The most important mechanical characteristics of the different titanium and steel alloys used in the ANTARES detector are presented in the table below.

Material	Designation	Yield strength (MPa)	Ultimate strength (MPa)	Young Modulus (MPa)
Titanium alloy	BT14	>750	>830	112800
Titanium alloy	PT3V	>500	>610	112800
Titanium alloy	ASTM grade 5	>828	>895	112800
Unalloyed titanium	ASTM grade 2	350	460	108000
Carbon steel	UNI-Fe690	>275	>690	210000
Stainless steel	AISI 316	>220	>515	210000

where the Young modulus represents the longitudinal proportionality constant between stress and strain, as defined in the theory of elasticity of materials. The yield strength measures the longitudinal stress at which a permanent longitudinal deformation of 0.2% occurs, while the ultimate strength represents the longitudinal stress at which rupture occurs. They are expressed in N/mm² (or MPa). The Titanium ASTM grade 2 is sometimes named T40 while the titanium alloy ASTM grade 5 (Ti +6%Al + 4%V) is also known as Ta6V.

Water tightness

All vessels have to be water tight, as moisture could seriously damage the electronics components inside. Special care has been taken to ensure that no water leakage would occur in shallow water (first phase of deployment), or in operating conditions. The design seals have been successfully qualified through an extensive campaign of tests at high pressure (310 bar) and low pressure. This last condition is considered the more severe, as the external pressure alone would not completely

squeeze the seal, hence the choice of screwed flanges.

Whenever possible, two O-rings have been mounted to increase reliability. This is particularly true in the interface between a penetrator and a vessel, as in the case of the connection of the [ElectroMechanical Cable \(EMC\)](#) to the [LCM](#). Here the first O-ring ("face O-ring") is mounted on the flat surface of the endcap, while the second is located on the cylindrical part of the penetrator (in contact with the surface of the hole in the LCM endcap). The face O-ring is compressed axially by the bolts and, after immersion, by the water pressure, while the second is compressed radially. The dimensions and tolerances of the groove, as well as the surface roughness are specified by the manufacturer and carefully respected in our design.

O-rings can be found in different materials, which choice depend on environmental conditions (acids, oils, salt water, gases.), pressures and cost. VITON and NITRILE are the most commonly indicated for our applications. The age resistance of VITON (20 years) is higher than NITRILE (4 years) and the compression set which indicates the 'reaction' of the material to compression is better in VITON than NITRILE. For these reasons, we choose VITON O-rings for all seals in the detector.

Pressure tests

In order to check pressure resistance and water tightness during undersea operation, each vessel used in the detector undergoes a pressure test in a hyperbaric chamber filled with water. The procedure comes directly from the safety requirements of IFREMER, the company responsible for the open sea operations, concerning the installation of vessels to be deployed undersea. The test programme consists of an initial static test, followed by a dynamic test. During both tests, provisions have to be made to carry out a continuous recording of the operating conditions (pressure and temperature).

Static test: the sequence of operations is:

- the geometrical shape of the vessel is measured with a micrometer or a CMM machine
- the vessel is filled with oil at 90 percent of its capacity
- the vessel is put in the pressure chamber
- the temperature of the water in the pressure chamber is brought down to 2°C
- the pressure in the chamber is increased at a rate of 12 bar per minute until the value of 310 bar is reached
- the vessel is kept in these conditions (constant temperature and pressure) for 24 hours
- the pressure is returned to atmospheric pressure at a rate of 12 bar per minute
- the vessel is taken out of the pressure chamber
- the geometrical shape of the vessel is measured with a micrometer or a CMM machine

Dynamic test: the sequence of operations with water at room temperature is:

- the vessel is filled with oil at 90 percent of its capacity
- the vessel is put in the pressure chamber
- the pressure in the chamber is increased at a rate of 12 bar per min until the value of 256 bar are reached
- the vessel is kept in these conditions for 1 hour
- the pressure is returned to atmospheric pressure at a rate of 12 bar per minute
- the vessel is kept at atmospheric pressure for 1 hour

- this pressure cycle is repeated 10 times
- the vessel is taken out of the pressure chamber
- the geometrical shape of the vessel is measured with a micrometer or a CMM machine

Corrosion and stress

All the components have been designed for the following conditions:

- external pressure: 310 [barg](#) (test pressure);
- temperature min/max: 0-60°C;
- operating life: 10 years
- environment: sea water
- $P < 5$ kPa for the contact pressure on the sea bed

To allow for the long operating life required and the corrosive environment, some basic rules have been adopted:

- use of corrosion-resistant alloys (titanium) for the most delicate parts; the effect of the sea water on the titanium alloys is well established and quantified with a corrosion rate less than 0.00025 mm/ year. For comparison, the corrosion rate for steel amounts to 0.1- 1 mm/ year.
- electrical insulation between different metals, to avoid electro-chemical corrosion, by means of plastic bushings;
- oversized thickness of carbon steel parts, as corrosion allowance;
- protective coating on carbon steel parts;
- galvanic protection of carbon steel parts, by means of zinc sacrificial anodes;
- minimal number of holes, screws and structural "closed volumes", i.e., volumes where water cannot flow freely.

The design of objects that will be subject to mechanical stress has been optimised using standard engineering rules and, for subsystems with more complex geometry, Finite Element Analysis (FEA).

Environmental constraints

Studies have been carried out to investigate possible damages during:

- storage;
- mounting of connectors and seals;
- road transport to Brest / Marseille / la Seyne sur Mer;
- mounting of frame on the end cap/ pre-integration tests ;
- integration in sector (for LCMs);
- line assembly (for LCMs, SCM, SPM);
- test immersion of line;
- loading on deployment vessel;

- deployment;
- operation;
- maintenance / line recovery

Mechanical structures and containers should be designed to withstand the following conditions:

- **Vibrations**

Studies performed on test lines show that during the operational phases, containers are subjected to vibrations in the range 1-5 Hz, due to sea currents. Taking into account vibration during transport and loading, the estimated frequency range is extended to 1-55 Hz.

- **Shocks:**

Although containers are protected from direct shocks during deployment by their supporting frames, shocks to the frame may be transmitted to the containers. There is also some risk that containers may be dropped during handling operations. Where possible, containers should be designed to withstand a fall of 0.7 m, and to protect their associated electronics from damage.

- **Solar radiation, salty mist, temperature cycles:**

Containers, electronics and PMTs associated with the Demonstrator line survived high temperatures, temperature cycles, UV from several months of solar exposure and salty mist, without noticeable degradation of performance. Tests should be conducted to confirm that design changes since the Demonstrator line have not compromised this.

Object handling

The stringent specifications ensure that all objects are of robust construction. However, to avoid damage or safety risks during transport, the following precautions should be taken:

- All objects should be transported in proper packaging, braced against "soft" materials (wood, rubber).
- Eyebolts will be provided for safe handling. Standard safety rules should be observed when handling heavy objects.
- Special care should be taken when handling carbon steel components, as lifting cables and ropes could easily scratch the protective coating. In the event of such damage, the surface should be repaired promptly.
- Plastic parts should be protected from direct sunlight, to avoid UV-induced aging
- O-rings should be stored in a cool, dry place and installed only during the final assembly stage, immediately before deployment.

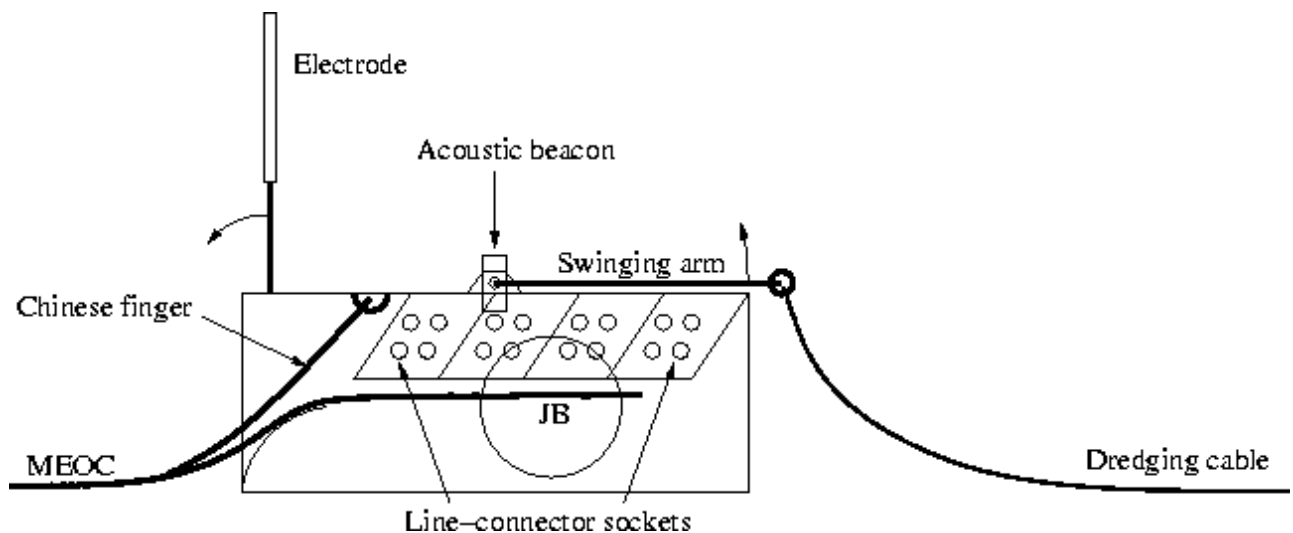
Maintenance

The detector is designed to operate for a nominal lifetime of 10 years without routine maintenance, and component specifications reflect this. However, the Junction Box is a critical component and a plan for its recovery from the sea bed has been developed, needing a combined operation with boat and submarine. Also, each individual string can be released from its anchor and reach the sea surface by means of its own buoyancy, leaving the lower part of the BSS, with its dead weight, which is lost.

PBS 1.1 Junction Box

The Junction Box (JB) is the interface between the main electro-optical cable ([MEOC](#)) arriving from the shore and the array of strings (cf [schematic of detector](#)). It comprises a frame, a container and links between the container and the underwater connector sockets. The sockets are mounted on a front panel on the periphery of the structure, for their connection by a remotely operated submarine vehicle (ROV) with the [Interconnecting Link](#) cables coming from the [SCMs](#). The JB is also equipped with an acoustic system to allow positioning during deployment and recovery operations. JB executive drawings can be found under <http://www.ge.infn.it/~aiace/Antares/JB.html>.

The figure below shows the complete JB arrangement.



1 Main Components of the JB

- [The JB frame](#)
- [The JB container](#) : general description and main elements.

2 [General considerations](#)

- Choice of material
- Structural and stability considerations
- Heat dissipation

3 [Manufacturing, assembly and Quality Assurance](#)

4 [JB test results](#)

List of references

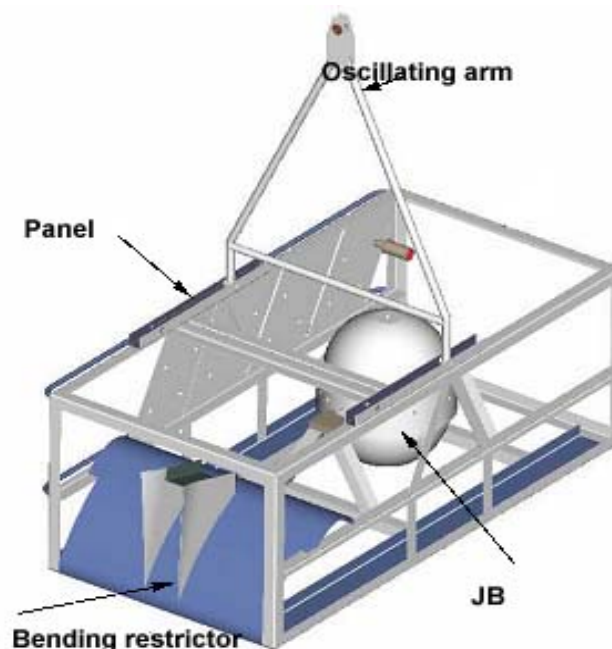
- JB details and executive drawings : <http://www.ge.infn.it/~aiace/Antares/JB.html>
- [Junction Box Objects](#) and [Product Breakdown Structure](#)

The JB frame

The JB frame is designed to allow for:

- deployment;
- recovery;
- stability of the position on the sea bed;
- long lifetime (10 years at least).

The structure is equipped with a special device to hold the electro-optical cable, a dredging cable for recovery and a front panel offering a safe interface for submarine vehicle operation. The frame must resist an immersion of 10 years in deep sea water (2500 m). It has to be pressure-proof (256 bars during working phase) and present a very low level of corrosion.



Schematic view of the JB including the frame and the container

General description

The JB frame is made in Ti grade 2 and Ti grade 5. These materials prevent possible galvanic currents with the titanium container and corrosion effects in the expected 10 years of operation. The JB frame includes a lateral panel to hold the 16 sockets for the connection to the cables from the strings. The connectors are fixed on four polyethylene panels, four connectors for each panel; this configuration is considered a good solution for the maintenance operations and for the structural resistance of the panels.

The Main Electro-Optical Cable from the shore is connected to the JB container through two Chinese fingers fixed to the horizontal axis. The bending restrictor avoids possible damage to the EO cable, when heavy loads may be applied in both vertical and radial directions: the radius of curvature of this protection is 1 m to match the characteristics of the cable.

The swinging arm, in the top part, is used during deployment. The total length is limited to 2 m to facilitate handling in case of limited height on board the ship. The swinging arm falls forward when the Junction Box is laid on the sea bed, to avoid fouling of the dredging tail with the connectors. In the upper corner of the structure, 4 lateral pad eyes are located to help during sea deployment.

The base of the frame is protected with polyamide saddles whose surface area of 2 m² limits the pressure on the sea bottom to 5 kPa. This protection is made with two sheets of polyamide instead of a large area in contact with the sea bottom, to avoid suction forces during the deployment phase.

The anode used for the sea current return is positioned on a 2-metre mast above the Junction Box frame. Due to the limited clearance under the ship crane, the mast may be inclined backwards.

A transponder is used to position the JB : the acoustic head is positioned vertically 0.2 m above the top, near the centre of the JB.

Design parameters and acceptance tests

The main constraints used to fix the design are the following:

- vertical load on the swinging arm: 2500 m of EO cable in water (1500 kg) plus the weight of the JB in air;
- dynamic load: 1.5 x total static load;
- lateral maximum dynamical load on the swinging arm when dredging: JB weight;
- vertical static and dynamic loads on lifting pad eyes: same as the swinging arm;
- lateral maximum dynamic load on each lateral pad eye: JB weight.

After manufacturing, the structure passes through the following acceptance tests:

- check of the horizontal equilibrium (+/- 5 deg) without cable load (suspension by the swinging arm);
- check of the equilibrium angle under cable load simulated by a heavy load;
- check of the horizontal equilibrium (+/- 5 deg.) without cable load with suspension by the two lifting pad eyes;
- vertical load on the swinging arm: 2.25 x JB weight + 2.25 x cable weight simulated with cable and heavy weight.

A **sea acceptance test** is performed at the end. During this test, the structure is installed on board and launching and recovery procedures are tested at 40 m depth with a 10 m electro-optical cable (EO) and a [dead weight](#) (500 kg) simulating the static load of 2500 m of EO cable. The structure is launched and a 100 m fishing tail is laid and its 500 kg dead weight is released. The fishing tail is recovered with the [Deniel grapple](#) and the structure is recovered. ([Link with JB installation in the sea operation chapter](#))

The JB container

Picture of the JB container in CPPM hall



General description

The JB houses the components listed in the [PBS of JB components](#). The main transformer is located in a separated, watertight compartment inside the JB, that must be filled with dielectric oil for cooling. The components in the other compartment stay in dry atmosphere, to avoid condensation on the cold walls while under sea.

Designation	Length	Width	Height	N°
[units]	[mm]	[mm]	[mm]	[-]
Main transformer	330	350	600	1
Clock module	320	200	20	1

ROR electronic-optic	110	170	50	1
AC switch /Remote control	130	140	150	16
Very low voltage supply	370	115	100	1
Timed relay	210	121	56	2
Short mode relay	140	90	56	1
JB control module	300	115	100	1
EOC-copper 5 kV terminal	110	170	150	1
Electrode terminal	110	170	50	1
1000 V terminal	110	170	50	1

The following openings are required:

- 16 holes for the electro-optical cables connecting the strings to the JB;
- 1 hole for the main electro-optical cable coming from the shore;
- 1 hole for a test penetrator;
- 1 hole for the high voltage return.

The JB is required to operate in the following environmental conditions:

- Operating pressure int/ext: 0/ 256 bar;
- Test pressure int/ext: 0 / 310 bar;
- Operating temperature: 13.2°C;
- Lifetime: 10 years.

The electronics inside the JB is expected to produce a heat loss of around 1200 W, mainly due to the transformer. This power has to be drained away through the walls of the JB, without increasing the temperature of the electronics above the maximum allowable operating value of 60°C.

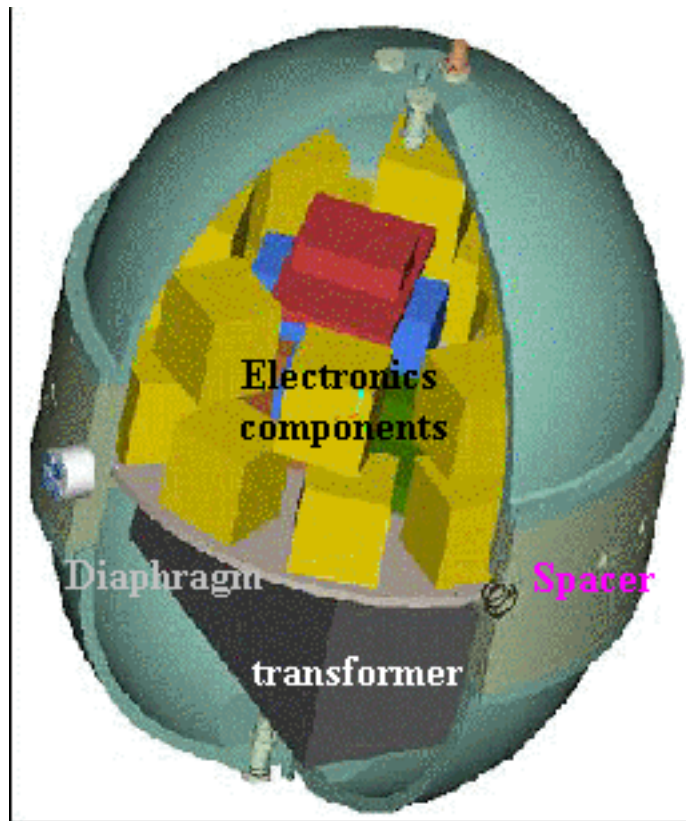
Component layout

Two existing hemispherical caps were used in the construction of the JB container to save costs. A 300 mm high spacer annulus was inserted between them to satisfy the space requirements, including room for the minimum bending radius specifications of the optical fibres. To avoid possible weakening of the structure, the annulus is forged from a massive piece of titanium and not from a bended and welded flat sheet. The assembly of the different components is described [in the JB assembly](#) section of this chapter.

The seals of the two mating flanges were carefully designed to avoid leaks, as described below.

JB Vessel (PBS 1.1.2.001)

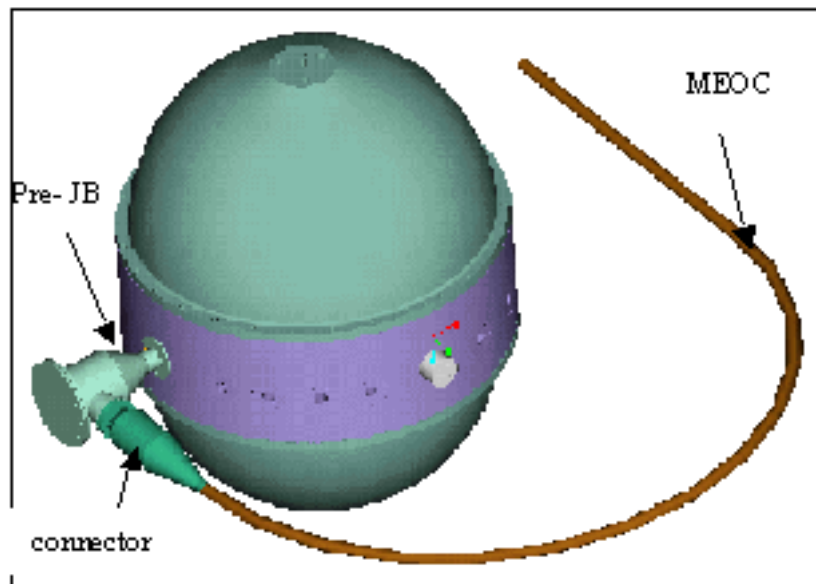
As already stated, the inner volume is divided into two watertight compartments: the lower one contains the transformer in its own dielectric oil bath, while the upper one houses all the other electronic components. This layout has been tested against heat dissipation as described in the [JB test section](#). The two compartments are separated by a stainless steel diaphragm that also supports all the components; it rests on a step machined on the inner surface of the spacer, while the tightness is ensured by an O-ring seal.



Layout of the components inside the JB.

The electrical connections between the two compartments are made with leak-tight **feed-through** connectors. To improve the thermal insulation between the two compartments, a 4 cm thick foam is fixed to the **diaphragm**. The **penetrators** enter the JB through the spacer annulus, that features 16 holes almost equally spaced, and then get into the lower compartment. The main cable initially enters an intermediate small box called pre-Junction Box that houses the socket contacts to make the connection easier on the boat during the JB deployment operation; this intermediate box is flanged to the spacer annulus and communicates with the lower compartment.

The high voltage return penetrator and the test penetrator, are installed in the spacer annulus, roughly opposite to the main cable entry, and communicate with the electronics compartment. The spacer annulus features two handles that allow the whole JB to be inverted, while resting on its supporting frame, for easier assembling and maintenance.



JB layout with main cable entry

Penetrators (cf section about [Interconnecting Link](#) cable PBS 1.4.1)

Different types of penetrators for the cables connecting the lines to the JB have been evaluated. As the cable connector (which is the most expensive part of the line) drives the choice of the penetrator, we agreed with all the suppliers in competition that their penetrators should comply with the following parameters that define the interface between the penetrator and the JB:

- Hole bore diameter : $32.0^{+0.05}_{-0.00}$ mm
- Screw holes: 6 x M8 on 66.6 mm diameter
- Flange outer diameter : 85.76 mm

Since all the suppliers have given a positive answer, competition is still alive.

Diaphragm (PBS 1.1.2.002)

A diaphragm is fitted on the titanium annulus spacer to separate the internal JB volume in two separate, leak-proof compartments. It has been built in AISI 316 stainless steel: as no moisture is allowed inside the JB, no electrochemical corrosion is expected between the diaphragm and the spacer. Tightness is achieved by means of an O-ring seal, made of VITON, that can withstand both thermal and chemical attacks well beyond the expected operating lifetime foreseen. As the pressure difference is expected to be very small, such a seal is not made as a fused piece, but simply joining a standard piece of cord.

The diaphragm also supports all the components: the transformer, on one side, and the electronics rack on the other one. Holes are drilled on the diaphragm to house the feed-throughs (PBS1.1.2.003) and some other components:

- 2 feed-throughs for the 5 kV ac
- 3 feed-throughs for the 1 kV ac
- 2 feed-throughs for the 240 V
- 1 instrumentation feed-through
- 1 oil filling plug
- 1 pressure balancing pipe.

Special pads are welded on the diaphragm, to allow easy dismantling and assembling of both transformer and electronics frame. The transformer is installed with its upper edge roughly 136 mm downwards from the diaphragm lower edge, while its compartment will be filled with oil in order to have the oil free surface at 60 mm from the same reference. This configuration maximises the inclination angle of the JB (up to 8°-12°) that keeps the transformer covered with at least 40 mm of oil, still compatible with reliable operation. This way, the gas volume in the transformer compartment becomes roughly 40 dm³. Finally, a 40 mm thick insulating foam carpet is installed on the diaphragm, on the electronics side, for better thermal insulation between the two compartments. Due to the heat from the transformer, the diaphragm radius expands from its value at 20° C up to 0.2 mm at 50 °C, while the JB shrinks because of the external pressure. To compensate for this effect the diameter of the screw holes in the diaphragm have been designed with an extra clearance

Pre Junction Box (PBS 1.1.2.004 PRE_JB)

The termination of the main electro-optical cable requires a bore of around 100 mm diameter that would imply an unacceptable increase in the stresses, if drilled in the annulus spacer. This leads us to propose an intermediate JB, made of the same alloy as the main JB, and large enough to house the socket for the plug of the main electro-optical cable ([MEOC](#)). The pre-JB also drives the optical fibres and the 5 kV wires to the electronic compartment in the JB; to provide a correct bending radius to the optical fibres (60 mm) a special bending restrictor is located inside while a blind flange at the free end is foreseen as a “hand hold” to make an easy assembly. This 'plug-in' solution has the advantage to speed up the operation during the connection of the MEOC to the JB on board; water tightness and optical transmission can also be checked by a dedicated on shore test which is planned at IFREMER. As the MEOC has a minimum bending radius of 800 mm, it would have been hard to get straight in the intermediate JB without exceeding the overall dimensions of the frame. For this reason, the intermediate box features a 90° entry of the cable.

O-ring seals (PBS 1.1.2.005)

The existing hemispherical caps feature, on their mating flange, just one O-ring groove. Insertion of the spacer annulus doubles the number of seal surfaces. To compensate for this lower reliability, we place a second O-ring, concentric to the previous one. As there is already a groove on one of the two existing caps, we use it without re-machining. Re-machining the caps is an expensive and potentially risky operation. The spacer with one groove on the surface is screwed to the cap where there is already a groove; the one with two grooves on the other surface is screwed to the cap where there are no grooves. The O-rings will be manufactured in one piece, without joints. A standard VITON O-ring, complying with all our requirements, was found but could fit only in the inner groove, machined on purpose, while for the outer O-ring, we have asked the suppliers to set up a special, custom designed mould.

Pressure balancing device (PBS 1.1.2.006)

Under normal operating conditions at the bottom of the sea, the JB shrinks because of the external pressure. Furthermore, the dielectric oil heats up and then increases its volume. The measurements performed in the hyperbaric chamber at 250 atm. have shown a volume decrease of 2.5 litres for the original 260 litres of the lower compartment of the JB. As the transformer, for cooling reasons, must stay completely immersed in its oil, the volume in the transformer compartment that can be left empty is too small and, consequently, the pressure acting on the stainless steel diaphragm would become too high.

To overcome this problem, we propose to install a balancing pipe that lets the gas-filled volume over the oil free surface (required not to have any oil expanding in the electronic compartment) communicate with the electronics compartment. The tests at operating temperature indicated that no

relevant amount of oil vapour flows through the balancing pipe. However the duration of this test was short (3 days), and due to the lower temperature of the pipe walls in the electronics compartment (30°C less than in the oil compartment), it cannot be excluded that vapour traces condense on the pipe walls and then flow back to the oil side. The routing of the balancing pipe is in principle free, with the only prescription being to drill the hole in the diaphragm right in its centre, to maximise the allowable inclination angle of the JB. As a safety precaution, the balancing pipe is equipped, at its electronics side end, with a vapour trap and a fine-mesh filter.

JB : General Considerations

Choice of Material

The existing titanium hemispherical caps are made of BT-23, an alloy common in Russia, whose properties and characteristics are summarised in the table in the introduction part, and which is known to withstand chemical attacks in sea water very well. The best choice would then have been to use the same material for the annulus spacer, but this kind of alloy requires a long procurement time, not compliant with our time schedule.

We then decided to use a standard ASTM alloy Ti 6 Al 4 V, commonly known as “titanium grade 5”, whose characteristics are very similar to those of the BT-23. While the ASTM alloy gave the same guarantees from the point of view of the corrosion in sea water, we had some concern about the electrochemical compatibility of the two different alloys in contact in salt water. However, the electrode potential of two specimens of the two alloys, proved on measurement to be very similar, so that no electrochemical corrosion is expected to happen, as described in the JB [test section](#).

No electrochemical corrosion is expected if two different metals are in contact in oil. As the two compartments inside the JB are filled with dielectric oil (transformer side) or dry gas (electronics side), we decided to manufacture the separation diaphragm in AISI 316 stainless steel, quite cheaper than titanium. Given that the diaphragm has to support all the components, AISI 316 has a higher Young modulus, implying a smaller bowing under static load.

Finally, we decided to use Viton for the O-ring seals, as it should better withstand the chemical attacks of both sea water and dielectric oil with a longer lifetime (around 20 years) compared to other elastomer compounds.

JB Structural and stability considerations

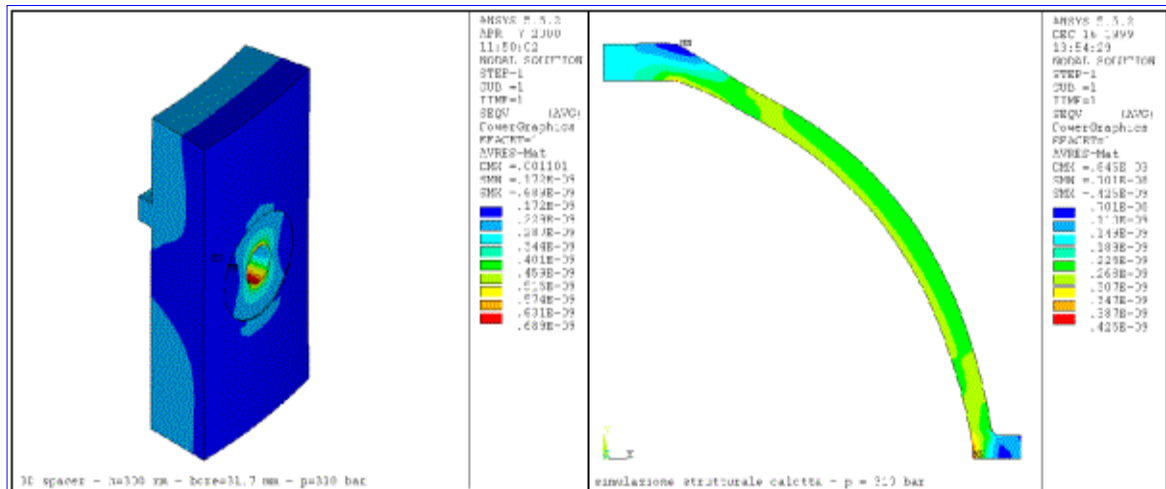
Structural stresses under test pressure load, as well as the displacements of the mating surfaces with the hemispherical caps, have been verified with a FEA model. The simulation shows that the highest stresses are just next to the penetrator holes, as expected because of the known phenomenon of stress concentration. Nevertheless, with a design thickness of 53.5 mm, the safety factor, compared to the minimum guaranteed yield strength of the material (828 MPa), complies with the requirements stated by the Italian norms for pressure vessels, both in test and operating conditions, the maximum observed stress results, in fact, below 700 MPa with 310 barg external pressure.

Furthermore, such a high thickness reduces the differential shrinkage between the spacer annulus and the hemispherical caps, as has also been verified with a FEA model down to 0.5 mm, thus minimising the friction on the O-ring seals. The screw diameter is defined so that both components could freely shrink, the friction being the only action interchanged. For the same reasons, the outer diameter and the screw holes of the stainless steel diaphragm are designed with some extra clearance.

An even better condition is found for the two hemispheres: the result of a similar FEA calculation shows in fact that the average stress in these regions is below 300 MPa with a small region close to the inner part of the diameter where a value of 425 MPa is found.

Finally, a stability check has been performed, using the formulae corresponding to the prescriptions of the main international Boards.

As a final check, we commissioned the supplier of the spacer to submit a calculation report, where a qualified engineer states that the design of the spacer complies with the structural requirements.



FEA analysis on some of the elements of the JB
left: the region close to the hole of the penetrator in the central spacer;
right: a section of the hemisphere
(click on the figure to have an enlarged view)

JB Heat dissipation

In order to evaluate the heat dissipation through the walls of the JB, we ran a FEA fluidynamics computational model. We considered a two dimensional symmetric model of the Junction Box and simulated the convective motion of the dielectric oil in two different layouts

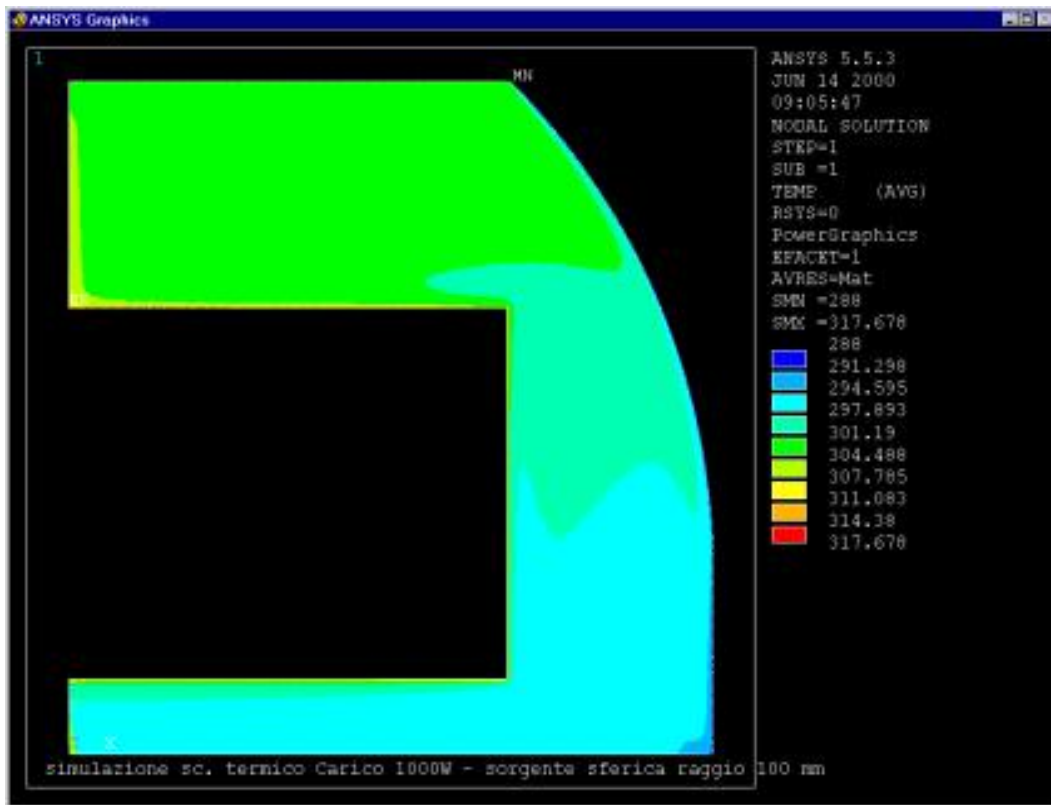
1. transformer and dielectric oil in the upper compartment of the JB
2. transformer and dielectric oil in the lower compartment of the JB

The characteristics of a standard dielectric oil for electric transformers are shown as a function of temperature in the table below.

Temperature [°C]	Density [kg / m ³]	Viscosity [m ² / s]	Thermal conductivity [W / m °C]	Specific Heat [J / kg °C]
0	889.68	9 10 ⁻⁵	0.145	1080.
20	886.78	3 10 ⁻⁵	0.143	1996.
50	867.43	10 ⁻⁵	0.140	1997.
100	835.18	3 10 ⁻⁶	0.136	2185.
150	802.93		0.131	2373.
200	770.68		0.126	2562.

Characteristics of the oil used in the simulation as a function of the temperature

In the simulation, we took into account the empty volume in the upper compartment of the JB. We then found the velocity and temperature distribution of the fluid inside the vessel; the results of the simulation showed that the heat is easily drained out through the walls of the Junction Box. As an example of the calculation, the temperature distribution for a 1kW power release at the position of the transformer, in the upper hemisphere, is displayed in the figure below.



Temperature distribution [K] of the oil inside the vessel

A maximum temperature of approximately 50 °C is obtained, for both positions of the transformer (lower or upper compartment). As transformers are usually expected to operate in the range 70-80°C, both layouts give satisfaction. When the transformer and dielectric oil are in the lower compartment, there is no risk of oil leakage through the O-ring. We therefore choose this configuration.

JB: Manufacturing, Assembly and Quality assurance

Manufacturing specification

The dimensions, the operating conditions and the characteristics of the material lead us to specify a manufacturing process whose steps are mainly casting, forging, annealing and chip machining. No welding is allowed. We also specify that the screw holes on the spacer annulus are drilled using the existing hemispherical caps as a mask, to be sure that the assembling could be done.

Quality control plan

The high quality of the materials, the tight specifications as well as the heavy operating conditions and the high reliability required convinced us to set up a quality assurance system. We then selected, already in the tender phase, only ISO 9000 qualified suppliers, that have been asked to foresee in their bids some extra tests besides the standard ones they are used to make in similar supplies. To be more precise, we asked the supplier to perform destructive (rupture and micrography) tests on specimens to check the characteristics of the material after the forging, and non-destructive (ultrasonic) tests on the forging to attest to the absence of inner cracks. A final dimensional check, that should certify the compliance with the specified tolerances, has also been requested. All the materials used are certified in compliance with the widely used ASTM/ASME standards. The most critical operations also follow those standards. We then reached an agreement with the supplier who took the order on all the details of the controls. An independent agency has been charged to inspect and report on the most critical phases of the production. The controls have been extended to the following points :

- Identification of the material
- Mill test certificates review
- Transfer of markings
- Forging
- Annealing and thermal treatment
- Mechanical test
- Micrographic test
- Ultrasonic test
- Forming test
- Final visual and dimensional check

Assembly considerations

The assembling sequence has not been completely defined, but it could be roughly broken down in the following steps:

- the stainless steel diaphragm is installed on the annulus spacer, with its O-ring and screws;
- the transformer is installed on the diaphragm, and connected to the feed-throughs;
- the oil is heated on a separate vessel to drive off the water vapour at a temperature which should be lower than 80°C.

- the pressure balancing pipe is installed on the diaphragm, with its oil trap;
- the upper hemispherical cap is installed on the annulus spacer, with its O-rings and screws;
- the assembly is inverted, to allow the installation of the other electronic components;
- the transformer compartment is filled with dielectric oil until the level reaches the specified value; the empty volume left in the transformer compartment is filled with nitrogen, flushing it through the two holes foreseen for this task in the diaphragm;
- the above mentioned holes are plugged;
- all the available penetrators (or the plugs, where no penetrator is available) are installed on the spacer annulus and the other hemispherical cap;
- the electronics supporting frame is installed on the stainless steel diaphragm; electro-optical connections are made;
- the second hemispherical cap is installed on the spacer annulus, with its O-rings and screws;
- nitrogen is flushed; the JB is closed; the **exact procedure** depends on the final solution that is adopted for the [Main Electro-Optical Cable](#) connection and termination.

Quality control is foreseen at each of the assembly steps.

JB test results

- Pressure tests
- Electrolytic currents
- Corrosion
- Heat dissipation test

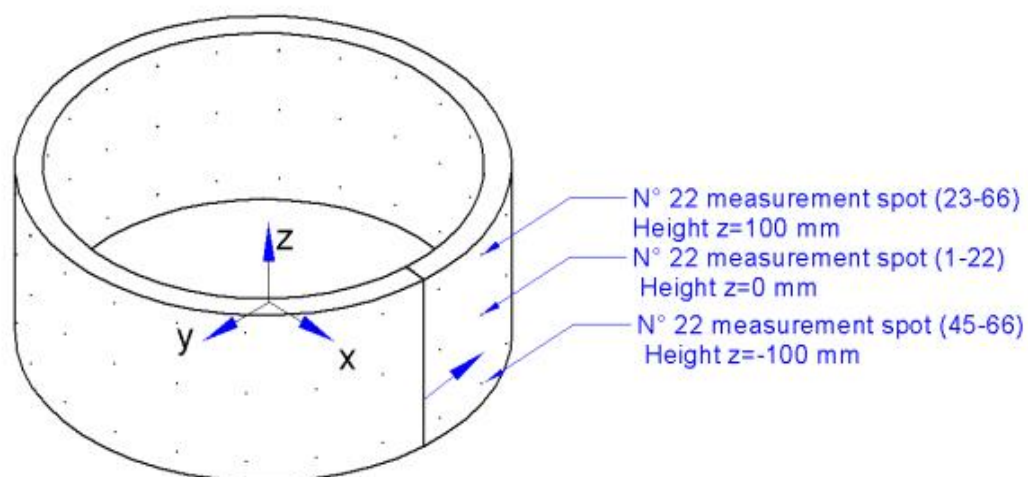
Pressure tests

In order to check the resistance and tightness of the vessel during undersea operation, a pressure test on a hyperbaric chamber has been performed.

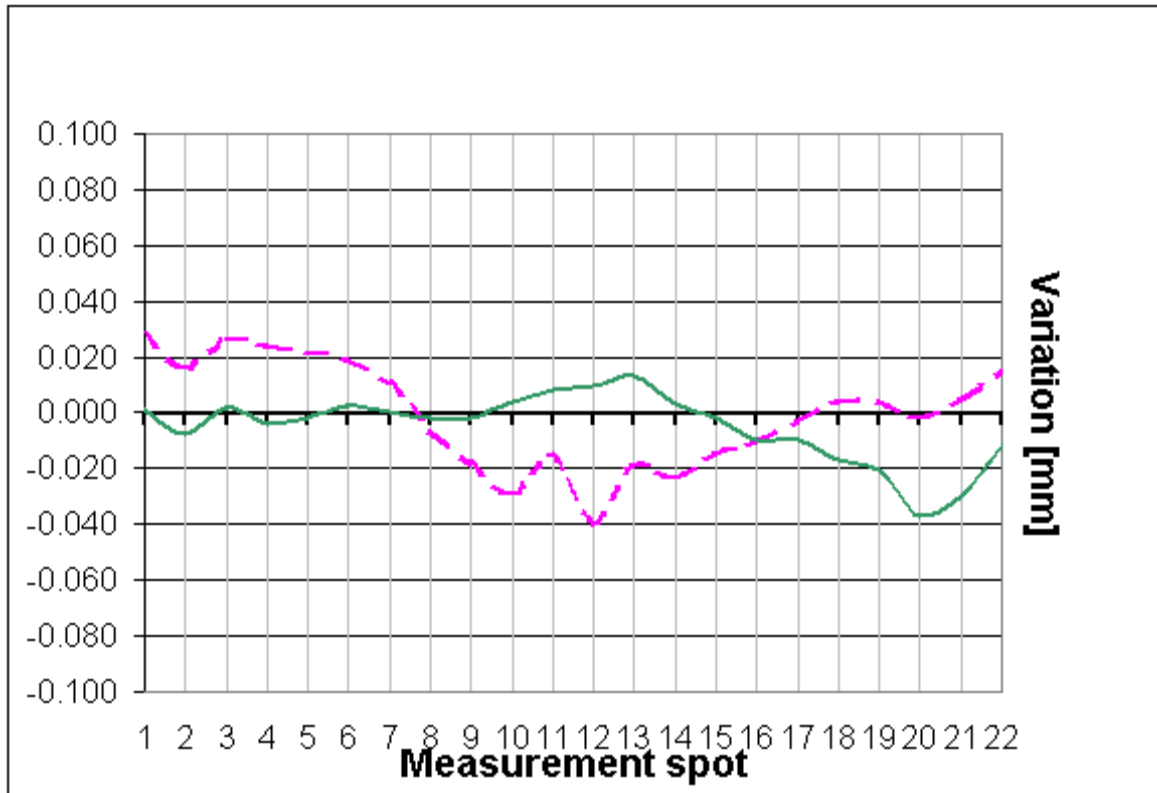
The procedure comes directly from the safety requirements of IFREMER, the company responsible for the open sea operations, concerning vessels to be deployed undersea. Properly edited, that procedure was used for the tender.

The subject of the test is a titanium vessel made of two half-spheres and an intermediate annular spacer whose overall rough dimensions are 988 mm in diameter x 1218 mm height. The pressure chamber should allow an extra-clearance of at least 50 mm on each side, to house some external equipment not foreseen at the moment, such as plugs, eyebolts, etc...

The supplier partially fills the vessel with oil prior to test, in order to protect his pressure chamber from possible implosion, but the amount of oil should fill less than 90% of the internal volume. After some investigations, we found a Company (Ringo Valve, Colico, Italy) with an hyperbaric chamber well suited for our test.



Distribution of the spots in the annulus



Results of the test in the hyperbaric chamber

Relative position variation for the different spots after the static (dashed) and the dynamic (continuous) test

The test programme is carried out in two stages: static test at 310 atm. and dynamic test at 256 atm. in that order. During both tests the operating values of pressure and temperature have been recorded. An example of the results of the test is shown in the two figures above. The upper one represents the distribution of the 66 points which have been spotted in the spacer to have an evaluation of possible inelastic distortions during the test. In the lower figure, the relative variation (mm) of the position of the spot after the static test (dotted) and the dynamic test (continuous) is presented. The observed values, < 0.04 mm are of the same order as the resolution of the instrument (0.01 mm), are very small; their ratio with respect to the radius, $0.04/450.$, indicates no evidence of inelastic deformations.

Electrolytic currents

The JB is made with two slightly different titanium alloys: BT-23 for the hemispheres and Ti 6 Al 4 grade 5 for the spacer. Possible galvanic currents between the two alloys can be created in the sea environment. To measure this effect, we performed the following tests:

- a pair of electrodes composed of silver and the Ti BT23 alloy were placed in a glass cell filled with sea water.
- the pair of electrodes was connected to a voltmeter over a 10 k Ω resistance.
- the reading of the meters was recorded for a period of 30 days.
- the same procedure was applied in parallel to another pair of electrodes composed of silver and the other Ti 6 Al 4 alloy.

The voltage between the two Ti alloys is compatible with zero for most of the time, indicating no

evidence of galvanic currents.

Corrosion

A small sample of titanium grade 5 was immersed in sea water for a period of two months: the test compared the material before and after immersion. The following procedure was adopted:

1. a thin slice of titanium grade 5 was machined to produce a 3mm hole in the centre
2. the sample was observed with 2 μm resolution using a confocal microscope with laser scanning
3. the sample was immersed in a 3% NaCl water solution for a period of two months
4. the sample was re-scanned in the same region and the results were compared to the measurements in step 2.

No clear evidence of corrosion effects was seen after immersion. We deduced an estimated corrosion rate of less than 0.25 mm in 10 years, limited by the resolution of the scan.

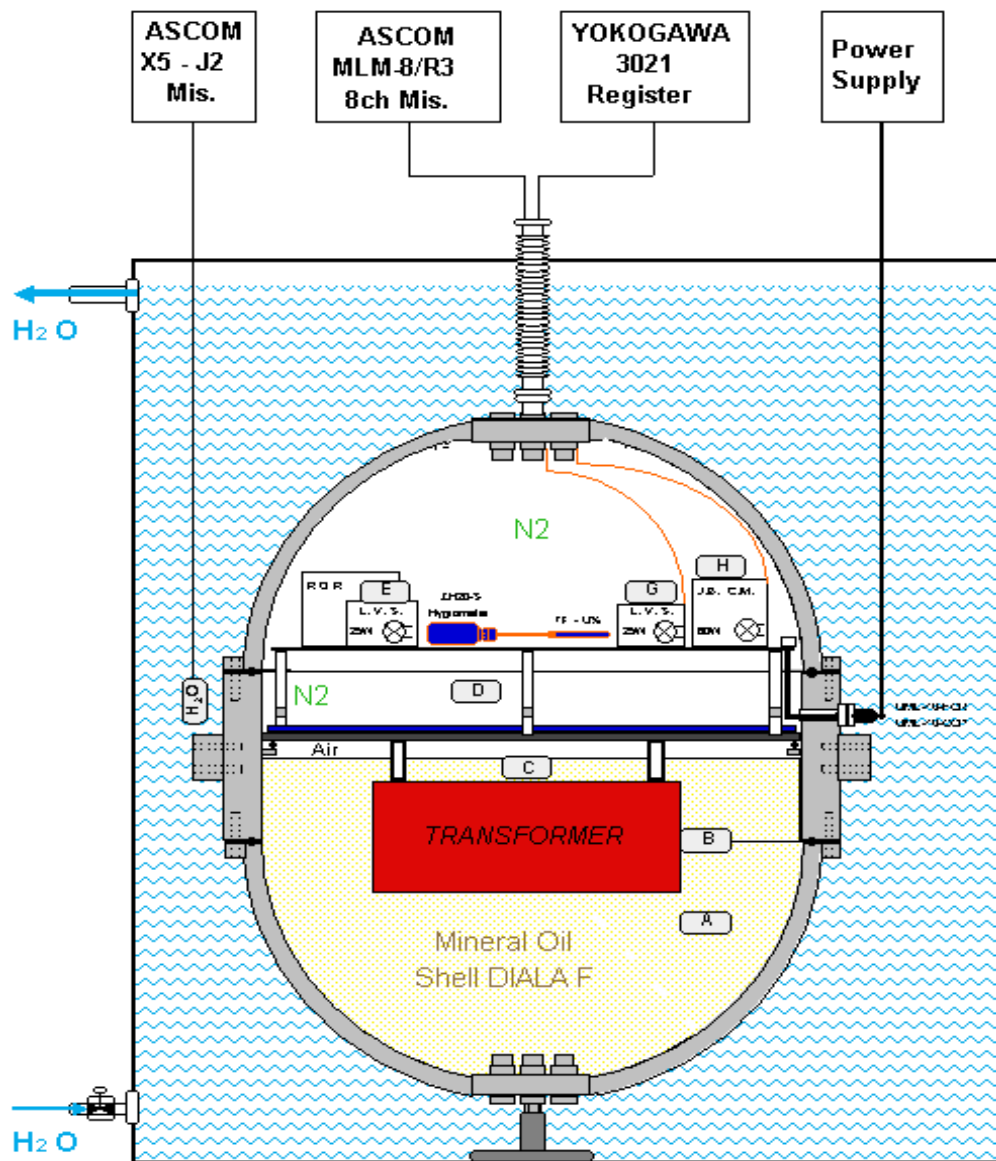
Heat dissipation test

The different active components housed inside the JB produce a total amount of heat greater than 1 kW. In particular, the transformer is expected to dissipate 1250 W during working conditions while an average value of 100 W is produced by the electronics. It is therefore important to guarantee a good heat dissipation in order to avoid damage to the instrumentation due to local overheating. To investigate this effect we have performed a test using the titanium container equipped with different heaters and immersed in a water bath at constant temperature to simulate the real conditions. The general layout of the apparatus that has been mounted in our laboratory in Genova is shown below. This set-up includes:

- A stainless steel disk of 800 mm diameter and 15 mm thickness to separate the transformer and electronics compartment. The disk is sandwiched between the large flanges present in the hemispheres; on the side which faces the electronic compartment, a 40 mm thick foam has been fixed to prevent heat transmission from the transformer region.
- A box of 300 x 300 x 500 mm made of a 3 mm thick copper sheet with dimensions very close to the real transformer, fixed by a support at 50 mm from the disk; this clearance is necessary to insulate the transformer from surrounding metallic components. Both the inner part of the box and the volume of the region are filled with 100 litres of mineral oil (Total Fina “Diekan1640”) using an external tube connected to one of the three holes already present in the top of the hemisphere. The remaining two holes are used for exhaust and to power the heaters;
- Six flat heater resistors of dimension 20x200x1 mm located in the inner part of each side of the box; each resistor is supplied with 250 V AC to give a power of 200 W: the total amount of heat released in the box is therefore 1200 W as in the 40 kVA transformer.
- A detailed mock-up of the electronics to simulate the real conditions. This mock-up includes a frame to hold the electronic components and three boxes with heaters inside to produce the 100 W expected during operation. Copper braids were also used to thermally connect these boxes to the titanium container.

In order to monitor the temperature at different locations, 7 platinum resistors are placed in the system: three in the lower hemisphere where the transformer is located (A,B,C), one in the region above the separation disk (D) and three in the boxes which simulate the electronic components

(E,G,H). To improve heat dissipation these boxes have been connected with copper braids to the titanium sphere which is expected to have the same temperature as the water outside (13°C). To monitor possible water leakages, a humidity sensor was also placed in the frame. The sensors (PT100 mod) are read out by an Ascon controller module MLM-8/33, that scans up to 8 different channels.



Vessel Volume 1800 l.
Cooling Water Volume 1042 l. - J.B. Volume 758 l.

The experimental apparatus for the heat dissipation test

The JB was placed in the middle of a big cylindrical tank containing 1500 litres of tap water maintained at constant temperature in the range 12 +/- 1.5°C by a chiller. The same temperature was measured in the seawater at 2500 m depth in the location where the JB will be positioned: we are therefore confident to simulate the real conditions of the experiment.

When all the parts of the system had reached the temperature of the water, we switched on the power and recorded the temperatures in 5-30 minute intervals up to the equilibrium value. The results of this test are very promising. The temperature in the transformer region is below 60°C even at the full power (1200 W): this value fits well the required conditions of the transformer. There is clear evidence that the foam disk insulates the two regions: in fact the temperature of the

sensor D located immediately above does not change significantly with respect to the different loads in the transformer (1200 W, 800 W, and 0 W). In contrast, an average temperature of 55° C is found in the boxes (sensors E,G,H). A reduction of this value would strongly improve the lifetime of the electronics. A study of a more efficient geometry to improve heat dissipation in this region is ongoing.

The Junction Box list of objects

The Junction Box (JB) is the heart of the ANTARES detector. It receives Power from the onshore [Power Hut](#) via the Main Electro-Optical Cable ([MEOC](#)) and distributes it to the strings via the Interconnecting Links ([IL](#)). Data, Clock, Trigger and Control signals also transit via the JB through the same cables.

Components are separated into [mechanics](#), [electronics](#) and [power](#) aspects and each of these aspects is described separately in the corresponding chapter.

Since it is the first detector system we build, to be installed in the sea, it has the first PBS number. The associated PBS numbering has been fixed by the collaboration organisational structure (starting with 1 for mechanics, 2 for electronics and 6 for power). A list of the components can be found below.

- **PBS 1.1 Junction Box: mechanics part**

PBS1.1.1	JB Frame	
PBS1.1.2	JB Container	
PBS1.1.2.001	JB Vessel	2 Ti hemispheres and 1 cylind. spacer
PBS1.1.2.002	JB Diaphragm	separates the transformer to the electronic volumes
PBS1.1.2.003	Feed-throughs	transmit power and diagnostic (7)
PBS1.1.2.004	PRE-JB	holds penetrator for connection to EO cable
PBS1.1.2.005	JB O-ring	
PBS1.1.2.006	Balancing device	
PBS1.1.3	Acoustic Beacon support	
PBS8.1.5	LBL Acoustic Beacon	gives the position of the frame

- **PBS 2.4 Junction Box clock distribution and trigger construction**

PBS2.4.001	JB_ELECBOX	contains electronics boards
PBS2.4.002	JB_SPLIT1	passive splitters for clock distribution
PBS2.4.003	JB_TRIG1	RoR signal construction
PBS2.1.013	UNIV1	Daughter board plugged on other board for slow control MODBUS interface

- **PBS6.4: Junction Box (Power part)**

PBS6.4.1	Penetrators and bulkhead receptacles
--------------------------	--------------------------------------

PBS6.4.2	Power components
PBS6.4.3	Power Remote diagnostic
PBS6.4.4	Very Low Voltage Power Supply
PBS6.4.5	Cabling and Connections
PBS6.4.6	Sensors
PBS6.4.7	Remote Control

links to TDR

- [Junction Box Mechanical Description](#)
- [Electronics Power Distribution](#)
- [Electrical Power system](#)

PBS 1.2 The Bottom String Socket (BSS)

[General description](#)

[Connection and release of the BSS structure](#)

[On board instrumentation](#)

[SCM/SPM containers](#)

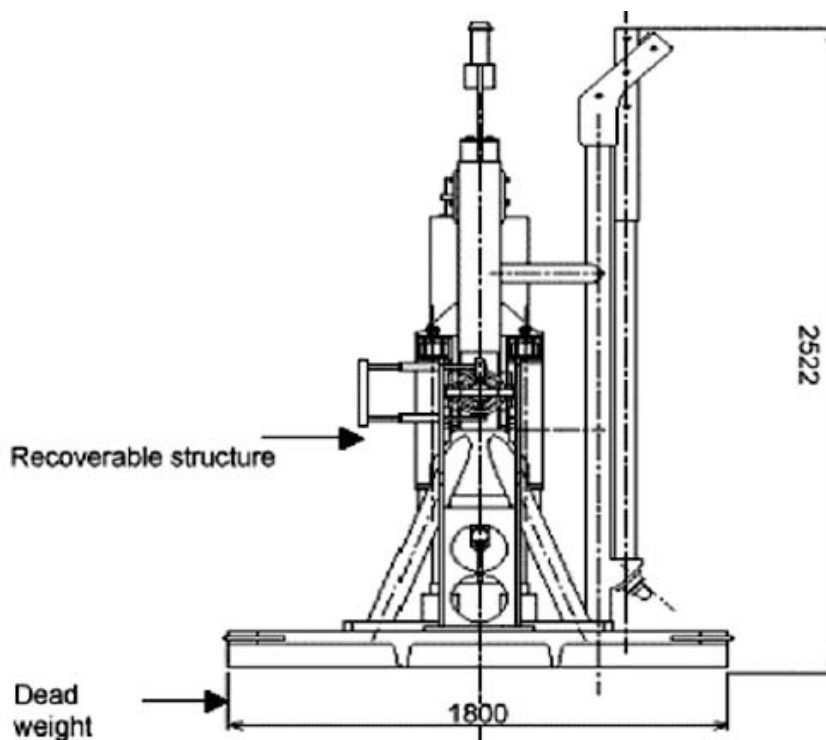
[The choice of material](#)

[Design rules](#)

General description

The BSS is the system which anchors each line of the detector to the sea bed. Each line has its own BSS connected with an electro-optical interconnecting link (IL) cable to the Junction Box. After deployment, a Remote Operated Vehicle (ROV) will connect the interlink cable to the BSS and the JB. The recovery of a string is achieved by the release of part of the BSS: the reduction in weight allows the string to rise towards the sea surface. This anchor consists of a recoverable structure and a dead weight, linked by a redundant acoustic system; the dead weight is lost at each line recovery.

BSS schematic design of the components



The BSS performs various functions including:

- the anchoring of the string to the sea bed;
- the release of the string;
- the support of the String Control Module (SCM) and the String Power Module (SPM);
- the connection to the junction box.

During deployment operations, the structure should facilitate precise string installation. It must therefore be optimised in terms of deployment and immersion with respect to:

- handling on the installation ship;
- resistance to shock;
- stability during its descent towards the sea bed and final landing.

In order to position the string at a predefined geographical location with a precision of a few metres, a dynamical positioning vessel is used for the deployment, together with an acoustic beacon on the BSS. This beacon is part of the acoustic release device whose requirements include accuracy and reliability of the acoustic signal [Low Frequency Long Baseline system](#).

After deployment, the SCM must be connected to the Junction Box. This connection is performed on the sea bed by means of a cable equipped with an underwater electrical connector. The BSS is designed to allow operations with the remotely operated submarine vehicle (ROV).

The dead weight is heavy enough to maintain the string on the sea bed. Its geometry gives the stability necessary to define a “fixed point” for the acoustic positioning ([High Frequency Long Base Line system](#)). An upward-looking hydrophone is fixed at the top of the recoverable structure to minimise of shadowing and reflections. The BSS must be able to release the string on a command from the surface, for maintenance reasons or in case the ROV encounters difficulties. The separation of the recoverable structure from the dead weight is assured by a redundant acoustic release device. The electronic and acoustic parts of the device will be made from commercially available products.

The dead weight should be made of inexpensive material (e.g., steel) since it is lost after recovery of the string. However, the interface with the recoverable structure must be resistant to corrosion to avoid any risk of unintentional release of the string. The BSS structure and its components must be resistant to salt water corrosion and to damage caused by gripping devices and by chafing. The weight in water of the BSS must be less than 3000 kg; this gives a cable safety factor of at least 6 (the ratio of the ultimate tensile load of the cable of 18000 kg, and the BSS weight in water).

All the tubes and the cavity of the BSS structure are open (hole) for hydrostatic pressure equalisation, which is desirable for any material, and for galvanisation where required. The line cable can move by 30° from the vertical without interfering with instrumentation or over-bending the cable at its end. For the BSS stability, the height of the line cable fixture is minimised, and the horizontal size of the dead weight is maximised. A 5kPa pressure is tolerated on the sea bed without excessive subsidence. The typical subsidence of the present design is estimated to be around 20 cm.

During the recovery phase, the string must rise vertically at a speed of 0.7 m/s, which is the lowest vertical speed acceptable to avoid interference between the released string and the neighbouring strings. We must consider 3 different configurations of the BSS:

1. Full line configuration (30 storeys);
2. Deployment test configuration (5 storeys without electronics);
3. Prototype sector line configuration (5 storeys with electronics).

Both the dead weight and the recoverable structure have different weights in these three configurations:

Configuration 1	Weight in water
BSS Structure	1400 kg
BSS anchor	1570 kg
Configuration 2	
BSS Structure	360 kg
BSS anchor	2640 kg
Configuration 3	
BSS Structure	430 kg
BSS anchor	1600 kg

Connection and release of the BSS structure

The connection between the BSS anchor (dead weight) and the BSS (recoverable) structure must be sufficiently rigid to withstand the following forces:

- the force during the connection of the cable by the ROV;
- the forces applied to the line by the sea currents: around 120 kg;
- the weight of the anchor during deployment (2640 kg in the deployment test configuration);
- the buoyancy of the string during operation (200 kg).

Release of the dead weight induces the automatic disconnection of the interconnecting cable, allowing the string to rise. This action may be required for different reasons:

- maintenance of the string;
- possible accident with the ROV requiring the release of the line.
- end of the detector life

The second point indicates that reliability is very important for the release system. In particular, the following specifications must be met:

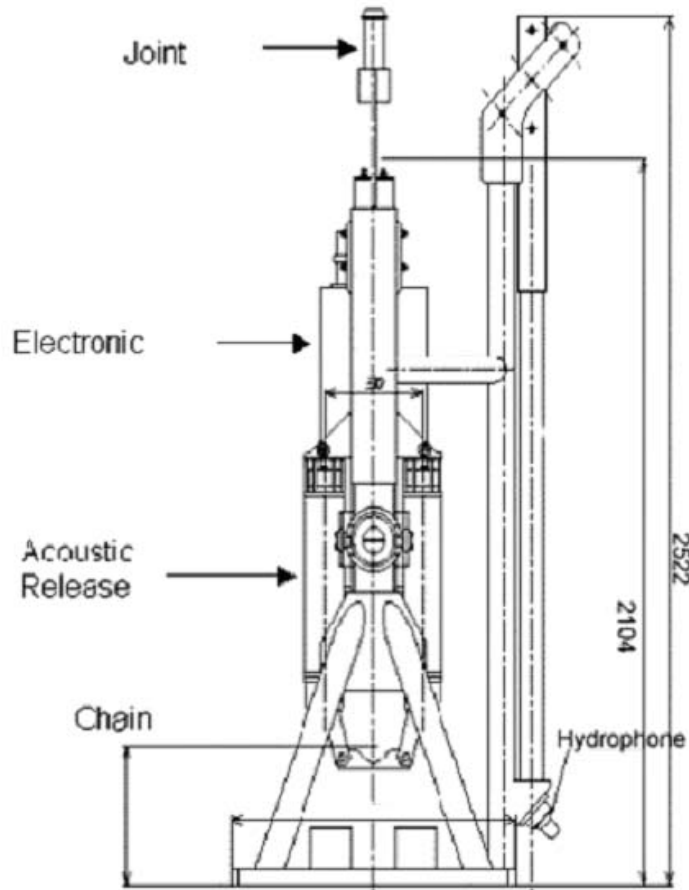
- The Interconnecting Link Cable must have negative buoyancy to avoid snagging.
- The BSS structure design must minimise the risk of trapping.
- The release system must include redundancy.
- The design of the release system must be compatible with a long period of operation in the sea water environment (10 years).

The present design of the BSS prototype is compatible with both of the connectors under consideration. The connector will be mated in a single horizontal motion. The minimum height of the connector above the sea bed is about 700 mm. The connection procedure is:

- Mate the connector (up to the lock) by horizontal motion/action and with the link at 45 degrees on the top.
- Move the side-lock to the left: the connector assembly is then free to rotate around its axis.

- Move/restore down the connector assembly.
- Restore the side lock to its initial position (to the right): the connector assembly is then locked in its bottom position where it is ready for automatic release.

The disconnection of the electro-optical jumper is automatic during the release of the line. The solution adopted in the present design includes a support fixed to the dead weight where the connector is housed: when the line is released the female part, which is directly linked to the BSS structure, is automatically disconnected by the traction of the line. After the release of the line, the rest of the interconnecting cable stays on the sea bed. This part must remain in the support and will be recovered by the ROV during the connection of a new line which will be installed in the vicinity..



Recoverable structure

On board instrumentation

The BSS must provide the mechanical support for several types of instrumentation. In particular, each BSS contains (cf [BSS objects PBS](#)):

- An [acoustic RxTx hydrophone](#)
- A [pressure sensor](#)
- A [sound velocimeter/CTD](#)

A [Laser Beacon](#) is present in the BSS of the instrumented line only.

The hydrophone support is made of 2 parts, one fixed in the structure and the other one mounted on top of the first one just before deployment. In the figure above, the hydrophone is shown in its folded position. Some conditions are necessary to ensure proper functioning of the acoustic hydrophone:

- No large metal part in the vicinity to avoid acoustic reflections;
- A hydrophone position as high as possible to avoid reflections off the ground.

SCM and SPM containers

All devices listed above are connected to a titanium container, the String Control Module ([SCM](#)) which contains all the electronics for the instrumentation and the detector line. The corresponding power supply is hosted in the String Power Module ([SPM](#)).

Both containers will be assembled in a "flat twin" shape thanks to a central junction part ([SPM-SCM](#)), where both the Electro-optical jumper and the EMC cable penetrate. This configuration allows an easy electrical interconnection between both containers. The SPM will be on the top and the SCM on the bottom in order to minimise the heat transfer by convection between the SPM (warmer) and the SCM (colder). The instruments of the BSS will be fed by 3 or 4 connectors, depending on the actual line (cf instrumentation section), which will be mounted on the SCM end cap at the bottom of the assembly. From the mechanical point of view, the design of both containers is close to the one of the [LCM container](#): same tube cross-section, same end caps shape and same set of rods. The exact length of the tubes, around 800 mm still need to be defined.

The choice of material

The cable end, a part of the chain, and the containers for the electronics systems are made of [titanium grade 2](#). The main structure and the dead weight are built with E 360 (UNI – Fe 690). The acoustic releases are also made of titanium grade 2, except for the deployment test, where they are in duplex stainless steel (*UNS32550*) – Model [MORS AR661B2S](#)

The insulator is made of ME730/ Vm EM2; this is a massive epoxy compound, where the glass fibre is not a web (“roving”) but a mat. As a consequence, this material is isotropic and can be machined. Its ultimate stress in perpendicular compression at 20°C is about 45 kg/mm². Its ultimate stress in traction at 20°C is about 28 kg/mm².

Design Rules

The parts made of different material are assembled via an electric insulator (plastic or composite material) to avoid any kind of galvanic corrosion problem. The insulator is present in:

- the chain;
- the connection system for the EMC;
- the connection system for the electronic containers (SCM and SPM);
- the connection system for the acoustic beacon;
- the connection system between the SCM and the Junction Box.

In addition to insulation, zinc sacrificial anodes are welded to the iron (less noble) parts of the structure. IFREMER has evaluated both the amount and spatial distribution of the material needed to guarantee a protection for a period of 10 years.

After machining, the structure will pass through the following acceptance tests:

- check horizontal equilibrium without the dead weight;
- check horizontal equilibrium with the dead weight;
- vertical load on the joint system: 2.25 x recoverable structure + 2.25 x dead weight;

In addition to these insulators, sacrificial anodes will be connected to the steel structure after the

deployment test according to the IFREMER procedures. A sea acceptance test will be performed at the end to check the deployment and release of the BSS. (A dry test of the acoustic release will be performed before the sea test, if feasible.)

SPM and SCM containers and connection

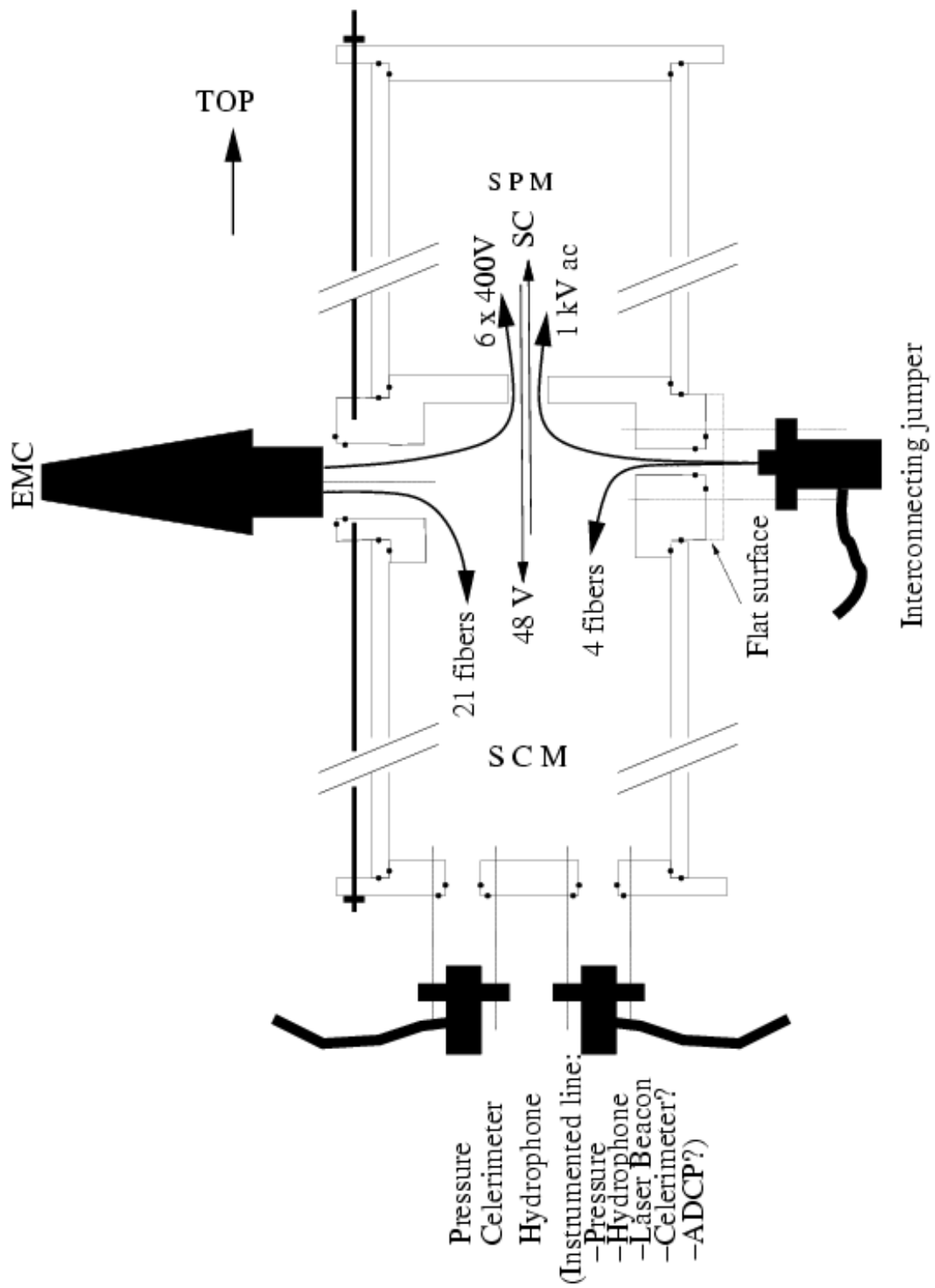
The SCM container and the SPM container are coupled by an intermediate titanium sleeve that provides the internal path for a 12-wire electrical cable, the SPM-SCM Link.

Specifications

The geometrical configuration and connection of these containers must satisfy the following requirements:

- The SCM and SPM must have the following connections for power transmission:
 - 1 kV ac input power from the penetrator of the Electro-Optical jumper for power transmission (one pair)
 - 6 x 400 V output power from the SPM to the EMC penetrator (9 conductors)
 - 48 V SCM power from the SPM to the SCM power box (one pair)
 - SPM control from the SCM to the SPM (one twisted pair)
- Noise from the high voltage (1 kV AC) should be avoided near the electronics boards of the SCM. To this extent, the central junction included a diaphragm reducing the thermal and EM perturbations between the SPM and SCM, with a hole in the centre for the conductors.
- The path of the optical fibres should be as short as possible. A possible solution drives the 21 + 4 optical fibres to the SCM in a way very similar to the top of the LCM: here the central junction plays the role of the LCM top end cap.
- The SCM is also connected to a velocimeter, a RxTx hydrophone and a pressure sensor. On the Instrumentation Line, a laser beacon is also present.

A possible configuration of the SCM and SPM is shown in the figure below:



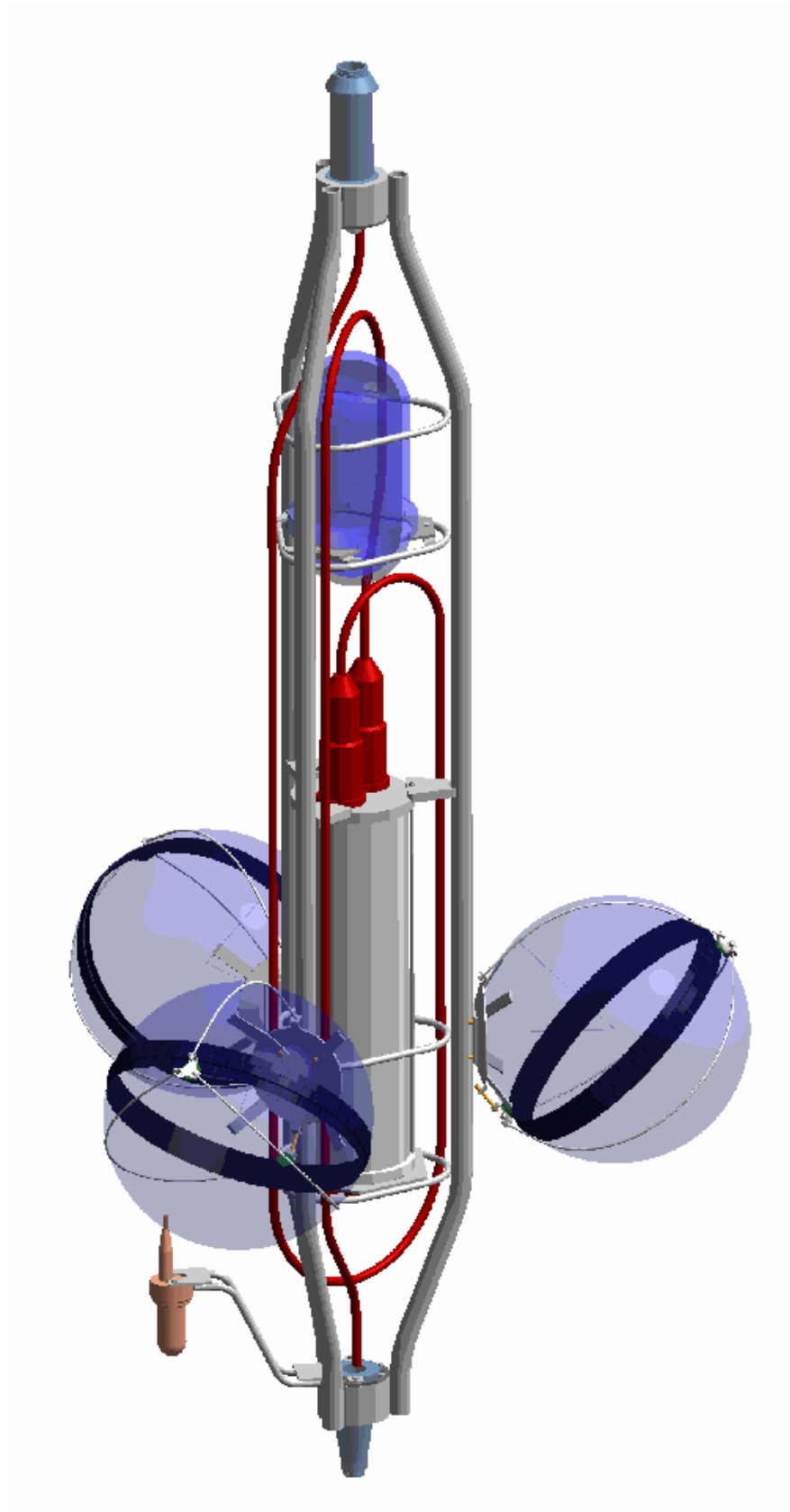
PBS 1.2: BSS objects

Object in subsystem	Description	PBS number
Structure	recoverable part of the BSS	1.2.1
Dead Weight	unrecoverable part of the BSS	1.2.2
RX_Hydrophone support		1.2.3
Pressure sensor support		1.2.4
Sound velocimeter support		1.2.5
SPM/SCM Container		Hosts the Power components and String Control electronics
SCM tube		1.2.6.1
SCM end cap		1.2.6.2
central junction part		1.2.6.3
SPM tube		1.2.6.4
SPM end cap		1.2.6.5
SPM/SCM Container Support		1.2.7
RXTX_Hydrophone	for acoustic positioning system	5.1.2.2
Pressure sensor and cables		5.1.4
Sound velocimeter and cable		5.1.5
BSS_release_Transp	system to link/release the Structure from the Dead Weight	8.1.2

PBS 1.3 The storey

The **storey (or floor)** is the subsystem in the line where three OMs are held together on an Optical Module Frame (OMF), which is the main support frame of the storey. Power is distributed to the photomultipliers, and electronics signals are received and locally processed inside the Local Control Module (LCM), which is located in the centre of the OMF. Positioning and calibration devices are also held in position on the OMF. The mechanical frames and supports are described in individual pages that can be accessed by clicking in the table below. The objects that can belong to a storey are also included in the table, although they are described in other sections.

List of objects	Description	Presence in Storey	PBS number
OMF	Structure of the Storey	all	1.3.001
LCM Container	- Contains the LCM_CRATE with all LCM electronics boards - Receives 6 penetrators /connectors	all	1.3.002
LCM support	Support of LCM	all	1.3.003
OM support	Support of OMs	all	1.3.004
hydrophone support	Support of hydrophone	1/sector	1.3.005
OMF interface with EMC	Interface device carrying cables	all	1.3.006
LED Optical beacon support	Support of LED Beacon	1/sector	1.3.007
LCM	All objects inside the LCM container	all	2.1
OM	Optical Modules	3/storey	4.
hydrophone	Acoustic positioning system	1/sector	5.1.1.2
LED Optical Beacon	LED calibration system	1/sector	5.3



Schematic view of a complete storey
You can click on a detail to get more informations

PBS 1.3.001 : Optical Module Frame

Schematic view of the Optical Module Frame



The Optical Module Frame (OMF) consists of an axial structure that links the cables located above and below the [storey](#). This structure looks like a cylindrical cage, enclosing the LCM container and the LED Beacon calibration device placed in the upper part of the cage. The hydrophone used for acoustic positioning is fixed underneath the cage. The calibration devices, LED Beacon and hydrophone, are not present on every storey.

The three Optical Modules of the storey are supported by metallic rings on three arms fixed near the bottom of the cage (cf [OM support](#)).

Specifications

- 3 main pipes positioned at 120° intervals on a circle of diameter 350 mm
- two sleeves (above and below) with 115 mm outside diameter and 85 mm inside diameter
- 4 triangular reinforcements.

Functions

The OMF supports the components in the storey:

- 3 Optical Modules, each oriented 45° down from the horizontal plane, separated by 120° in azimuth
- 1 Hydrophone (in some storeys)
- 1 LED Optical Beacon (in some storeys)
- 1 LCM container

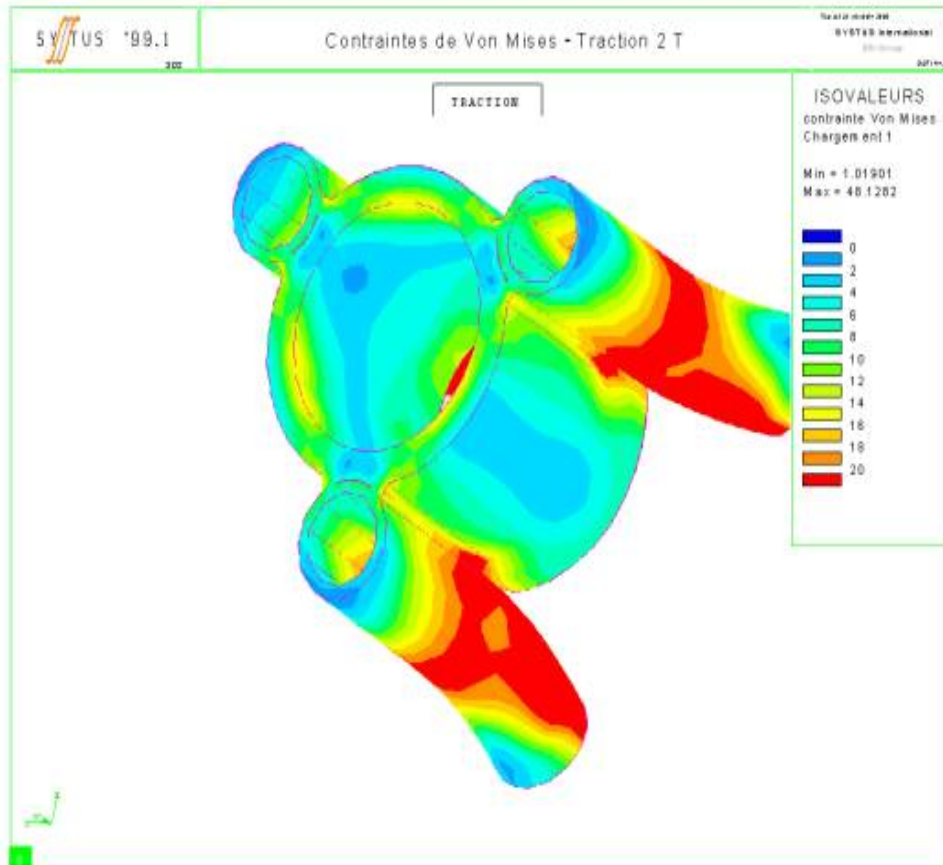
The OMF also ensures the mechanical interface (link and stress transmission) with the two electro-mechanical cables located above and below the frame. The design was finalised after detailed studies described in technical note [3OMF 01 02 A](#).

Dimensions, technological features:

- The OMF is 2.335 m long (2.12 m without termination) and 400 mm in diameter. The pipes have an outer diameter of 33.4 mm and a thickness of 3.38mm. The reinforcements have a diameter of 12 mm.
- The selected material for all parts of the OMF is titanium T40. All parts are bent and welded.
- Only the sleeves are machined in order to have the best adjustment with the extremity of the two electro-mechanical cables. On each sleeve, two half rings (like circlips) support the weight.
- The maximum stress in the structure is 50 MPa (see hereafter).

Mass and weight of equipped OMF:

	Mass (kg)	Weight (N)	$g \cdot \rho_{\text{water}} \cdot V$ (N)	Buoyancy (N)
Optical Module	19.3	189.2	421.8	+232.3
OMF	25	245.1	78.5	-166.7
LCM	27	264.7	1156.9	-107.8
Total without cable				+ 421
EMC (10m)	10.5	102.9	78.5	-24.5
EMC (100m)	75	735.3	588.6	-147.1



**Calculation of the maximum stress in the structure
for a maximum load of 20000 N**

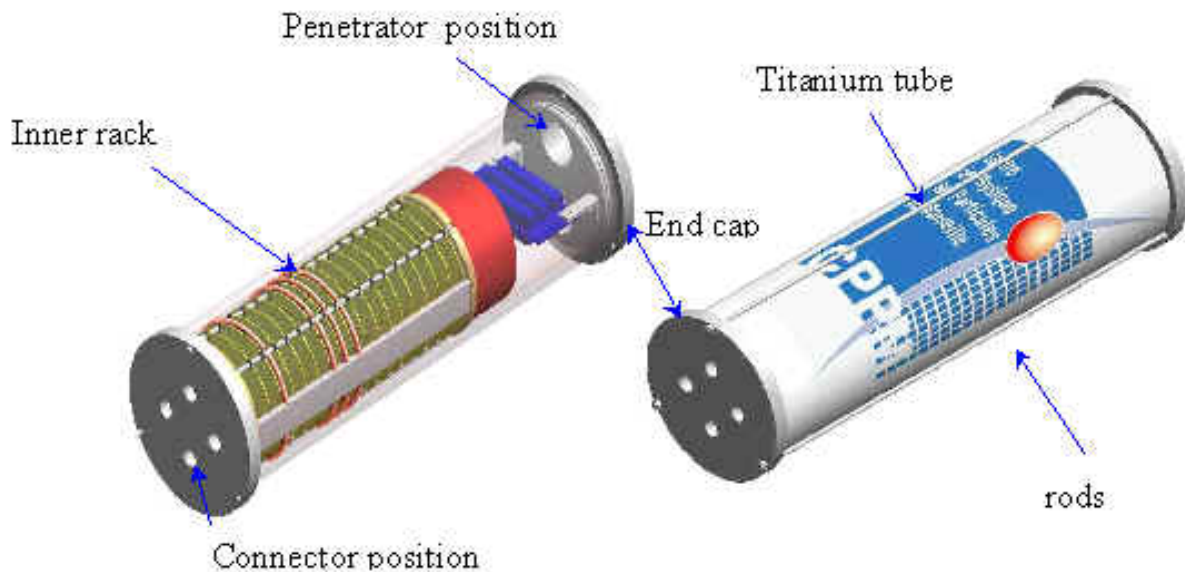
Associated Technical Notes:

<http://antares.in2p3.fr/internal/decim2/tableaux/OMF.htm>

- [3-OMF-01-05-B](#) : OMF structure

PBS 1.3.002 : LCM_CONTAINER (in OMF)

The LCM container is cylindrical, made of one tube and two flat endplates and contains electronics boards. A schematic view of the container and its inner electronics rack is shown in the figure below.



Schematic view of the LCM container

Interfaces:

Cables (electrical and optical) enter the container at both endplates.

- The Optical Modules and the instrumentation (hydrophone, LED Ball Optical Beacon) are connected to the lower endplate. The optical module link is connected on the LCM by a Subconn bulkhead socket with 12 female gold-plated contacts. Characteristics are described in the document [3 OMS 02 05 B](#). The [RX HYDRO BULKHEAD](#) (PBS 5.1.1.3) is mounted on one LCM end plate (one per sector) (cf [line schematics](#)).
- The upper flat endplate receives the two EMC cables, one coming from the LCM below and one coming from the LCM above (cf [EMC](#) cable and bulkhead descriptions).

Requirements :

- The LCM container is immersed into sea water at about 2500 m depth
- After detector immersion, the external temperature is stable around 13°C, the external pressure is 256 bars while the internal pressure is atmospheric.
- The container has to withstand an immersion of 10 years, without any loss of its performance.
- In addition, its material must be non-magnetic; titanium alloy has been chosen.

Dimensions, technological features:

- Tube inner diameter: 157 mm
- Tube external diameter :179 mm
- Tube length : 600 mm
- End cap diameter : 199 mm
- End cap thickness : 30 mm
- End cap hole diameter for connector : 21 mm
- End cap hole diameter for penetrator : 50 mm
- Set of 3 rods diameter : 6 mm
- Set of 3 rods length: 670 mm
- The thickness of the tube depends on the yield stress of the selected material. For TA6V alloy, a thickness of 11 mm is sufficient.
- Every metallic part of the container is machined. In order to reduce the sensitivity to buckling, the cylindrical form must stay within +/- 0.2 mm. These tolerances are not realistic for composite materials; consequently, safety factors related to buckling risk will be more severe in this case. Both inner and outer diameters must be chamfered.
- Obviously, water tightness is the main requirement for this container. Two O-ring seals are used on each end. They are mounted on the endplates and press on the tube. To get the best efficiency for the seals, the bearings are machined precisely: the surface finish is about 0.8 μm and the gap between the edge and the tube diameters is less than 80 μm .

Calculations performed

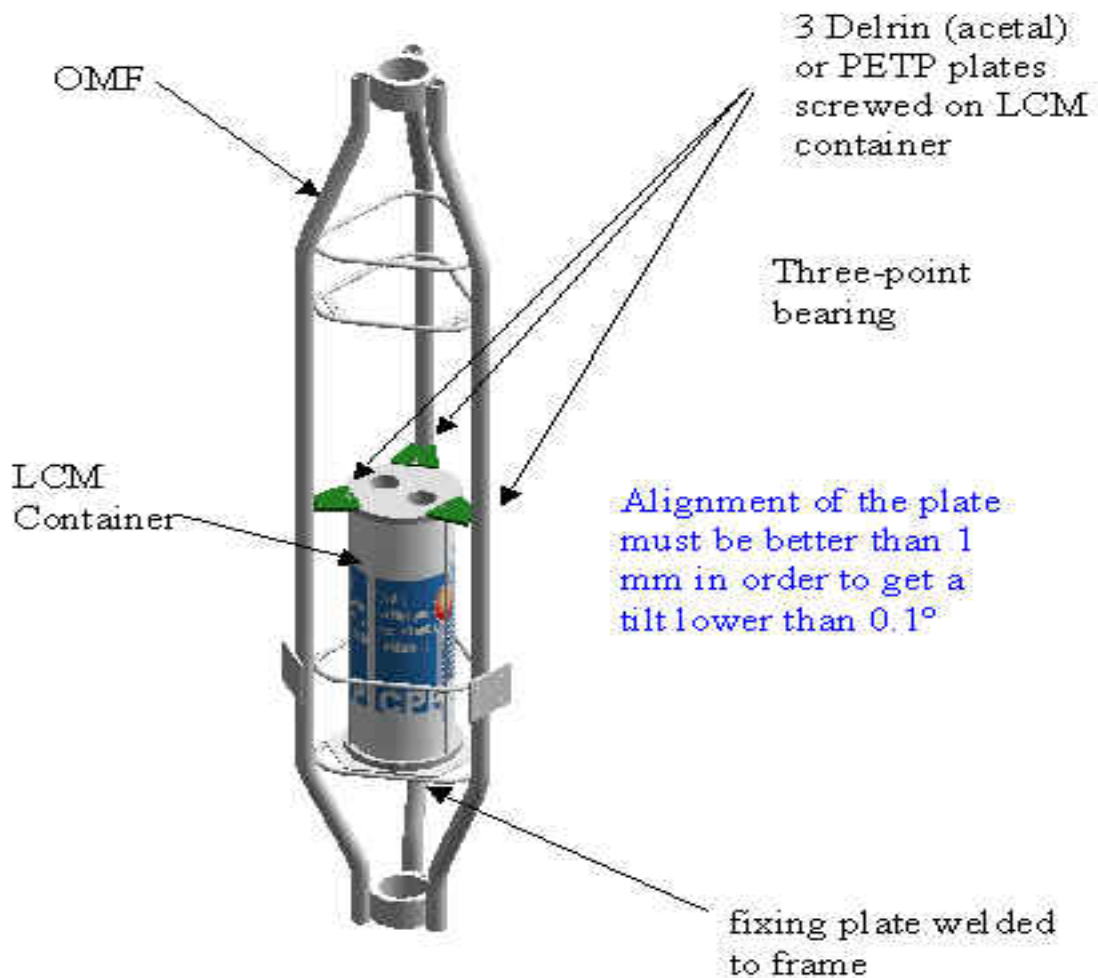
FEA calculations have been performed in order to define the dimensions of the metallic container and the endplates. A few prototypes will be made as soon as the design is finished. They will be qualified by a high pressure test.

- [3 LCM-01-00 A](#) Specification of titanium container
- 3 LCM-01-01 A LCM Container
- [3 LCM-01-02 B](#) Bottom endcap - version 2
- [3 LCM-01-03 B](#) Tube - version 1
- [3 LCM-01-04 B](#) Tube - version 2
- 3 LCM-01-05 A Descriptif du conteneur LCM
- 3 LCM-01-06 A Titanium tubes - Test report
- [3 LCM-01-07 A](#) Etanchéité
- 3 LCM-01-09 A Pénétrateur
- 3 LCM-01-10 B Dummy of penetrateur
- [3 LCM-01-11 A](#) Conteneur LCM
- [3 LCM-01-12 A](#) Bottom endcap - version 1
- [3 LCM-01-13 A](#) Top endcap - version 1
- [3 LCM-01-14 A](#) LCM version 1
- [3 LCM-01-15 A](#) Screw rod
- [3 LCM-01-16 A](#) Top endcap - version 2

- [3 LCM-01-17 A](#) LCM version 2
- 3 LCM-01-18 A Dummy of connector

PBS 1.3.003 : LCM support (inside OMF)

Schematic view of the LCM support



Requirements

- The LCM container is located on the axis of the support cable, in a vertical position
- It is fixed at one end inside the cage of the OMF.
- Fixation components must be resistant to a force of 800 N in air and 400 N in water. This includes the LCM weight with a safety factor of ~ 3.

Dimensions, technological features:

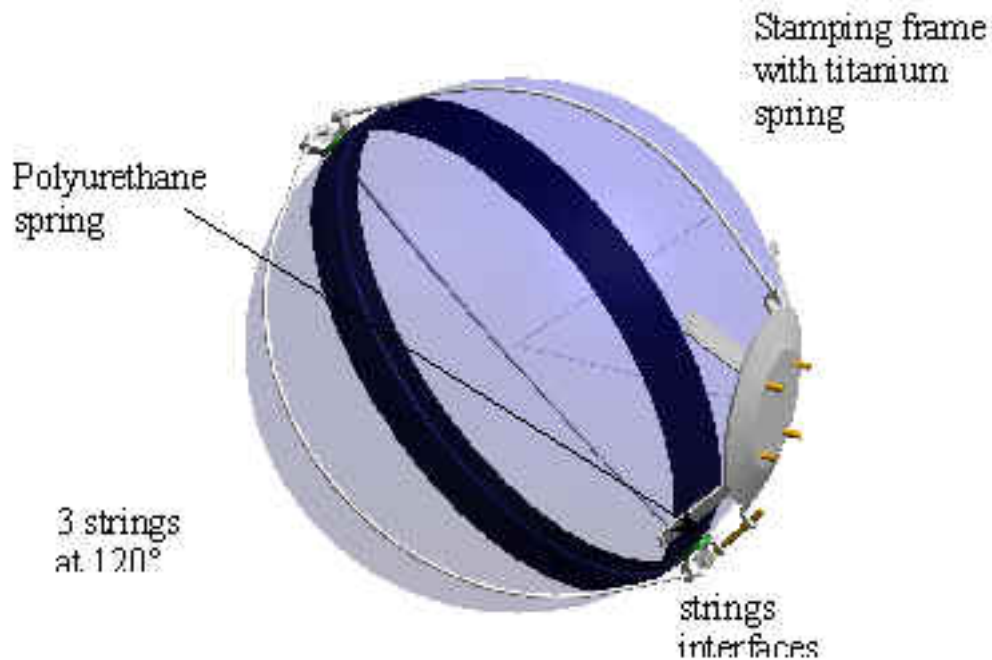
- Tube external diameter : 179 mm
 - End cap external diameter : 199 mm
 - Total length : 636 mm
-

List of references

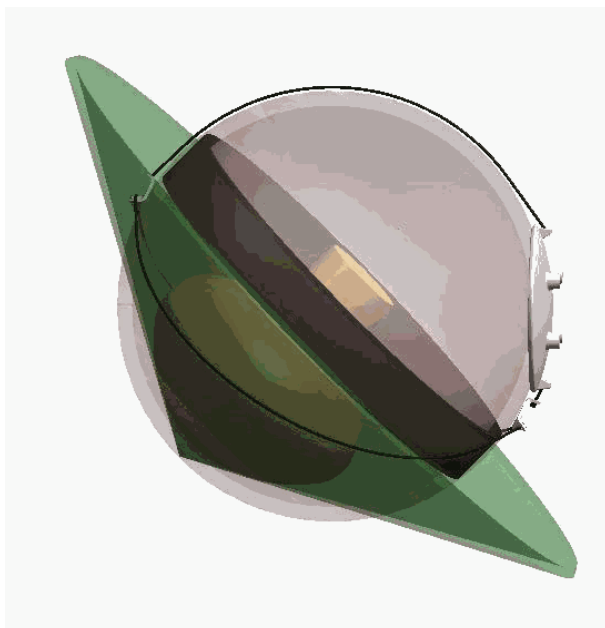
<http://antares.in2p3.fr/internal/decim2/tableaux/OMF.htm>

- [3-OMF-01-05-B](#) : OMF Structure
- [3-LCM-01-20-A](#) : Alignment pin
- [3-LCM-01-21-A](#) : LCM upper fixation

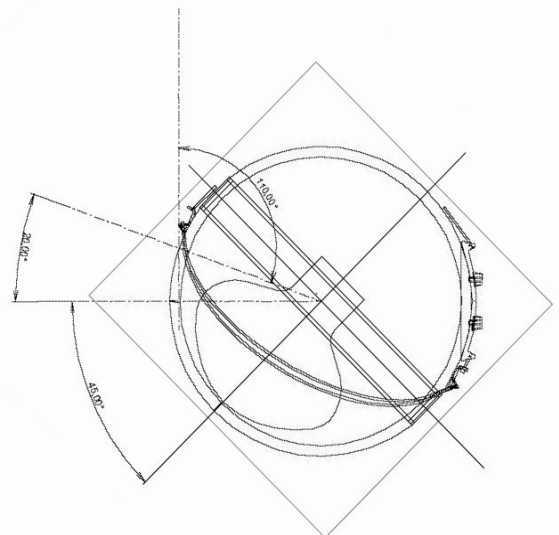
PBS 1.3.004: Optical Module support



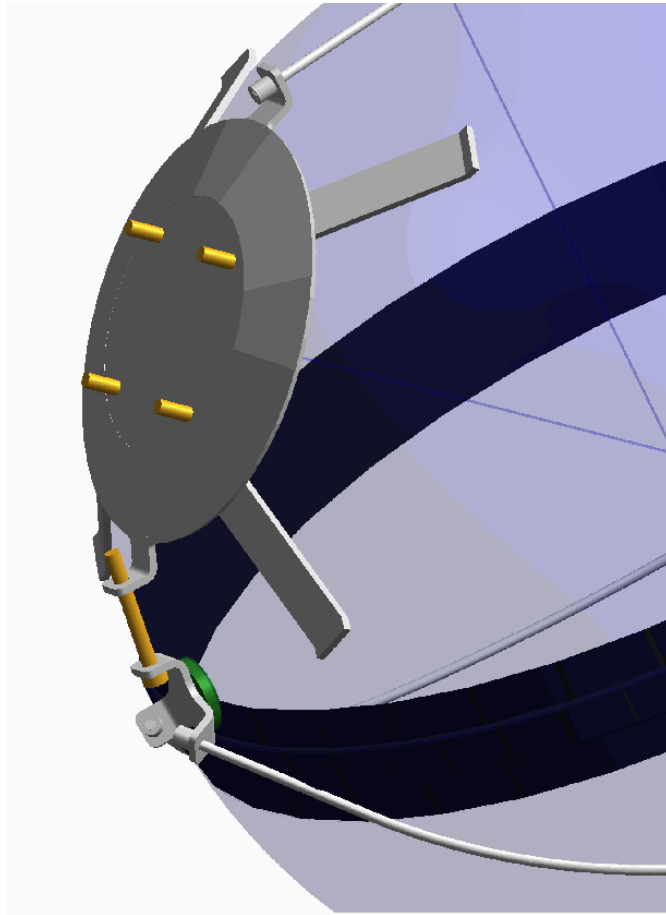
The Optical Module is held inside a ring using three flanges equipped with polyurethane springs. These springs allow a gentle contact between the flanges and the Optical Module, and accommodate the deformation under pressure of the glass sphere (decrease of diameter is 1.25 mm at 2500 m depth). Three metallic strings are tightened on the surface of the sphere, at 120°, and ensure that the Optical Module is held correctly



120° PMT area



45° OM slope



[Titanium tightening system](#)

Requirements

- The main mechanical function is to support the weight of the OM.
- Each OM arm must support a weight of 740 N in air and a buoyancy of 640 N in water.
- Three Optical Modules are oriented at 120° , the axis of each photo-multiplier being tilted by 45° with respect to the downward vertical.
- The distance between the frame axis and the sphere centre is 410 mm.
- The angular aperture must reach $\pm 60^\circ$ from the axis of the PMT.
- A safety factor of ~ 3 is included, which takes into account extra stress occurring during deployment or handling.

Dimensions, technological features:

- Mounting frame (stamping frame) diameter: 165 mm
- String diameter: 4 mm
- Total string length: 449 mm and 2 x 667 mm
- Titanium material for corrosion resistance

Associated Technical Notes:

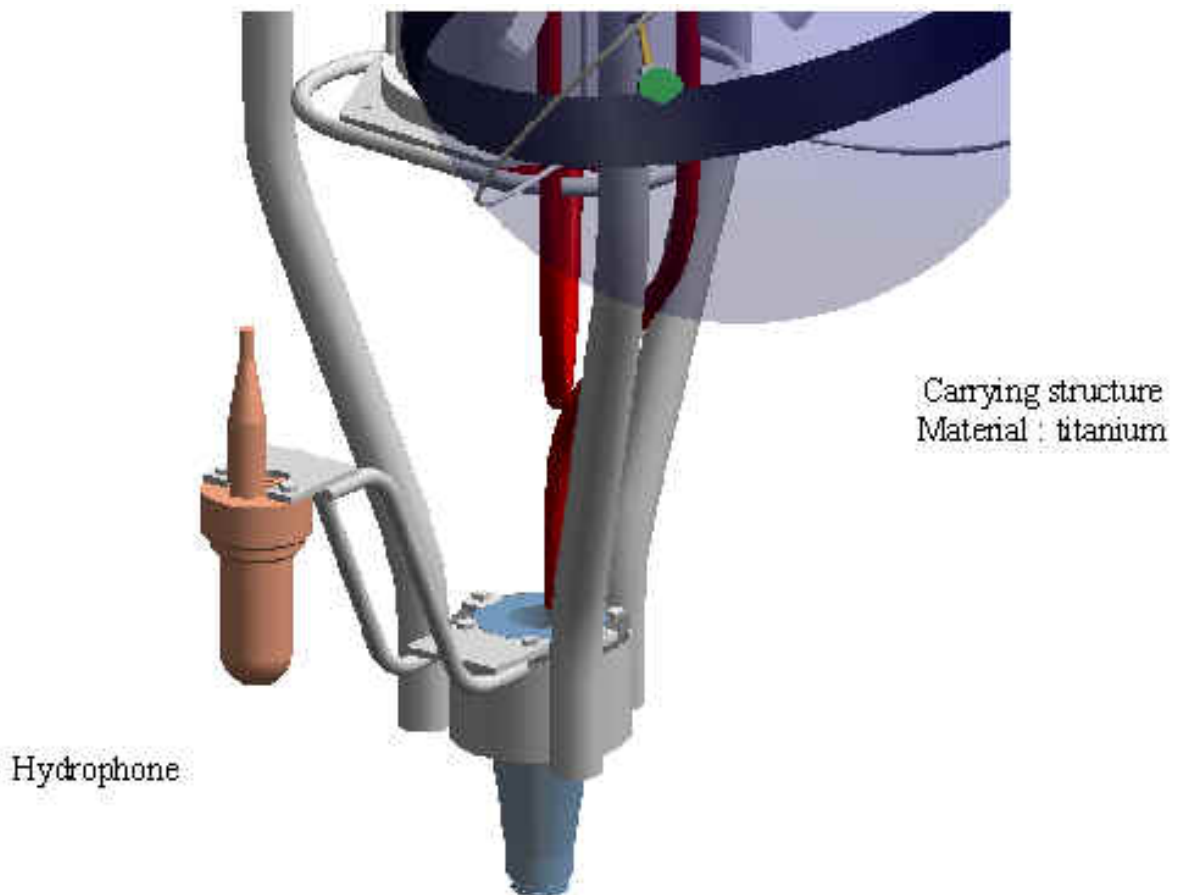
[3 OMF-02-01 A](#) Ensemble de fixation de MO

PBS 1.3.005: Hydrophone support

Introduction:

The hydrophones belong to the [acoustic positioning system](#) of the lines. They measure the position compared to beacons placed on the sea-bed and communicate by ultrasound and communicate by ultrasound (40-65 kHz). There are 6 hydrophones per line.

Specific tests have been performed in order to define the best position of the hydrophone and to evaluate the acoustic perturbations caused by the surrounding structure. The location of the hydrophone in the OMF has been chosen in order to avoid any masking between 0 and 60° with respect to the vertical, and to avoid important acoustic reflexion on the glass spheres.



A schematic view of the Hydrophone support

Description :

- The support is made with two titanium pipes of 12 mm diameter, which are bent and welded on two titanium screws.
- The hydrophone is fixed on the support with 2 titanium screws

- The support is fixed by two fixations points on the two half rings with the same screws used for the fixation of the termination.

Requirements :

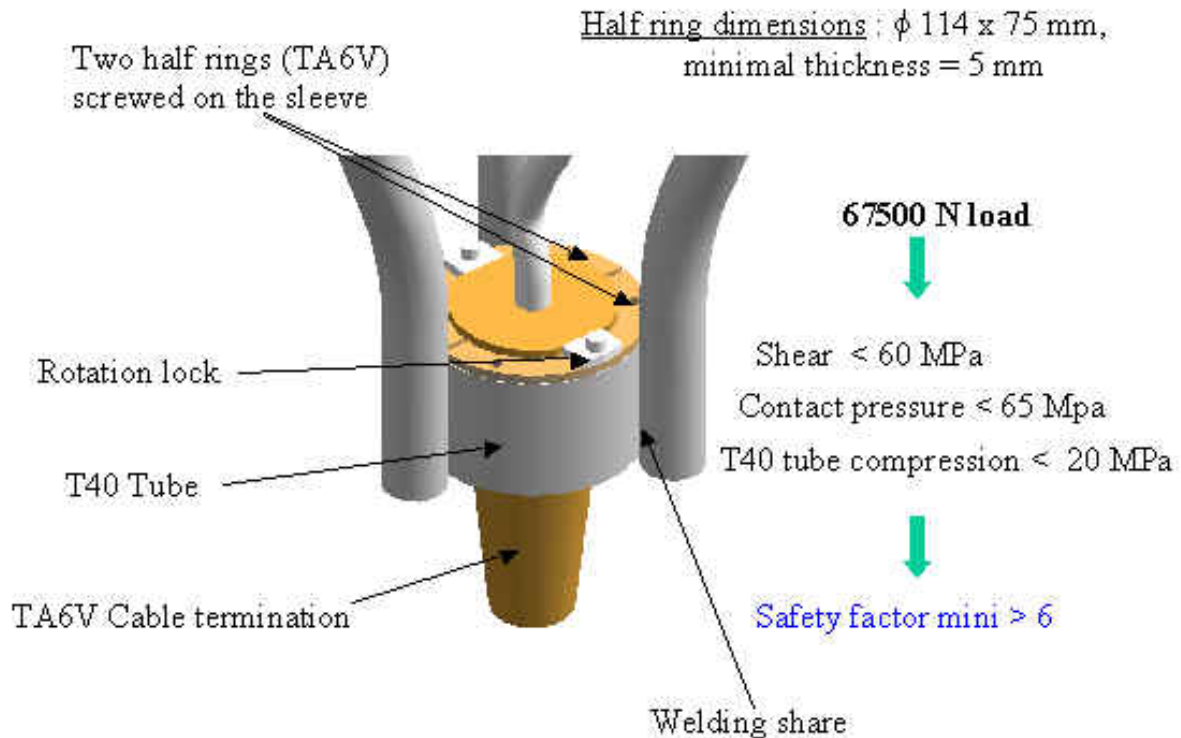
- The hydrophone is placed underneath the Optical Modules, looking downwards.
 - The positioning system must be able to support the hydrophone in a stable position on the structure.
 - To minimise shadowing and reflections, it is necessary to locate the hydrophone as far as possible from the other components : Optical Module, LCM Container and above all, the titanium termination of the Electromechanical Cable.
-

References:

- [3 INS-01-07 B](#) Système de positionnement acoustique Base Longue
- 3 OMF-03-01A Bride de l' acoustique

PBS 1.3.006: OMF Interface with carrying cables

The Electro-Mechanical Cable is the only link between two adjacent OMFs. The mechanical termination of the cable must support all the strains and the top edge of the interface must match the special form of the cable deployment tool.



Specifications

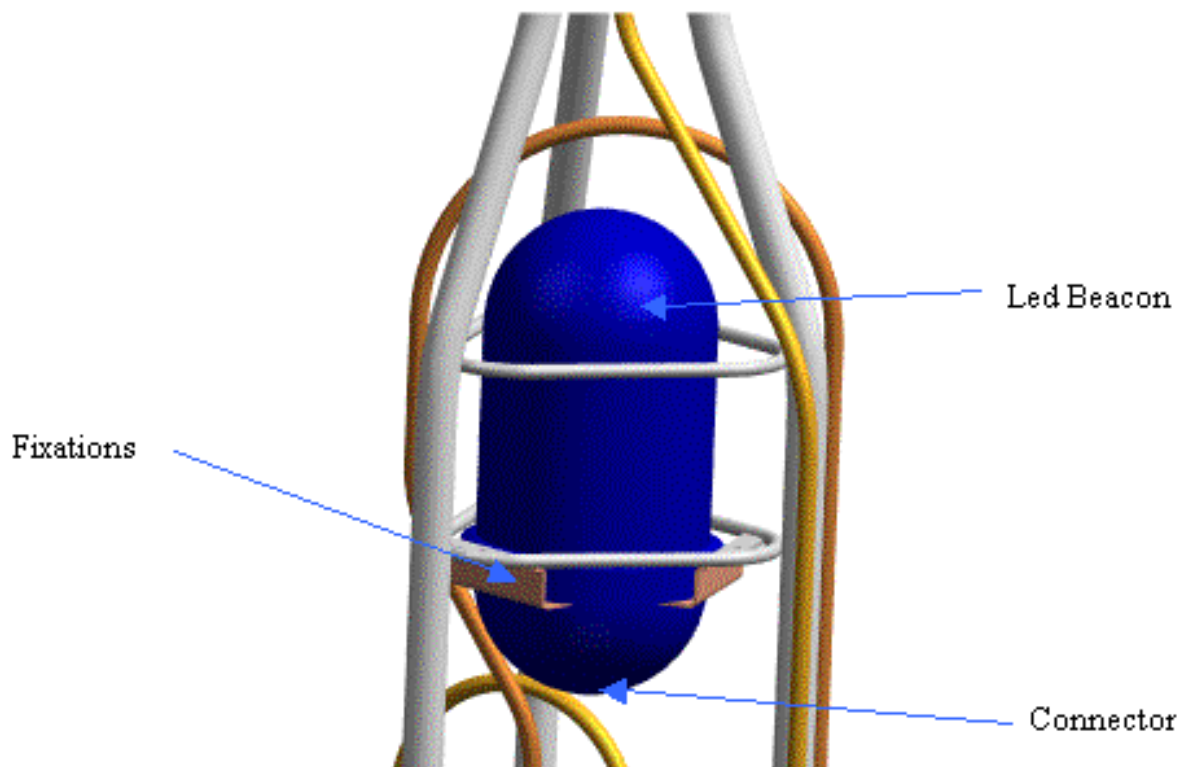
- 2 half rings are screwed on the OMF with two rotation locks.
- All parts made of TA6V.
- The ultimate tensile strength must be larger than $3000 \times 9.8 \times 1,5 \times 1,5 = 66190$ N.
- The special shape of the top part was designed to fit with the deployment tool (top interface only).

References:

- [3 LIN-01-01B](#) Specifications
- [3 LIN-01-04B](#) Data Sheet Electromechanical cable (EMC) for sector line
- [3-LIN-03-01A](#) : Rotation lock
- [3-LIN-03-02A](#) : Half ring
- [3-LIN-03-03A](#) : Calculation Note of the Cable Termination

PBS 1.3.007 : LED Optical Beacon Support

The [LED Beacons](#) are used for the [calibration](#) of the lines. They are equipped with LED light sources placed in a cylindrical glass container. These LEDs produce a horizontal ring of light to ensure that all Optical Modules on neighbouring strings are illuminated. The LED Beacon is placed in the OMF, above the LCM and is linked to it by a Beacon [cable](#).



Schematic view of the LED Beacon

The optical emission by the LED Beacon is mainly in the horizontal plane, the aperture angle being 70° from equator to the top and 45° from equator to the bottom of the sphere. The structure produces little additional shadowing.

A high pressure test with 310 bars external pressure is performed, whereas the internal pressure is atmospheric, prior to mounting on the OMF.

Dimensions

The glass cylinder of the LED Beacon has an outer diameter of 187 mm and is 250 mm long. It has 2 hemispherical end caps. The overall dimensions are 210 mm outer diameter (with the fixation ring) and 443 mm length.

The LED Beacon is maintained in the vertical position by a ring and a plate fixed on the OMF. The electrical connector is on the bottom of the LED Beacon.

References:

- [3 INS-03-02-A](#) : LED Beacon container preliminary specifications
- [3 INS-03-03-A](#) : Specifications and design of the optical beacon
- [3 OMF-04-01 A](#) : LED Beacon support

PBS 1.4 Cables in the detector

Most of the cables used in ANTARES are electro-optical cables, which transport high voltages and provide the optical fibres for the control of the detector and the transmission of data.

The Main Electro-Optical Cable ([MEOC](#)) links the Power Hut on shore to the Junction Box. The JB and the strings are connected via the Interconnecting Link cables. In a given string, a 100 metre piece of Electro-Mechanical cable connects the BSS to the lowest storey in the string, and each storey is connected to the next one by 10 metres of EMC, until the top floor. The penetrators, connectors and bulkheads on each end of the cables are described in the following cable sections.

PBS1.4.1 [Interconnecting Link \(IL\)](#)

PBS1.4.2 [Electro Mechanical Cable \(EMC\)](#)

The electrical cables connecting the OMs, the LED Beacon and the positioning instruments to the local LCM, which provide the power locally on each floor, are described in the relevant sections ([OM-LCM link](#), [BEACON_CABLE](#), [Acoustic Reception module](#)).

On shore, there is an optical cable (the Shore Link) which connects the optical fibre outputs from the MEOC to the Shore station, which is 4 km away at la Seyne sur Mer.

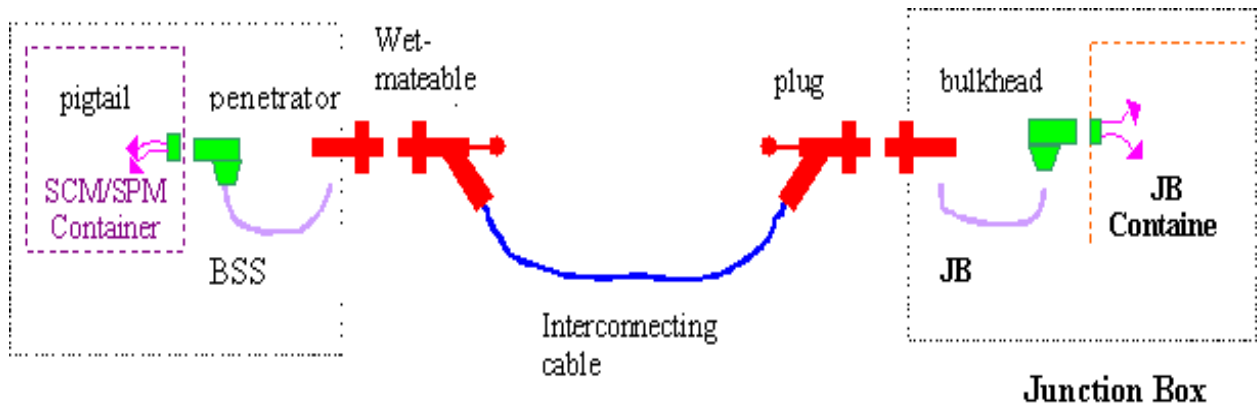
PBS 1.4.1 Interconnecting Link (IL)

The Interconnecting Link designates a group of cables, and their connectors, which link the Junction Box to the strings to transfer power, data and other signals. The distances involved necessitate the use of optical fibres for signal transmission. The undersea connections are made using the remotely operated submarine vehicle (ROV). An automatic disconnection can be controlled remotely by the string release system. The link cables are terminated by electro-optical wet-mateable connectors at each end.

Description

To facilitate ROV access, the connector is not placed on the container (JB and SCM or SPM) but on the periphery of the frame. Therefore, the Interconnecting Link is composed of 3 parts : 2 jumpers fixed on the BSS and the Junction Box and an interconnecting cable between the frames. The jumpers are composed of a penetrator fixed on the container, linked to the bulkhead of the wet-mateable connector by an equipressure cable. The interconnecting cable is composed of a length of cable (dry or equipressure cable) terminated at each end by the plug of the wet-mateable connector.

Schematic view of the Interconnecting Link



General specifications for the Interconnecting Link

Composition: This link has 4 optical fibres and 2 electrical wires :

- 2 fibres for Data/SC transmission
- 1 fibre for Clock distribution
- 1 fibre for Trigger/Readout Request signals
- 2 wires for power distribution

Optical characteristics

- Attenuation : 0.2 dB/km at 1550 nm and 0.36 dB/km at 1310 nm
- Dispersion coefficient : < 18 ps/nm.km at 1550 nm and < 3 ps/nm.km at 1310 nm

Electrical characteristics

- Nominal voltage : 1000 VAC
- Intensity : 5 A maximum
- Wire sections : 2 mm²

Material: All metallic parts in contact with sea water are in Titanium alloy TA6V (or grade 5).

Specific characteristics

Wet-mateable connector

The plug is connected under pressure by a ROV. The plug has a specific handle and a mechanical latch for automatic disconnection. A visual system ensures that the plug is properly connected during installation. The mating force of the connector is less than 300 N and the demating force less than 400 N. The maximal allowed number of connections/disconnections without maintenance is 100. The electrical characteristics are described above and the optical attenuation of the optical contact is < 0.75 dB.

Every plug can be connected with every bulkhead without performance degradation.

The cable exits the plug at 45° and at right angles to the bulkhead.

Penetrator

The penetrator is equipped with a water blocked system to avoid water entry in the container from the cable end. It is fixed on the container by 6 screws. There are 2 O-ring seals for water tightness between the container and the penetrator.

The electrical and optical characteristics are the same as for the connector. The cable exit is at right angles. The optical fibres in the pigtail are equipped with the OPTOCLIP II connector from Deutsch Company. Each fibre has a protective sheath of 1 mm diameter.

BSS Jumper

This jumper fixed on the BSS is roughly 2 m long and the pigtail on the penetrator is 30 cm long. The electrical wires terminate without connectors.

JB Jumper

The Junction Box has 16 jumpers for the 10 detector lines, the instrumentation line and spares. All jumpers will have the same length of 2.5 m. The electrical wires terminate without connectors.

Interconnecting Cables

The cables are laid on the sea bed and connected by the ROV (cf [sea operations for IL](#)). The cable characteristics required by the submarine operations and the deployment procedure are :

- Total weight in water < 500 N
- Breaking load of the cable < 5000 N (for the safety of the ROV)
- External diameter of the cable < 20 mm
- Cable weight heavy enough to lie on the sea bed
- Small minimum bend radius < 200 mm

These cables have different lengths because of the string implementation on the sea bed (cf [layout of the strings on the sea bed](#))

Table of lengths

Line number	Length in m
Instrumentation line	350
Lines 1, 2, 5, 6	300
Lines 3, 4, 9, 10	240
Lines 7, 8, 13, 14	180
Lines 11, 12	120

PBS 1.4.2 The Electro-Mechanical Cables (EMC)

The backbone of the line consists of an Electro-Mechanical Cable (EMC) linking neighbouring storeys (EMC/T) and linking the first storey to the BSS (EMC/B). A standard segmentation structure (sections) based on identical elements has been chosen.

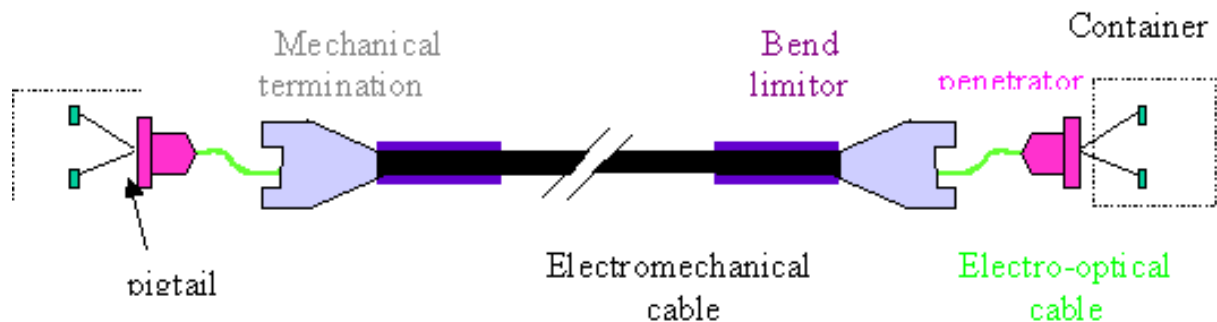
The **EMC cable for the instrumentation line** should be similar to those for the detector lines.

DESCRIPTION

This cable ensures the mechanical link between all floors of the string. It must be able to withstand the tension, torsion and flexion induced in the string. It must also resist the external water pressure, mainly in term of water tightness, and resist corrosion during a lifetime of 10 years.

The cable also transfers the electrical and optical signals between the elements of a string. The EMC is composed of a length of electro-mechanical cable terminated at both ends by a mechanical termination plus an electro-optical connection to the LCM via a penetrator. The length of the EMC/T sections between mechanical terminations is **10 m**; the length for the EMC/B is **98 m**.

Schematic view of an EMC section



General Specification of the EM cable

Constitution

For a line comprising 6 sectors of 5 storeys the requirement is the following:

- 9 wires 1 mm² for power distribution (6 for power + 3 for common ground); nominal voltage 600 V; conductor resistance : 22 Ohms/Km
- 21 single mode fibres which include:
 - 12 for Data transmission (2 per sector)
 - 1 for Slow Control transmission in the sector
 - 6 for Clock distribution
 - 2 for Trigger/Readout Request signal

Optical characteristics

- attenuation at 1285-1330 nm < 0.4 dB/Km; attenuation at 1550 nm: < 0.3 dB/Km

- dispersion coefficient at 1285-1330 nm: < 3.5 ps/nm/Km; at 1350 nm : < 18 ps/nm/km

General characteristics

- breaking load > 18 tons
- working pressure: 260 bar
- working temperature : -10, + 60 C
- dynamic bending radius: > 440 mm
- static bending radius: >235 mm
- weight in air: 0.8 kg/m
- weight in water: 0.11 kg/m

The cable is designed to resist the stresses induced on the line. A carrying cable made with braided Kevlar Aramid fibres satisfies these requirements in terms of low weight, size, flexibility, small bend radius. A peripheral carrier has been chosen for its higher resistance to the torsion and the protection offered to the electro-optical cable.

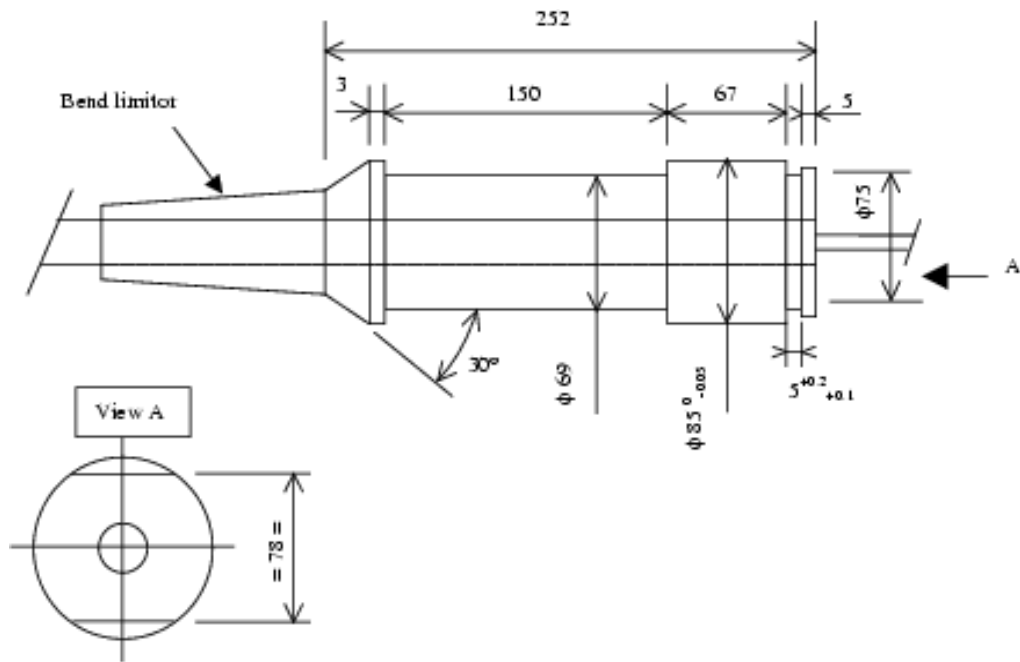
The static load of the cable in operation is different for each section. The maximum is 2 tons for EMC/B and the minimum at the top of the line in the last section with about 0.7 ton. The static load during sea operation is 3 tons. The breaking strength of the cable is 18 tons at minimum. This value is a compromise between different mechanical parameters of the line itself and the behaviour of the cable (size, stiffness,...). It leads to a safety coefficient of 6, which is a minimum for this type of cable.

It is difficult to manufacture the sections with a precision on the length better than +/- 5 cm for the 10 m EMC/T and +/-25 cm for the 98 m EMC/B. However the length of each EMC/T section will be measured under 2 loads (1 and 2 tonnes) with a precision of +/- 0.5 cm.

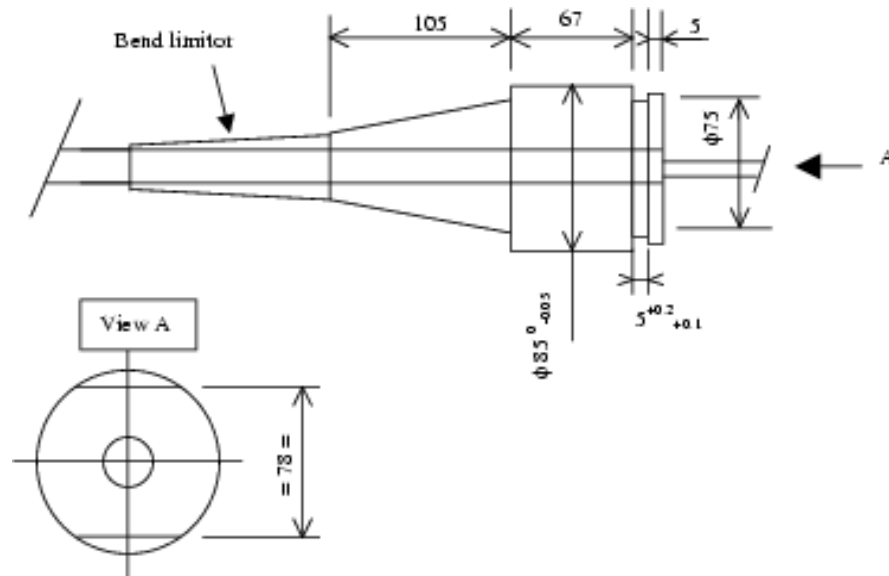
Mechanical terminations

The mechanical termination ensures the interface between the carrying cable and the OMF. A bend limiter is added in the termination around the carrying cable to avoid a smaller bend radius that could damage the cable. For the down termination there is no special constraint but for the upper termination the bend limiter must absorb the weight of 5 m of cable in air.

The shape of the termination is different for the upper and lower parts. The upper part incorporates the mechanical system for handling the hook during deployment. The output of the electro-optical cable is on the axis of the termination. Titanium alloy (TA6V or grade 5) is selected because of its resistance to corrosion, its lightness and its good mechanical properties.



Upper termination



Lower termination

Penetrator

Penetrators were selected in preference to connectors because of the lower cost and the small expected number of connections/disconnections during the lifetime of the experiment. This choice complicates the operations in the assembly protocol, since the containers have to be closed during line assembly operations.

The use of a water block for the 21 fibres and the 9 electrical wires is important to avoid water leakage into the container from the cable.

The optical attenuation induced by the penetrator is $< 0.01\text{dB}$.

The external diameter of the penetrator is 80 mm at maximum and the diameter which fits into

the container is 50mm at maximum. The metallic parts are in titanium alloy (TA6V or grade 5).

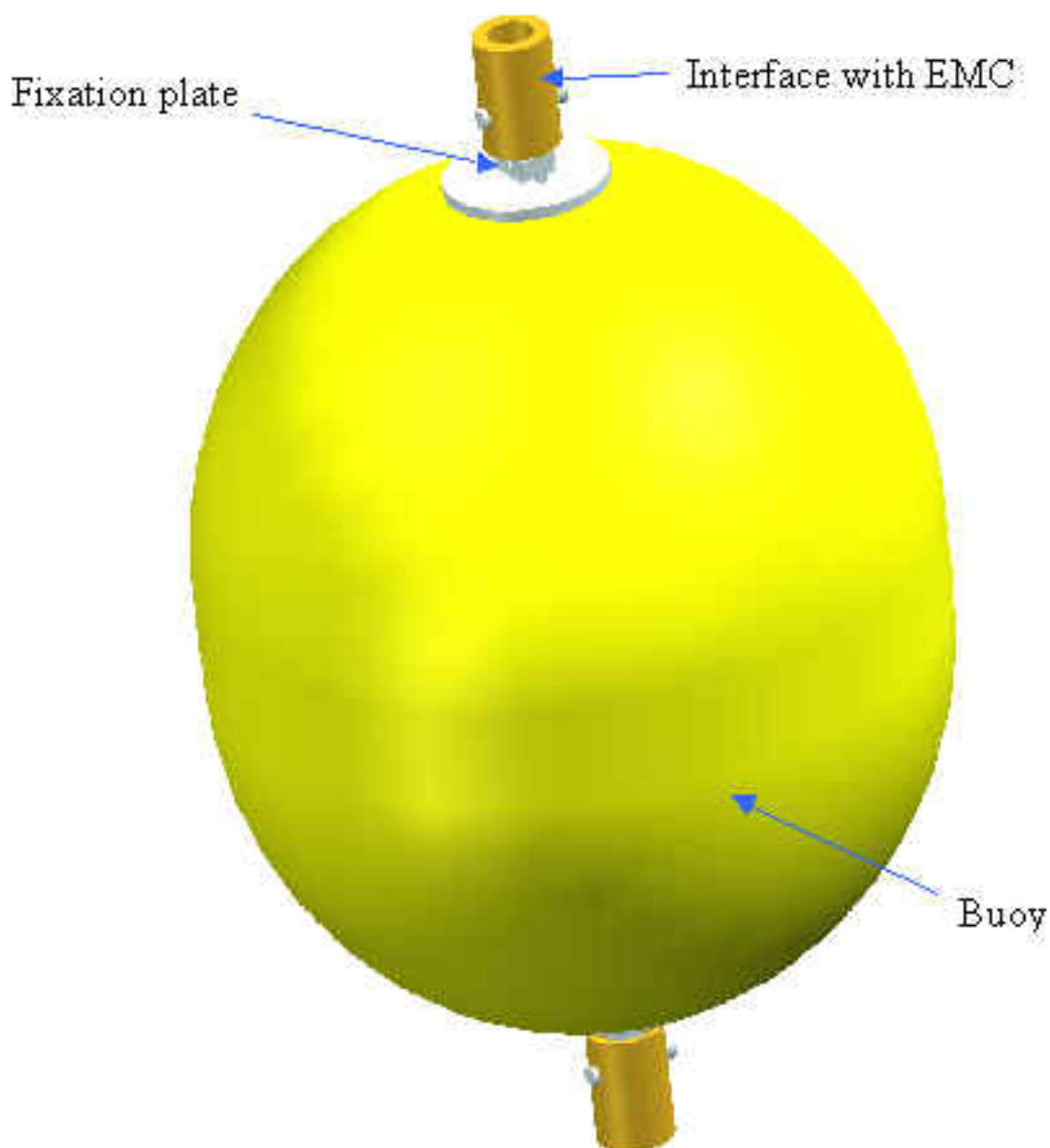
The length of the electrical and optical pigtails will be fixed as soon as a complete simulation of the full integration of a LCM and OMF is performed. This also has consequences for the choice of the type of connections for the optical fibres (splice fusion or connectors).

Cable lengths

	between mechanical terminations	between the lower termination and the penetrator	between the upper termination and the penetrator
EMC/T	10 m	2.8 m	3 m
EMC/B	98 m	2.8 m	3 m

PBS 1.5 : The Buoy

Schematic view of the Buoy



Description

The buoy is made with a syntactic sphere (1330 mm outer diameter, 1846 mm long) and has 2 interfaces with the electro-mechanical cable EMC. The weight in air is 6370 N. The maximum depth of immersion is 2500 m and the top buoyancy is 6370 N.

Specifications:

- The anchor weight is sufficient to ensure the anchorage of the line
- When anchored, the horizontal displacement of the top of the line is less than 10 metres (for a sea current of 0.15 m/s)
- The speed of the line during its ascent is roughly 1 m/s
- During the recovery phase, the line remains vertical, with only the top buoy floating at the sea surface.

Dimensioning:

● Application to the entire line

The final dimensioning of the line will wait for the results of the deployment test. The velocity of the line, for instance, is not measured but only estimated. The values currently foreseen are: (measured in water)

- Top buoyancy : 6370 N
- OMF buoyancy : 421 N
- BSS structure : 14000 N
- BSS anchor : 15680 N

The safety factor on the cable is 6 and the horizontal displacement of the top buoy is 22 m under a 0.25 m/s water current.

● Application to the deployment test

For the deployment test, the philosophy is different, because it is important to keep the same load on the first cable ([EMC/B](#), length 98 m) that is to say to keep the same BSS weight. In this case, the OMF is equipped with LCM and empty glass spheres only. The buoyancy of such an OMF is estimated at 451 N. The weight of cables will be about 225 N. In order to make the test as significant as possible, the top buoy is kept the same. We propose the following dimensioning for the deployment test (values in water):

- Top buoyancy : 6370 N (from the Demonstrator line)
- 5 x OMF buoyancy : 451 N
- BSS structure : 3920 N
- BSS anchor : 25480 N (and 15680 N)

The estimated speed of the line when it is rising is 1.4 m/s. In a such line, the maximal tension on the line is kept (29400 N), therefore the tension on the handling steel cable is higher than in the realistic operation (21462 N instead of 11270 N).

If we decide to check the behaviour of the line during the descent, it could be interesting to have the right tension in the handling cable. Then a second test could be performed (just after the previous one) using a **BSS anchor of 15680 N, while the other components do not change.**

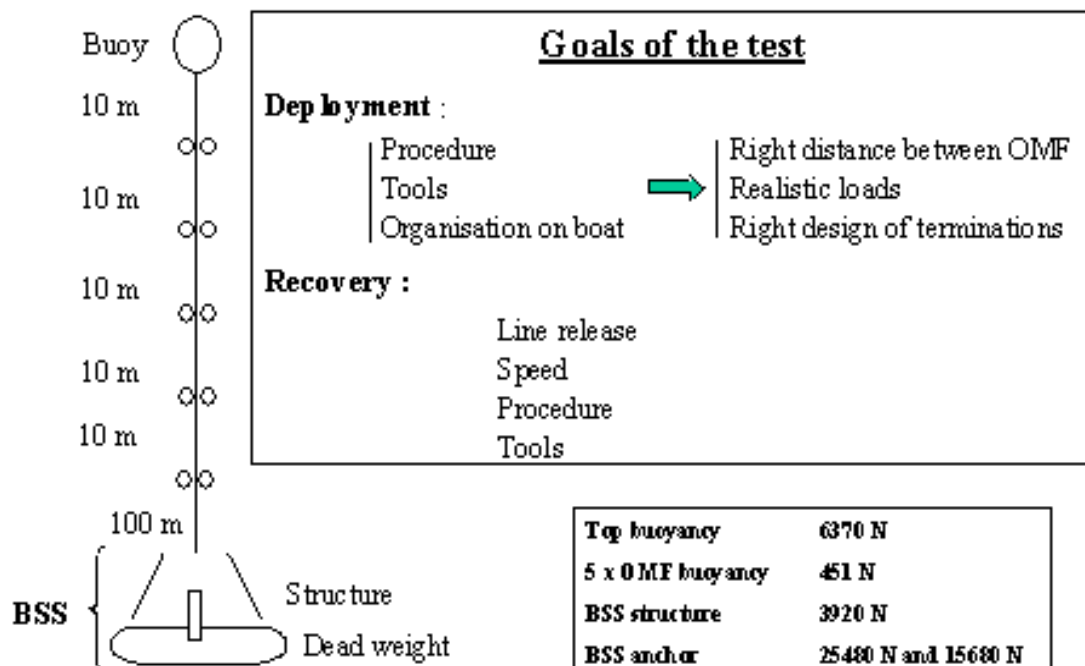
● Application to the sector line

For the sector line, there is no need to overload the carrying cable (the goal is not to test the deployment of the full line). Moreover, as the speed of the line during its rise is not critical, the nominal top buoy (6370 N) will be used. The BSS structure will be very close to the final one and all the instrumentation will be there, so it is convenient that its weight is close to the final one. It means that the load on the top cable at the surface is higher than the nominal one, but this is acceptable. Furthermore, it is interesting to have a global weight of the line close to the final one, in order to appreciate some parameters linked to the laying and positioning of the line.

The sector line will therefore have the following characteristics : (values given in water)

- Top buoyancy : 6370 N
- OMF buoyancy : 421 N
- BSS structure : 3920 N (the one of the deployment test is convenient)
- BSS anchor : 15680 N (same as the full line)

It gives a safety factor on the cables of 8.9. The estimated speed of the line when it is rising is 1.1 m/s.



Schematic view of the sector line configuration

References:

- [3 LIN-02-01 B](#) Line dimensioning: Calculations on weight of mechanical components of the line
- FL 298/650/2500 Dessin du flotteur