A SEABED INFRASTRUCTURE FOR MEUST/KM3NET-TOULON

Mediterranean Eurocentre for Underwater Sciences and Technologies

INFRASTRUCTURE
MEUST/KM3NET-TOULON

Permanent deep cabled underwater observatory

Missions of the infrastructure are :

- To transport and provide energy to the users of the observatory.
- To accommodate the network of data exchange.

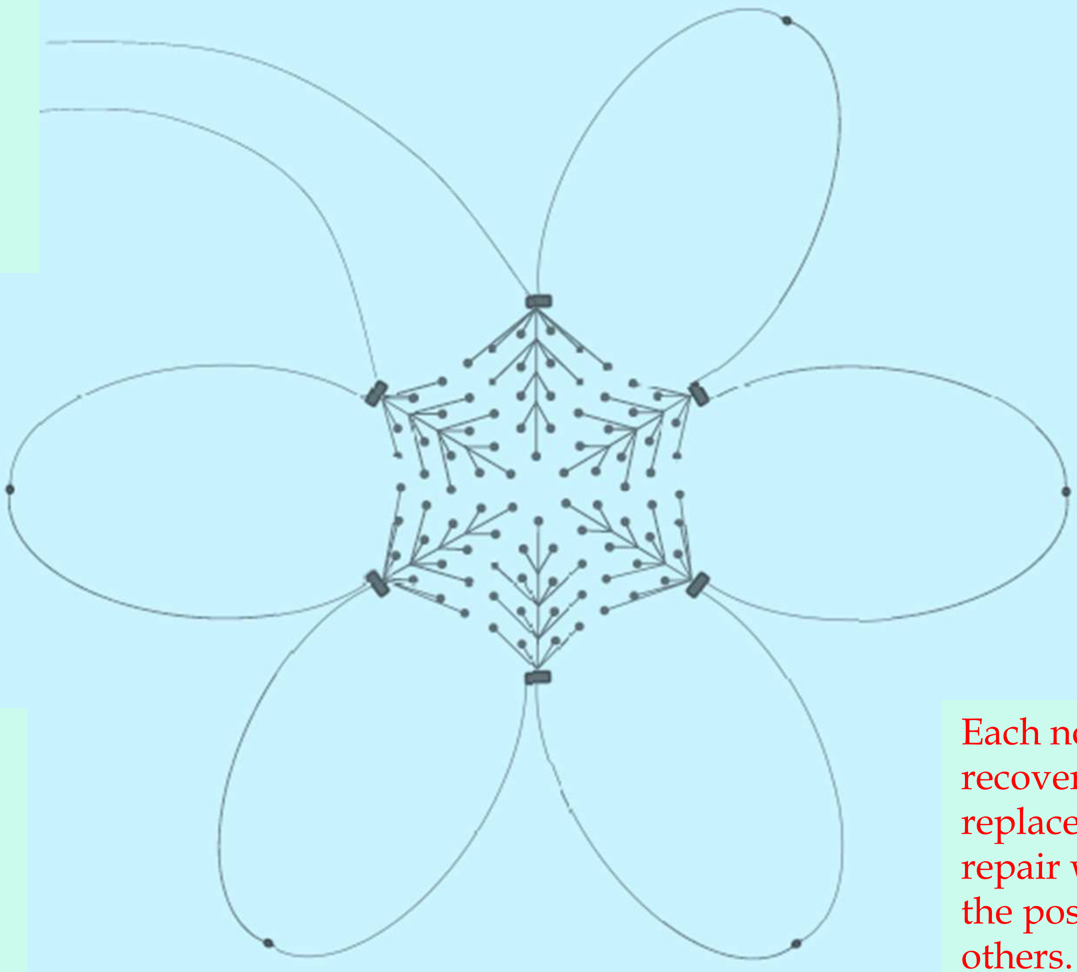
Infrastructure MEUST

Installation mainly composed by:

- a station on the shore (power room)
- a cable of telecommunication and power supply
- a network marine resources

Marigold concept

The main idea of Marigold is to deploy each node one after another with its link ready to connect to the next node.

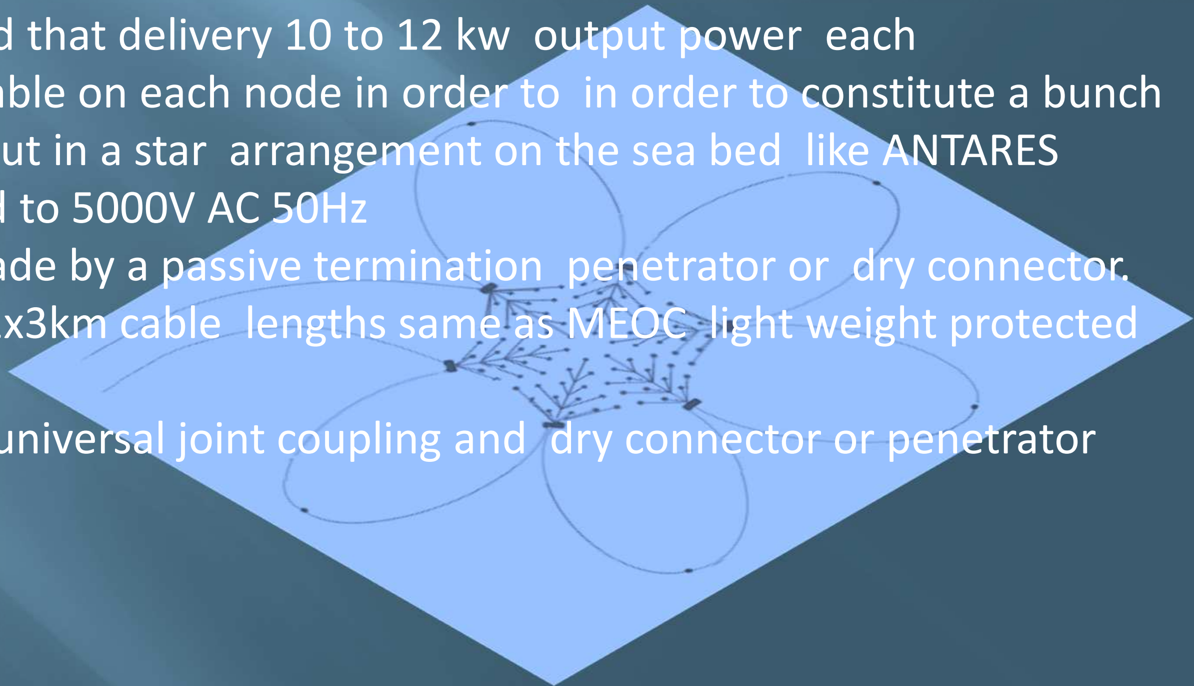


Laid to sea bed with standard procedures and methods used in maintenance and repair operation by specialized cable ship.

Each node could be recovery for replacement on board repair without affecting the position of the others.

General provision for seabed network

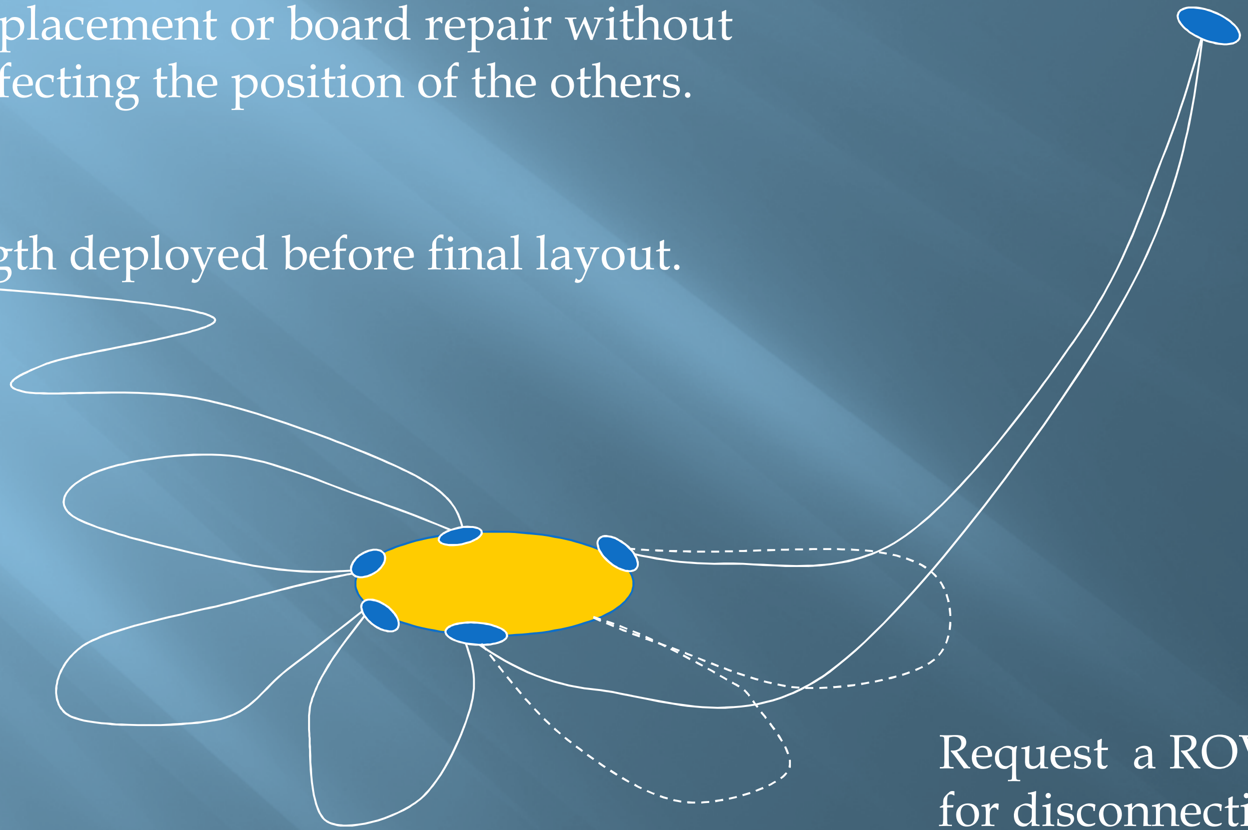
- Conceived for a setting in progressive operation off Toulon (30-50km)
- Dimensioned for a hundred lines of detection neutrinos
- Two shore cables (MEOC) access
- Ring network topology : double supply by looped connection
- Fibers are distributed in two branches (2*36 min fibers each).
- Electrical energy is transported in alternative current
- Return current by sea
- Six nodes when completed that delivery 10 to 12 kw output power each
- 18 ROV connections available on each node in order to in order to constitute a bunch of lines of detection laid out in a star arrangement on the sea bed like ANTARES
- Input node voltage limited to 5000V AC 50Hz
- Shore MEOC extremity made by a passive termination penetrator or dry connector.
- Inter node links made of 2x3km cable lengths same as MEOC light weight protected section.
- Endings required with an universal joint coupling and dry connector or penetrator



Marigold node recovery

Each node could be recovery for replacement or board repair without affecting the position of the others.

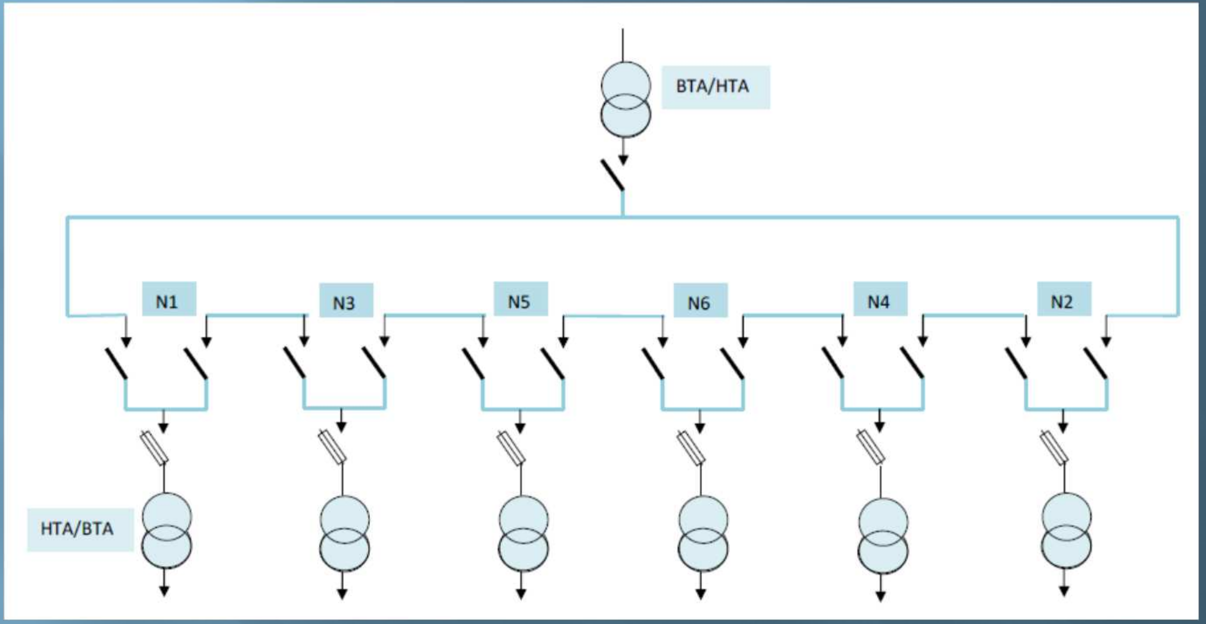
Extra length deployed before final layout.



Request a ROV intervention for disconnecting all the users of the node and hooking the cable winch recovery.

Seabed network electric power distribution

General structure :



- Energy transport is considered in single phase AC current 50Hz.
- Voltage is raised up to 6500 volts for transport in shore source substation.
- High specific submarine capacitance compensated to reduce reactive power.
- Sea return current (standard sub-marine telecommunication cables used)
- Network designed in double supply by looped connection.

electric power distribution

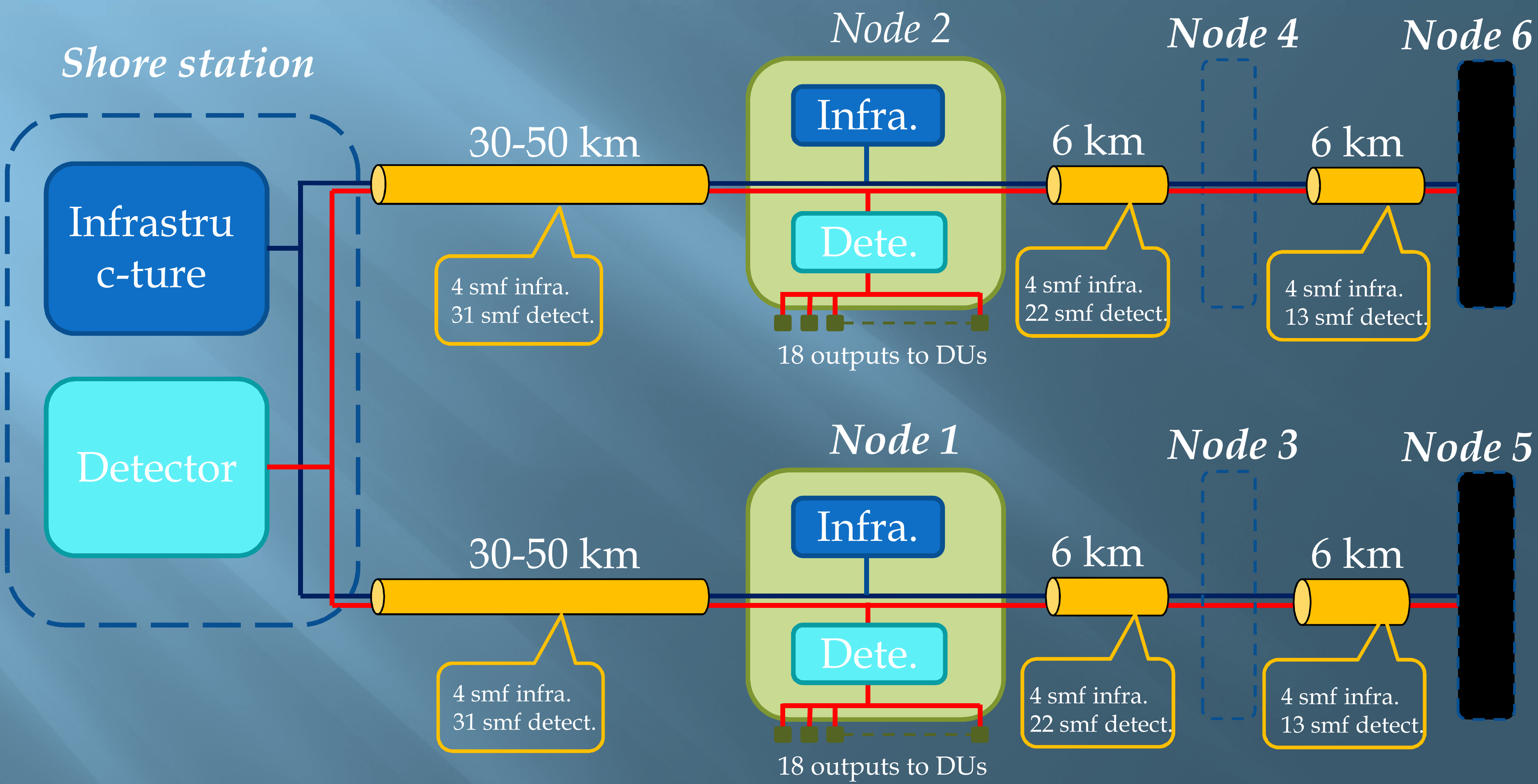
➢Calculation assumptions :

- P_u per node : 18 x 500W
- NIL de 6km
- R_{MEOC} de 0,7Ω/km
- C_{MEOC} de 200nF/km

Configu-ration	longueur MEOC	V_{out_local}	I_{out_local}	S_{out_local}	P_{out_local}	Q_{out_local}	V_{in_noeud}			I_{in_noeud}			S_{in_noeud}
							Nœud 1	Nœud 2	Nœud 3	Nœud 1	Nœud 2	Nœud 3	
1 nœud 3 lignes	30km	1336,17	3,01	4022,29	2338,93	3272,34	1308,66			1,71			2236,84
	50km	1058,08	3,88	4109,19	2526,04	3241,07	995,90			2,25			2236,84
1 nœud 18 lignes	30km	3074,51	6,98	21446,06	12660,50	17310,27	3009,32			4,02			12105,26
	50km	2440,61	9,01	21981,62	13677,65	17207,95	2293,68			5,28			12105,26
2 nœuds 18 lignes	30km	3590,17	10,52	37757,48	25781,62	27585,05	3473,47	3459,80		3,48	3,49		12105,26
	50km	3215,98	13,35	42930,62	27999,27	32543,49	2990,39	2974,18		4,05	4,07		12105,26
3 nœuds 18 lignes	30km	3641,94	13,92	50683,90	39695,11	31514,38	3455,98	3428,98	3415,11	3,50	3,53	3,54	12105,26
	50km	3716,79	17,08	63473,64	43057,94	46635,99	3418,50	3391,14	3377,09	3,54	3,57	3,58	12105,26

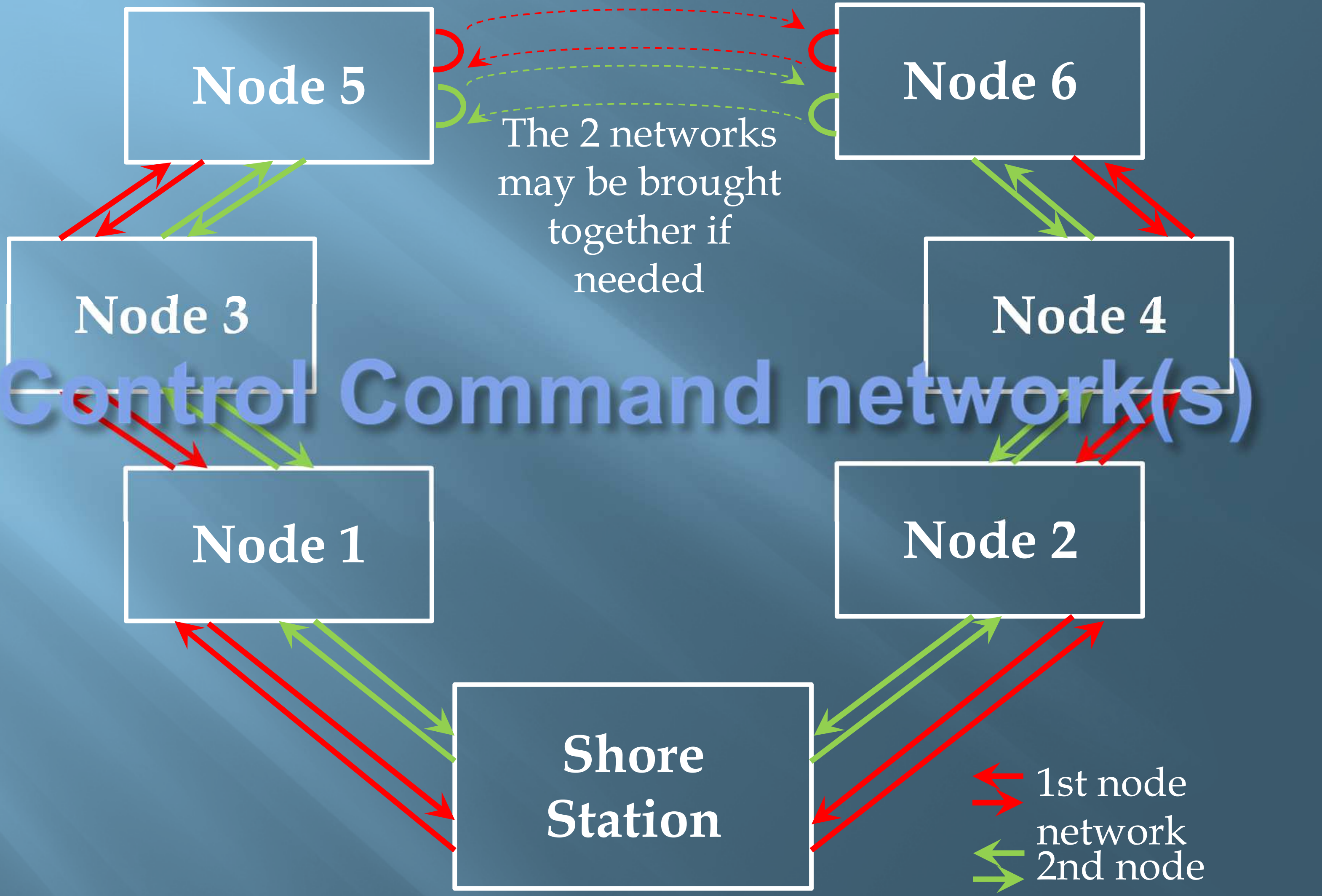
Contact : Stephane Theraube : theraube@cppm.in2p3.fr

General optical layout



All nodes almost identical

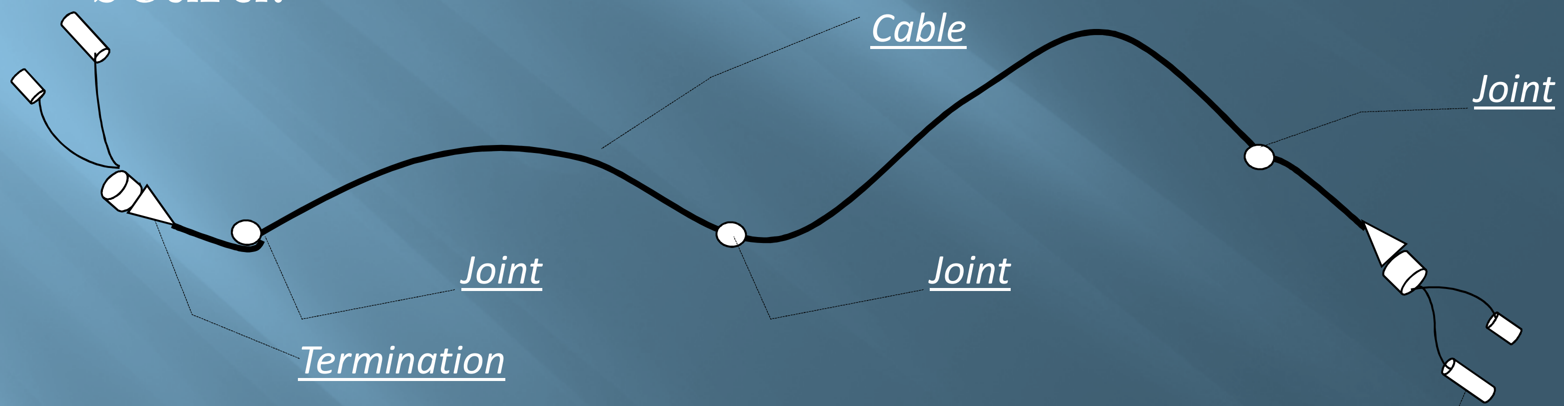
Control Command network(s)



MARIGOLD Network components

Electro-optical Marigold links :

- Made of 2x3 km lengths jointed of standard LWP cable section
- Designed to allow dry connections operation to the nodes on shore and standard jointing on board.



- High voltage specification.

Figure 11 Typical Cable Termination

penetrators

- Specially designed to be compatible with standard submarine cable (LWP) : One conductor and 36 optical fibers 30Amps 5000Volts
- Double direction water block resistant
- Two potential candidate suppliers (need to be qualified)
- No mechanical large acceptable strains and strengths (need external bending and pulling restrictors)
- Unit cost < 10 k€

Infrastructure MEUST

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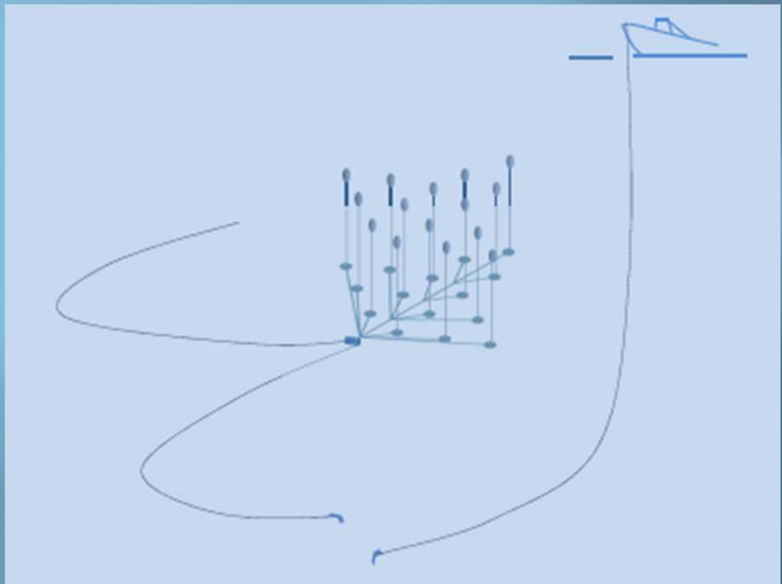
Deployment scenario

SEABED NETWORK LAYING

Deployment and connection of a node scenario

1st Phase stage 1: deployment of the half link of connection.



This half-link is put on standby on buoy.

- Operation carried out with the methods and means
standards of use by a cable-laying ship specialized in the
pose or the repair of underwater cables of telecommunication.

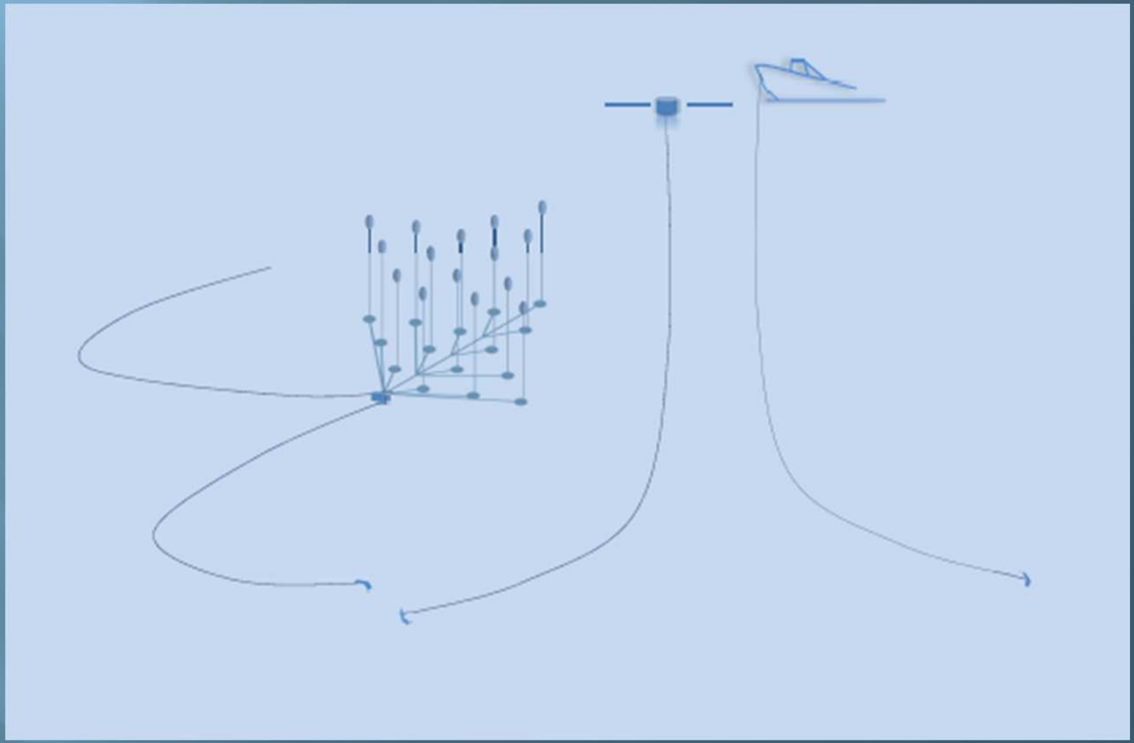
The operation proceeds in two phases of four steps each:

1st phase: deployment of the node;
2nd phase: connection of the node to the network.

The initial provision is the following one:
a node
is already in operation, the half-link of connection of the following node of network is laid on the bottom waiting its half next

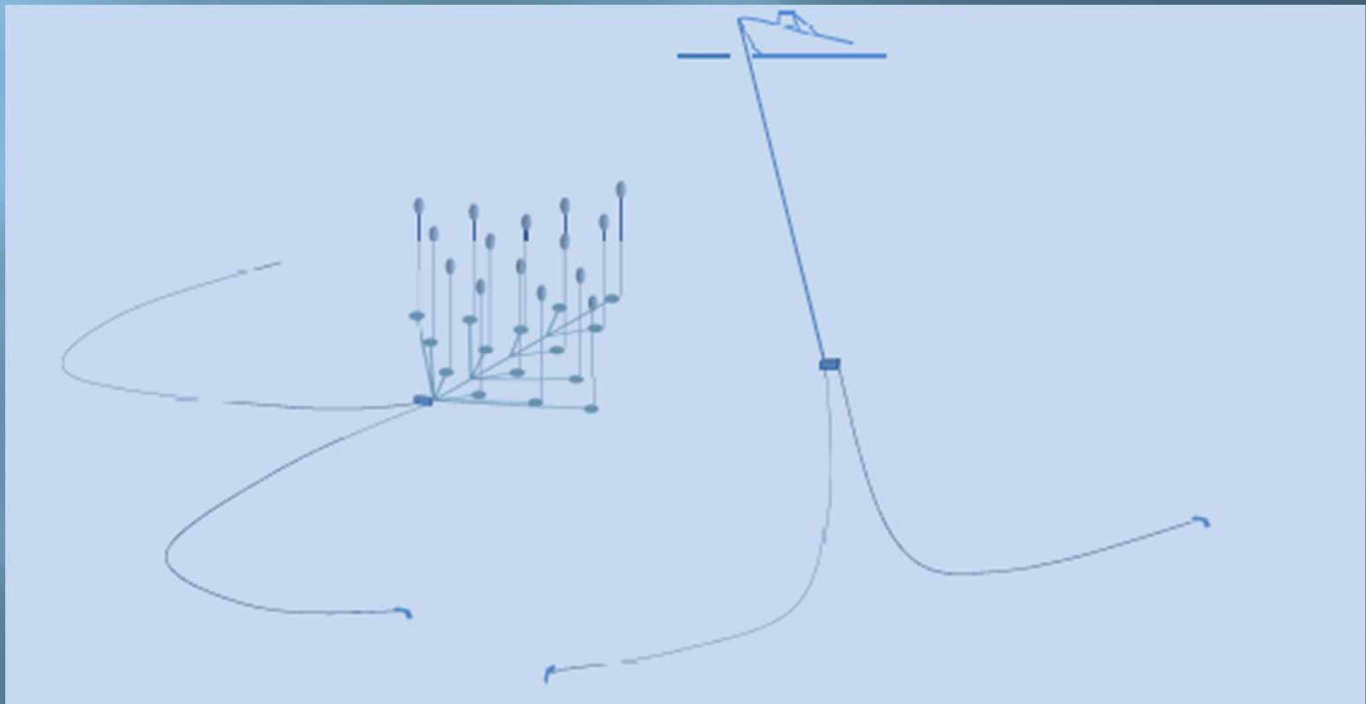
1st Phase stage 2:

deployment of the second half-link



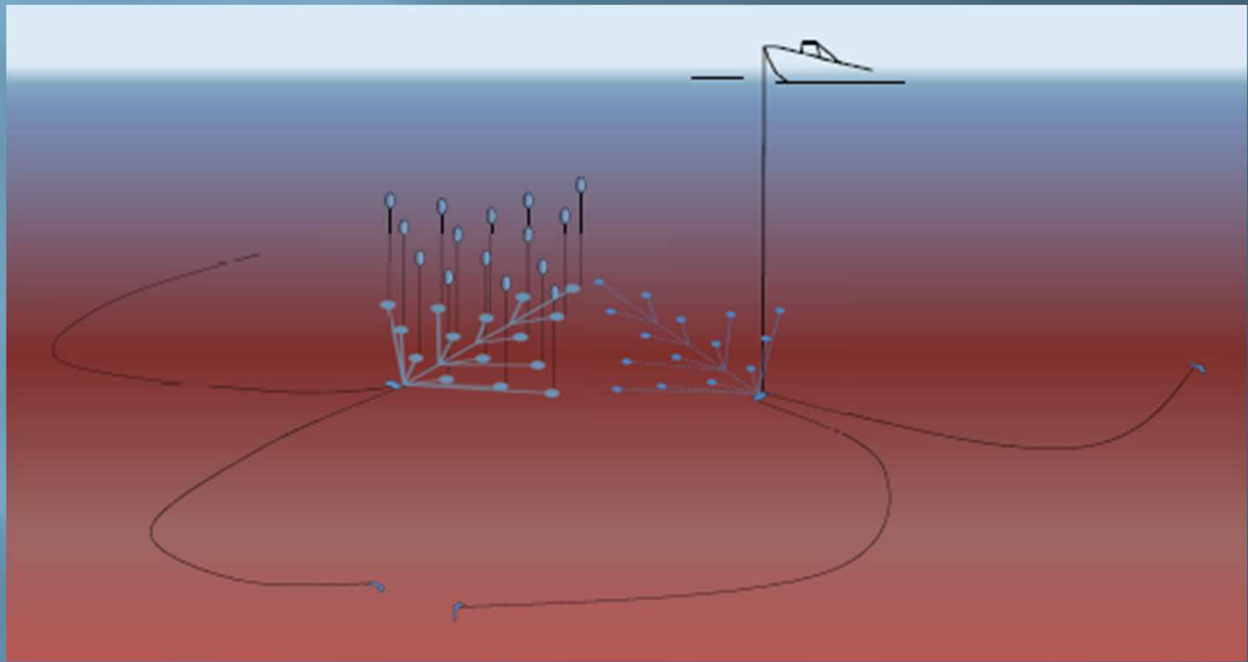
1st phase (continue) 3rd stage:

The node is connected to the two-half links upstream and downstream by standard
jointing on board. Then the node is seized and deployed with the winch while the road of installation is controlled by the ship DP S.



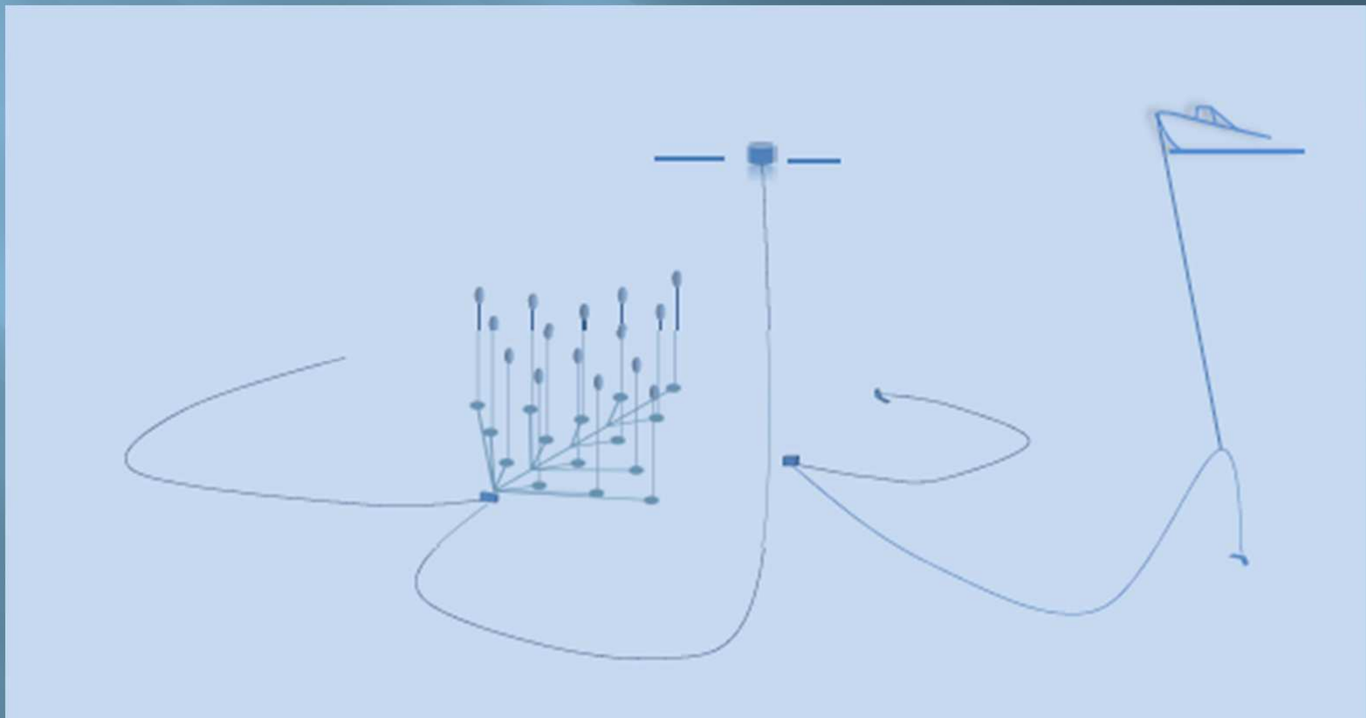
1st phase stage 4 (last):

The node is laid at its final location and the cable of winch is released.

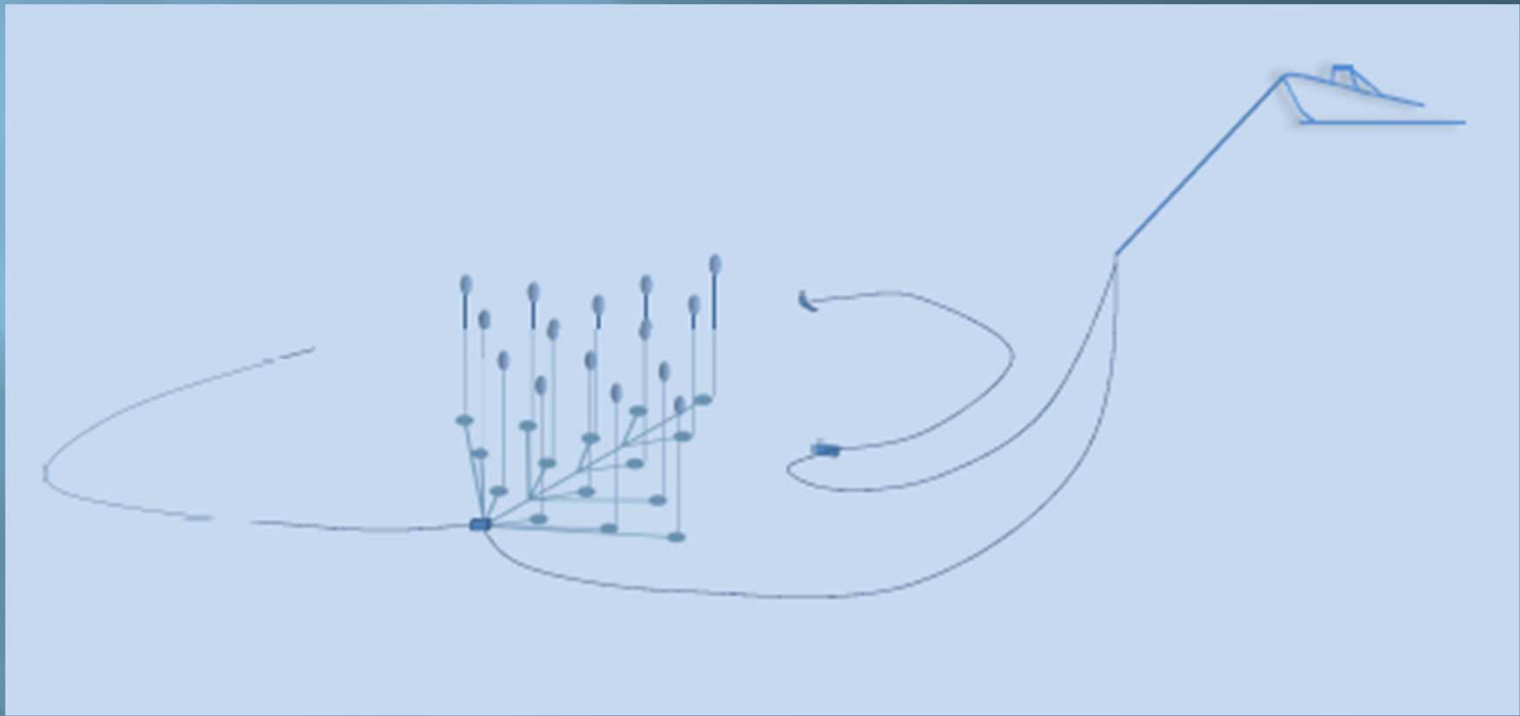


2nd Phase 1st stage: the end of the half-link upstream is dredged and put on sea level surface standby on buoy.

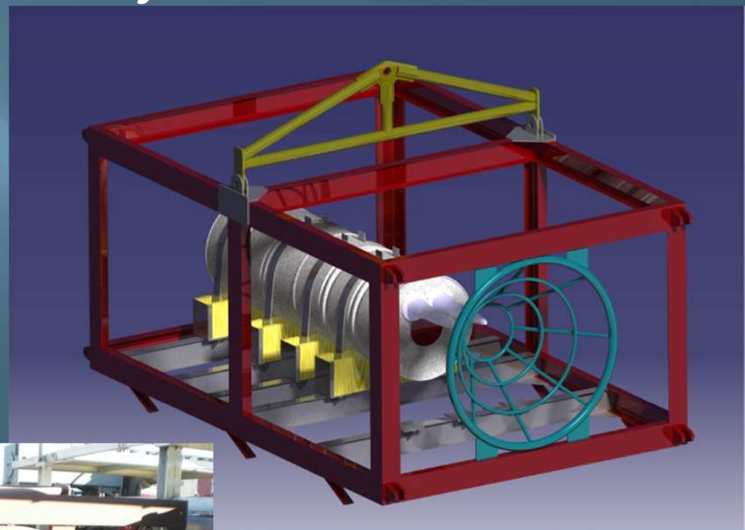
2nd stage: the end of the half-link downstream is dredged and maintained on board



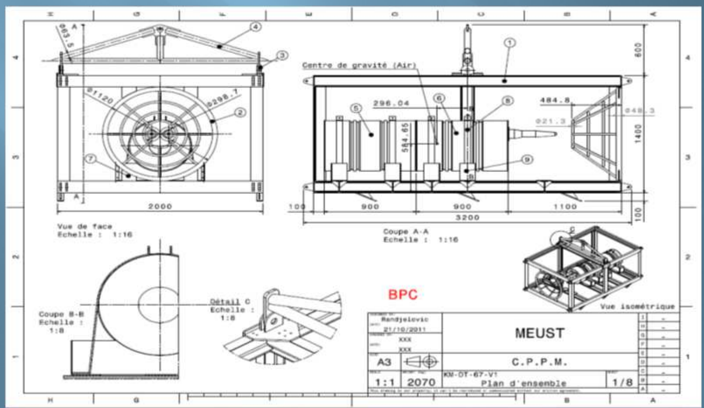
2nd Phase 3rd stage: the half-links are joined together by a jointing carried out on board.
4th stage: the bond inter node is deployed with the winch while the ship controls the road of installation on the bottom.



- Very first practice campaign already planned with the FT Marine cable ship "Raymond Croze"
- (3 days of training foreseen) in the very next weeks.



Frame node mockup : air mass~ 2200kg



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SHORE STATION POWER SOURCE

Shore power source
(Basic principles)

Closely located to the shore the power room hosts three main parts from electrical point of view:

- Power supply sources
- Low Voltage – High Voltage converters
- Reactive compensation systems

Basically the total electrical power of the seabed network is delivery by the public electrical network.

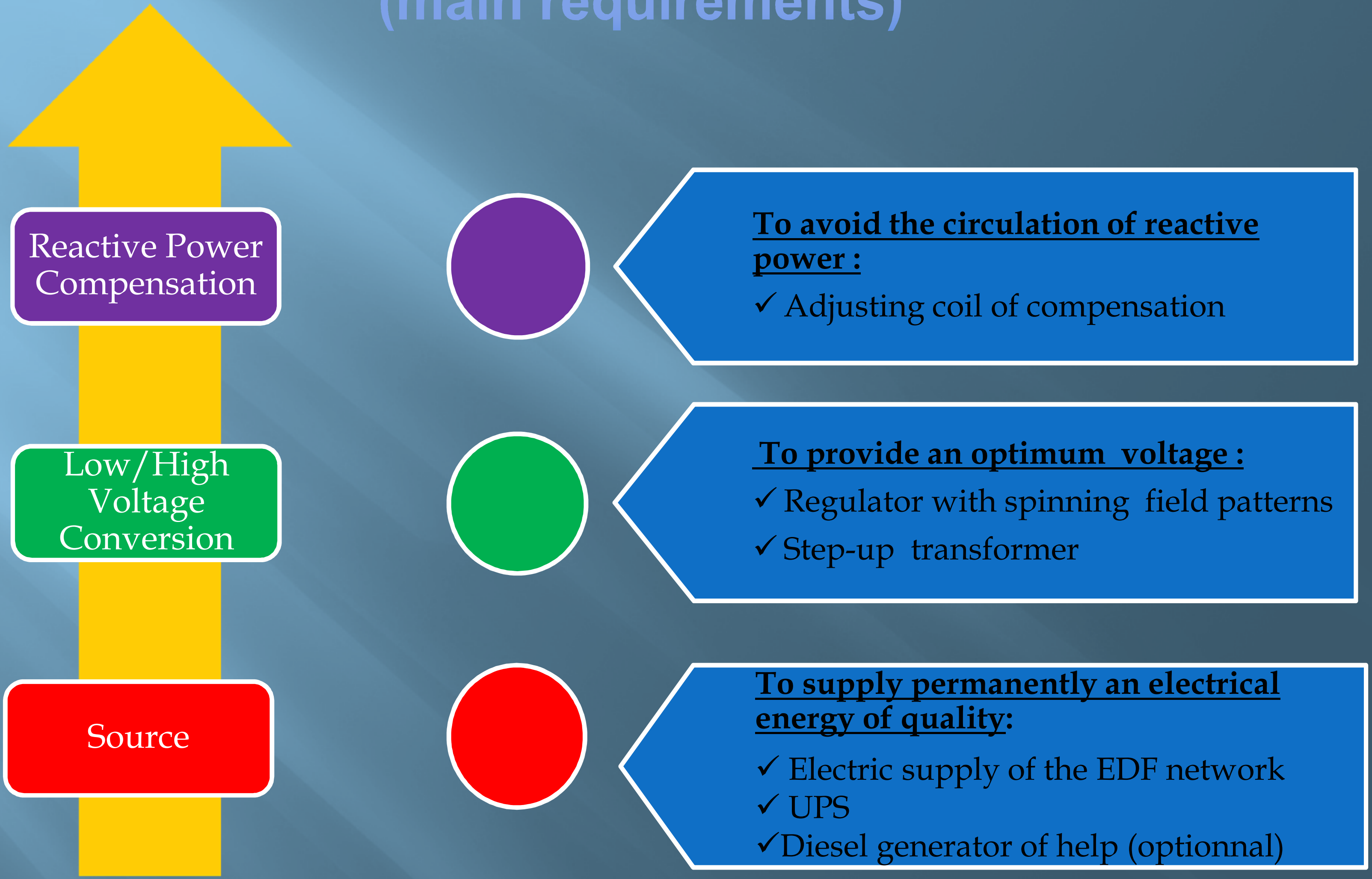
In case of short (<10mn) failure of the public delivery, a local power supply stored in batteries will run automatically.

If long(>10mn) public networks breakdown occurs, the electrical power could be delivery by a diesel generator.

As soon as the situation comes back to normal the power source turns automatically to the public network

Shore power source

(main requirements)

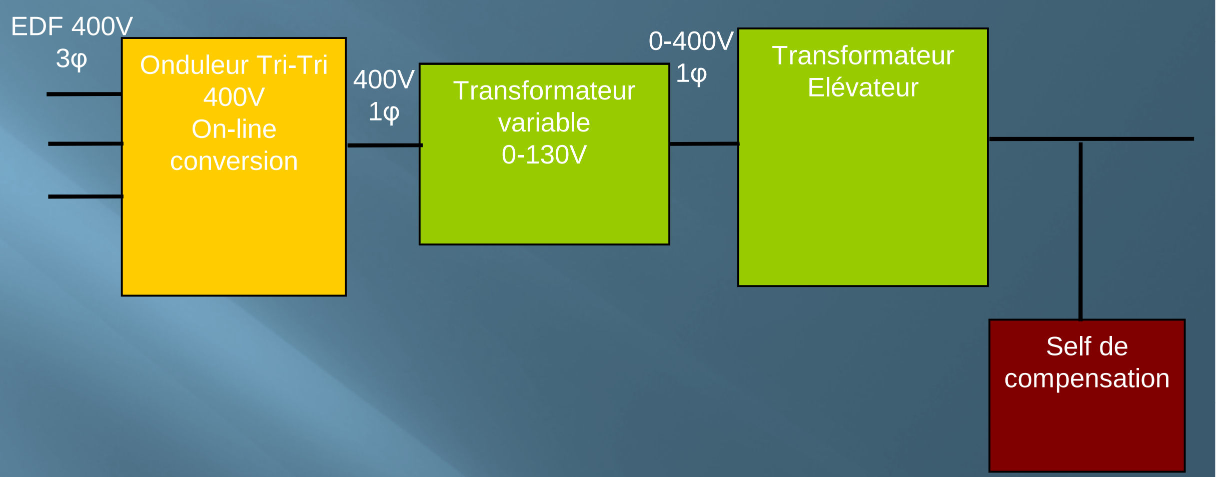


Shore power source

General configuration for energy distribution

First, in this place the three phases 400V -50Hz are provided by the public network. Then the three-one phase conversion and the adaptation of the voltage to the load are made.

At last the reactive power due to the strong capacitive impedance of the main electro-optical cable is compensated.

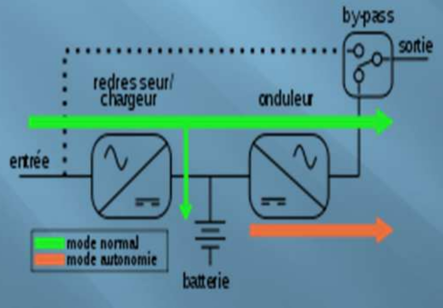


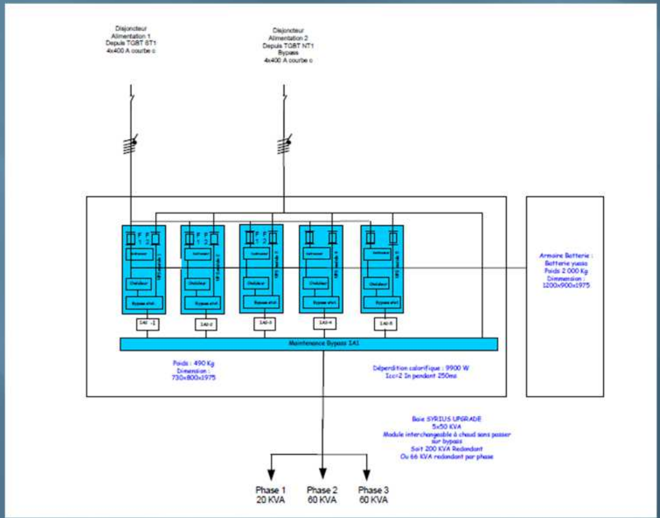
The technology “on-line conversion” of the UPS three phases to one phase allows to secure the power supply of the installation when little power cuts occurs and to filter perturbations generated by the public network.
If needed an external diesel generator could be added in the installation as safety power source when long breakdown of the public network.

Double converters UPS using BESS technology

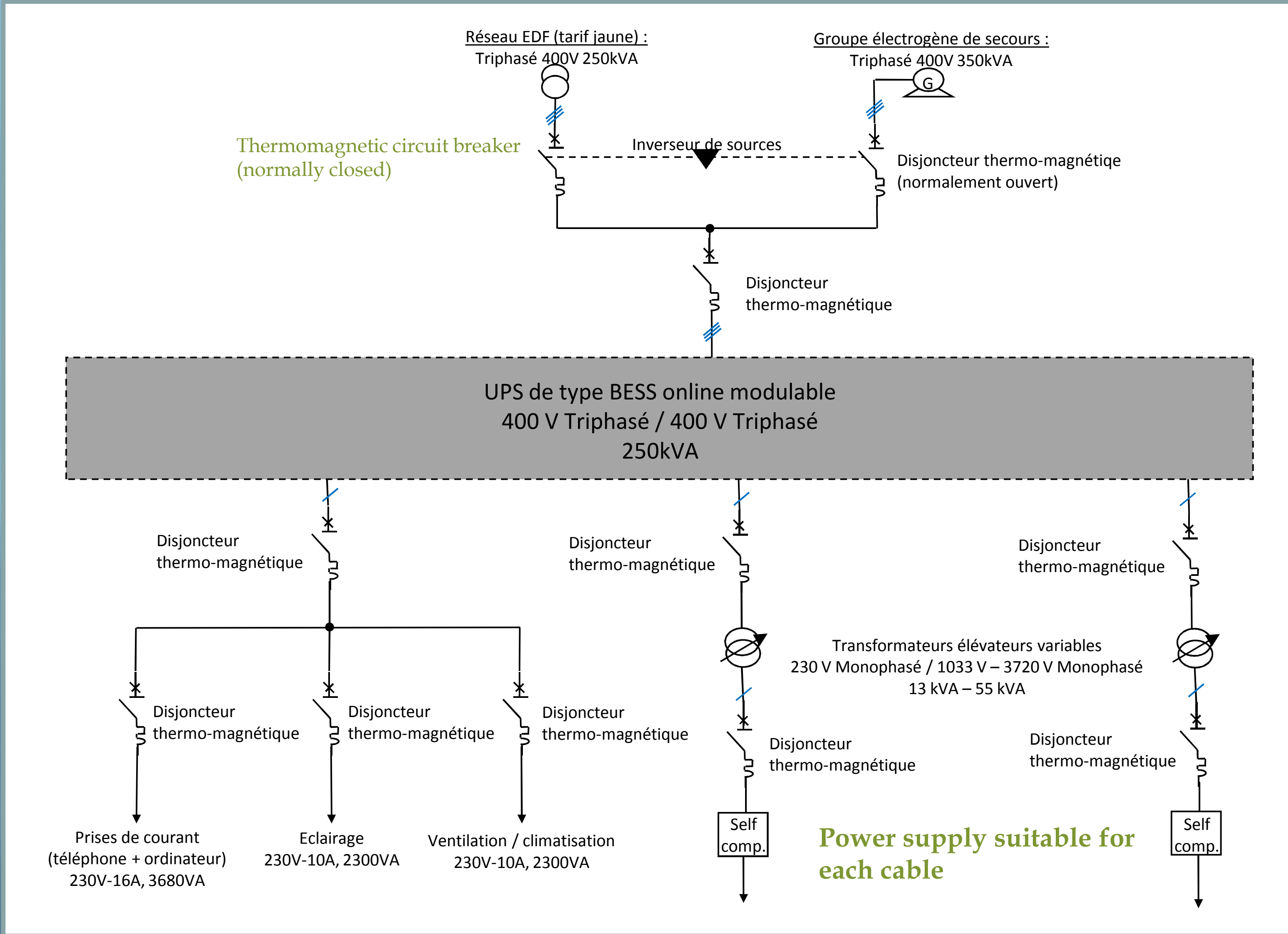
The UPS as "Uninterruptible Power Supply" offers to the users installation a stable and secure electrical power source without cuts and disturbances present on the public network.
The UPS is mainly constituted by an AC/DC converter followed by a power storage device and a DC/AC converter operating at a fixed frequency (50 Hz in our application)

The "Battery Energy Storage System" gives 10mn autonomy delay without expensive maintenance constraints.

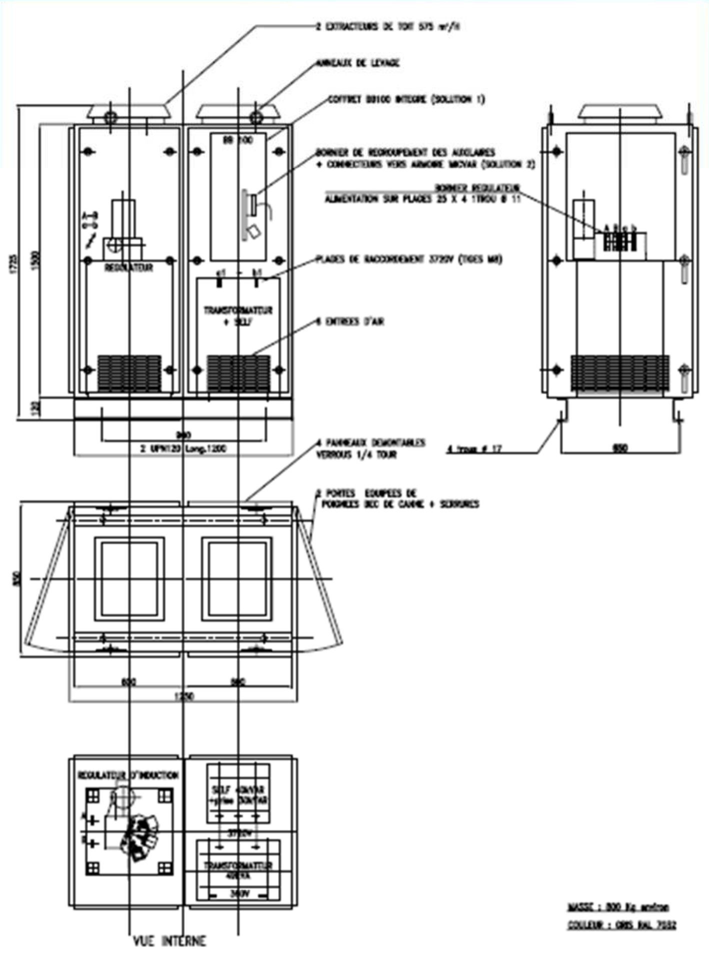




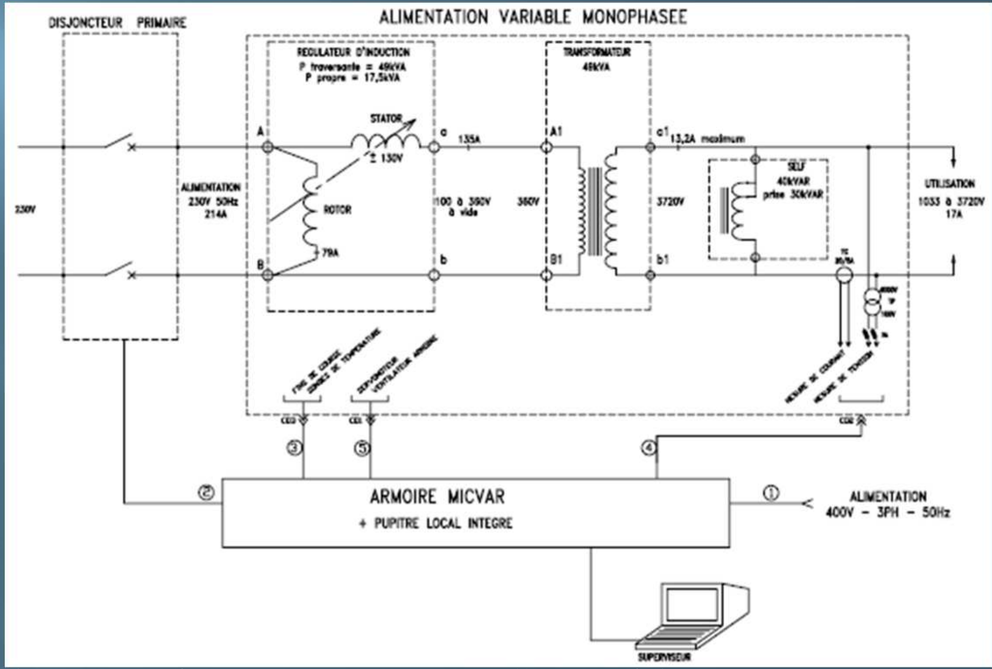
Shore power source
diagram of general provision



VARIABLE STEP-UP TRANSFORMERS



Similar system successfully used by ANTARES



The seabed network resources evolved in the course of time: progressive installation of the network, failure of one or more electric nodes, maintenance… The transformer must permanently adjust the output voltage when input voltage is fixed. That must make it to control the network according to the level of load and optimize the losses identified during the transport of energy.

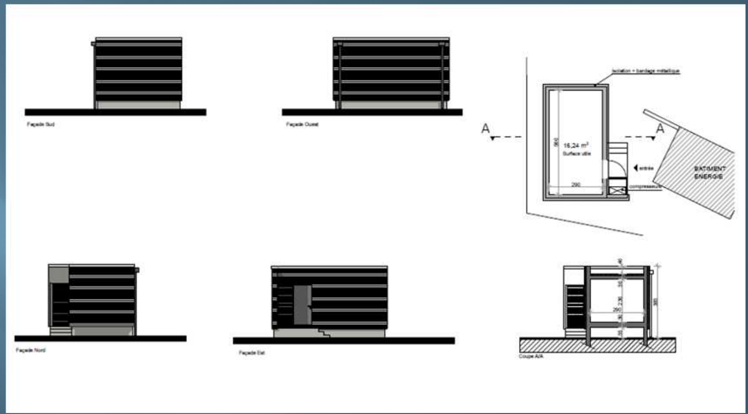
The MEUST power source

- Where are we ?



Close to the existing power source ANTARES

- A new building needed:



Local Agreement accepted

Pre-design already existing

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MEOC
(MAIN ELECTRO-OPTICAL CABLE)

Made of standard electro-optical cable manufactured for submarine inter-continental telecommunications

Cable route diagram

Requirement for a branch network of MEUST with 36 fibers similar to ANTARES main electro-optical cable :

Beach Manhole

Landing Area

Sea Bed Termination

Depth : 2350-2450m

Supply Room

located 150m back from the beach manhole

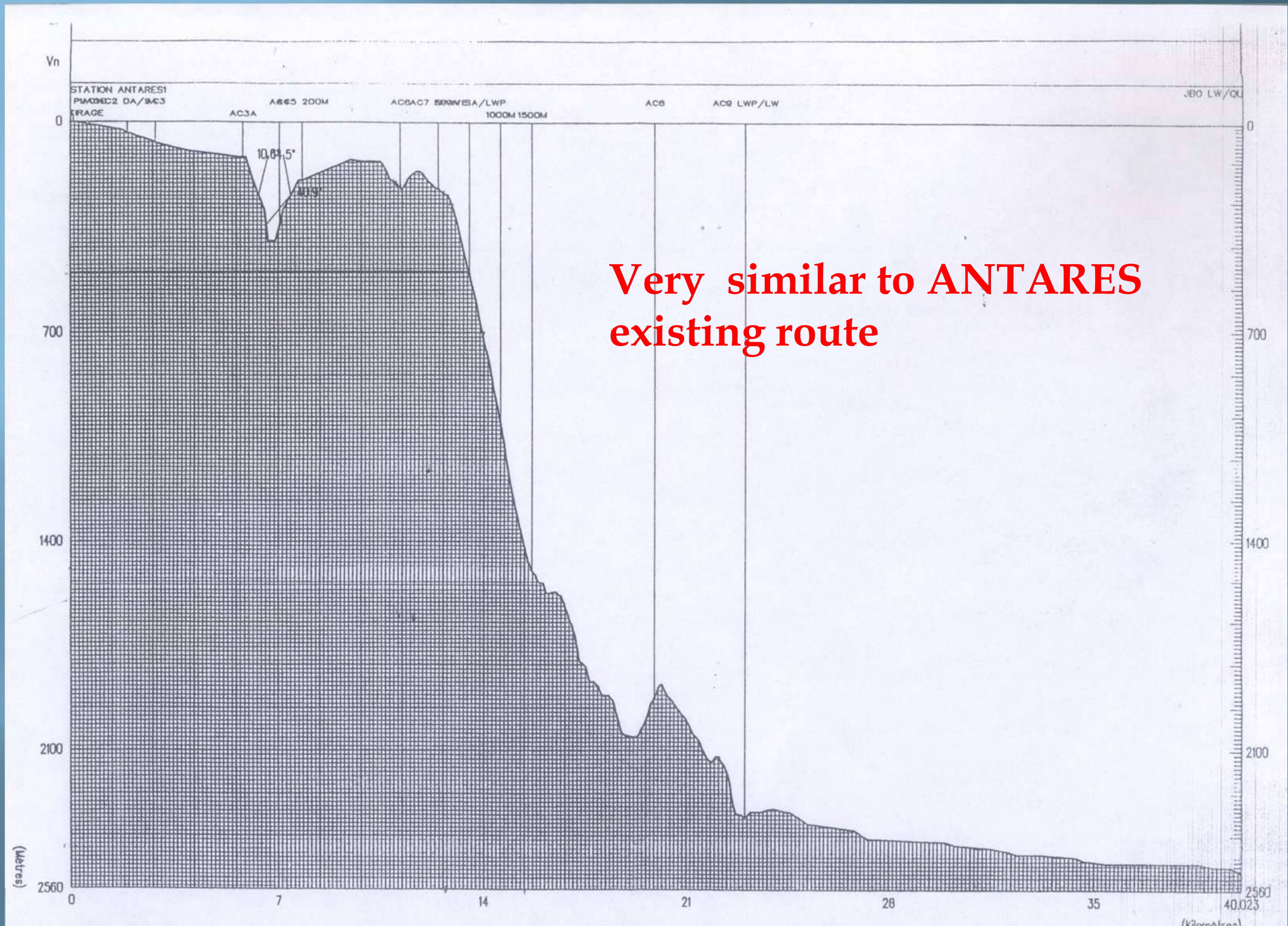
Control Room

1300 m link of optical terrestrial cable

Submarine cable section lenghts required

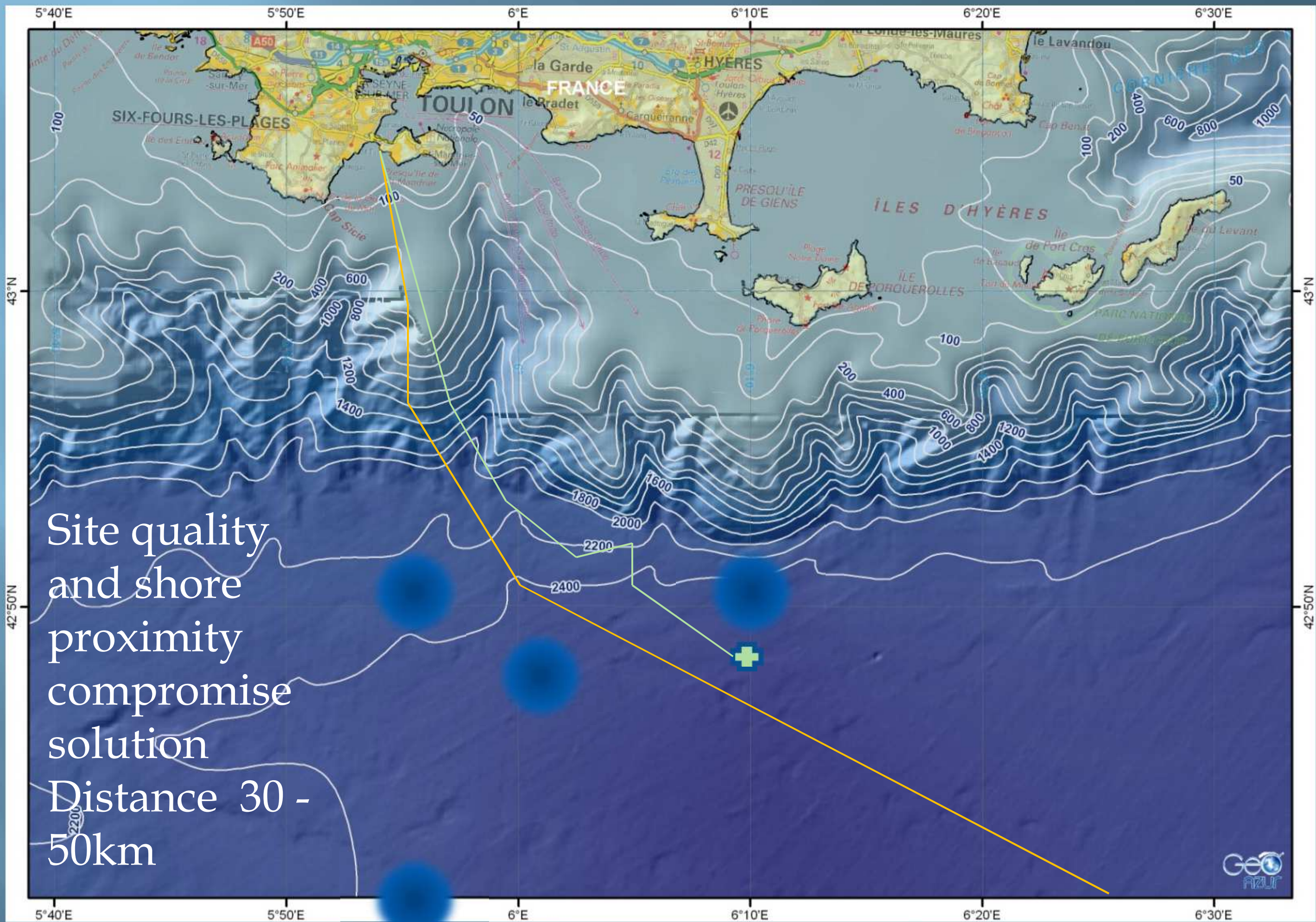
Double Armoured :	1500 -2000 m	(baie des Sablettes)
Single Armoured :	10000-12000m	(plateau< 1000m)
Light Weight Protected :	10000m – 12000m	(slope->2000m)
Light Weight :	5000 m - 15 000m	(according site choice;)

Cable route diagram



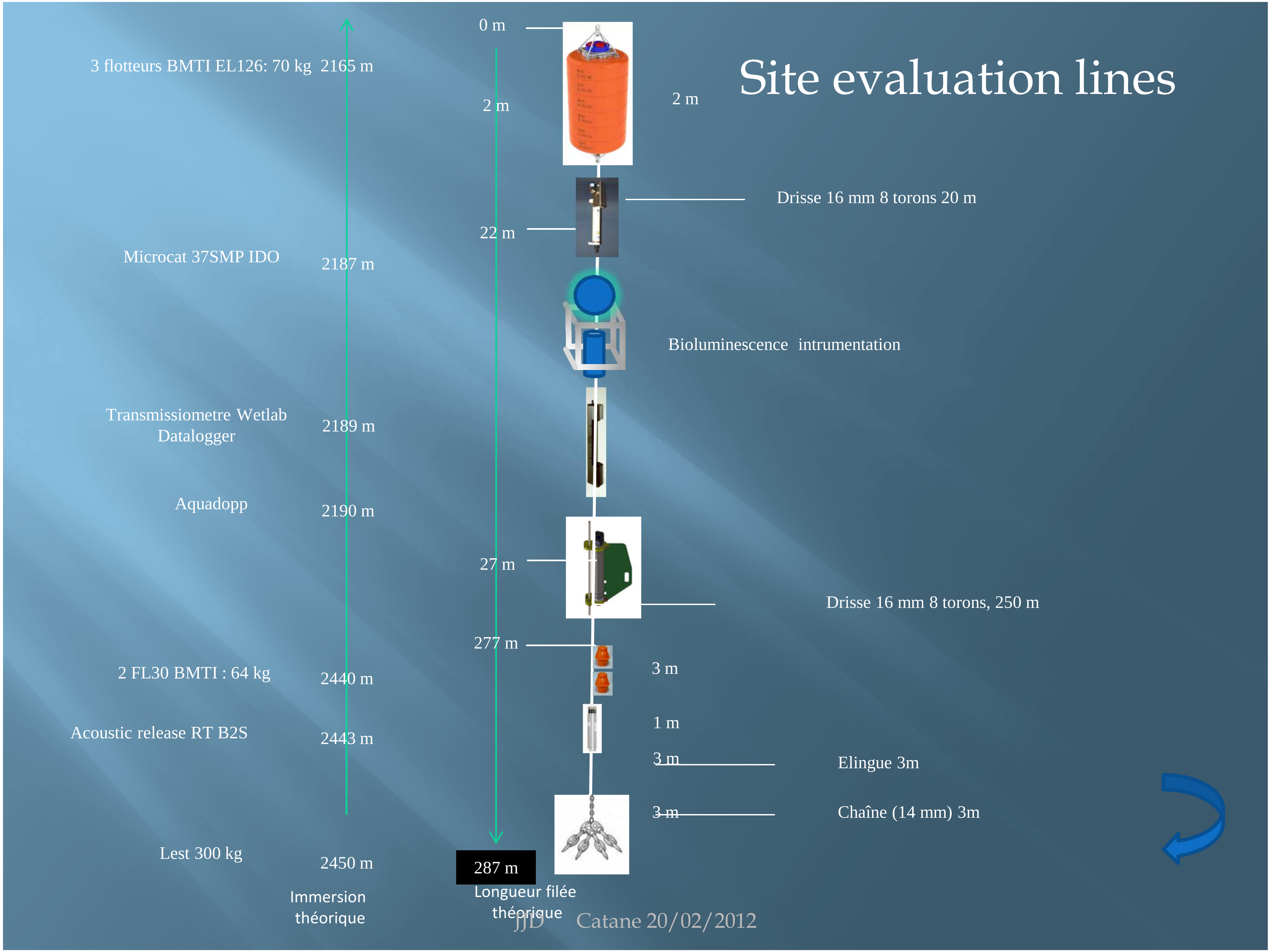
Very similar to ANTARES existing route

MEUST site survey



Site quality
and shore
proximity
compromise
solution
Distance 30 -
50km

Existing preliminary bathymetric survey (50m) of a potential candidate site


Site evaluation lines
0 m
3 flotteurs BMTI EL126: 70 kg
2165 m
2 m
2 m
Drisse 16 mm 8 torons 20 m
22 m
Microcat 37SMP IDO
2187 m
Bioluminescence intrumentation
Transmissiometre Wetlab
Datalogger
2189 m
Aquadopp
2190 m
27 m
Drisse 16 mm 8 torons, 250 m
277 m
2 FL30 BMTI : 64 kg
2440 m
3 m
1 m
Acoustic release RT B2S
2443 m
3 m
Elingue 3m
3 m
Chaîne (14 mm) 3m
Lest 300 kg
2450 m
287 m
Immersion
théorique
Longueur filée
théorique
JJD
Catane 20/02/2012

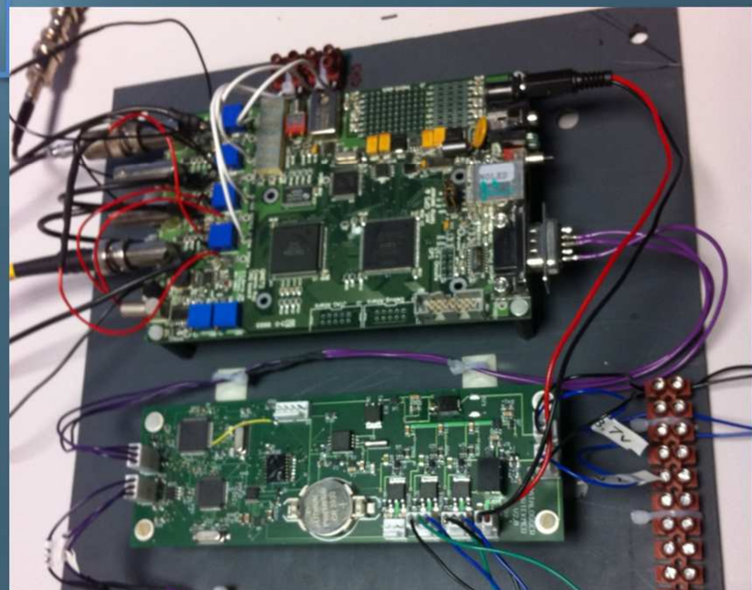
Bioluminescence instrumentation
Configuration

outside sphere

Lithium Polymère

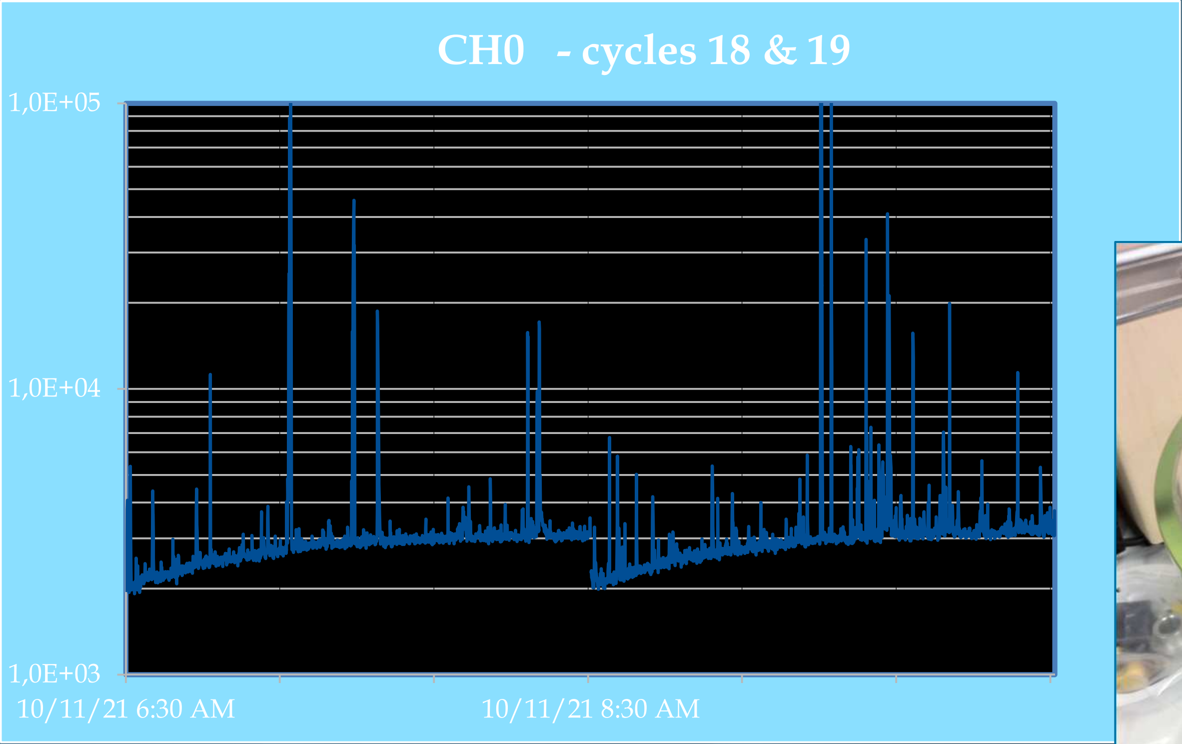
2x

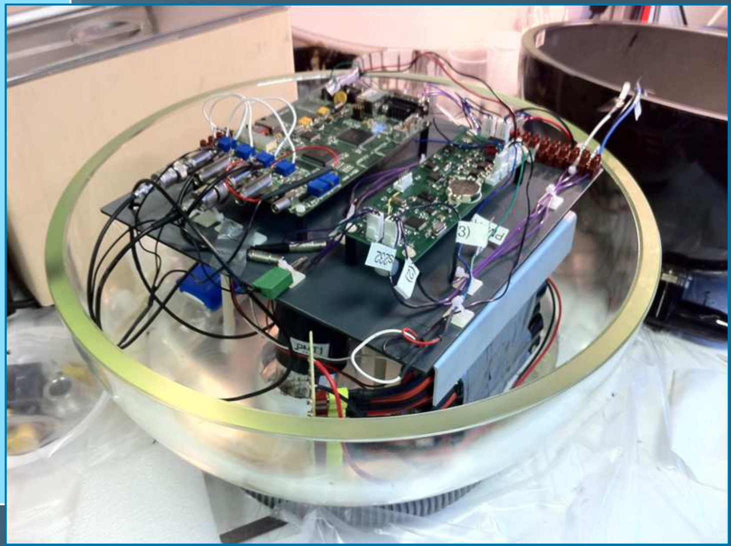
Hamamatsu R6233



First Sea Test: october 11

30 cycles of 2h (OFF 90min – ON 30 min)





Next steps:

1. Assembly of 3 OM & tests at CPPM: **ongoing…**

2. Cross calibration in deep sea: **within 2 weeks**

3. Deployments in 2 sites + ANTARES: **# mid-march**
   Measurements : 30′ every 4 hours

Contact: Sylvain Henry: shenry@cppm.in2p3.fr

Specific MEUST requirements for MEOC

General provision:

- AC current power transport
- Total length : 30-50 km depending on final site location
- Depth max: 2500m
- Sea water: North Mediterranean 38g/kg
- Temperature: 5 to 45 °C

Electrical requirements :

- Conductor: one
- Permanent max duty voltage: 6500 VAC (peak value 50Hz)
- Permanent max duty current: 30A AC (RMS value)
- Resistance: less than 1 ohm/km
- Capacitance: less than 200nF/km
- Inductance: non specified

Specific MEUST requirements for MEOC

Optical requirements:

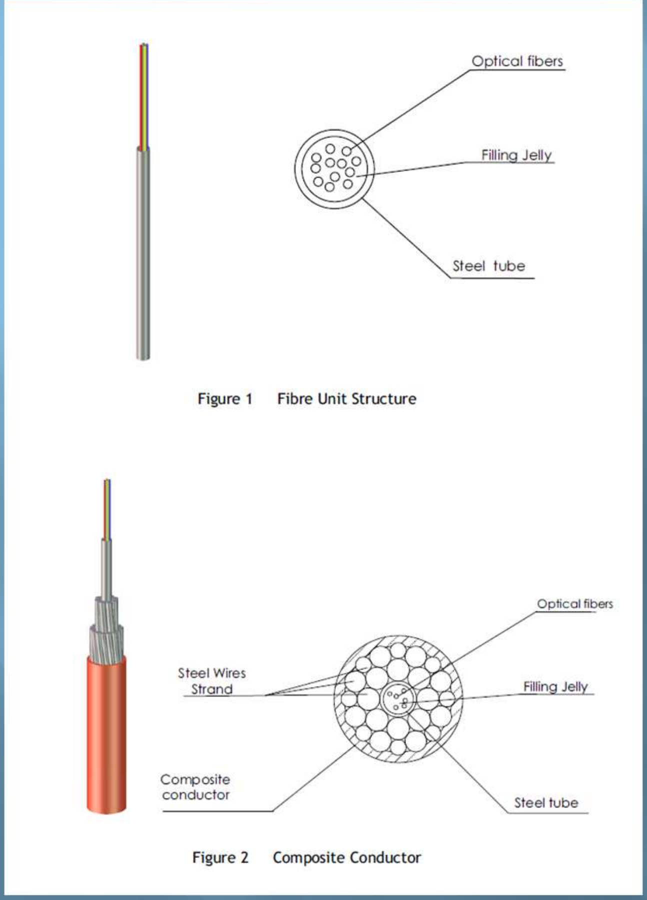
- Optical fibers: min 36 monomode fibers per branch according to ITU-T G.655 specifications (harmonic dispersion to be specified)
- Main bandwidth: 1550nm (band C)
- Attenuation: better than 0.25 dB/km
- Fibers continously identified with factory marker process (ink)

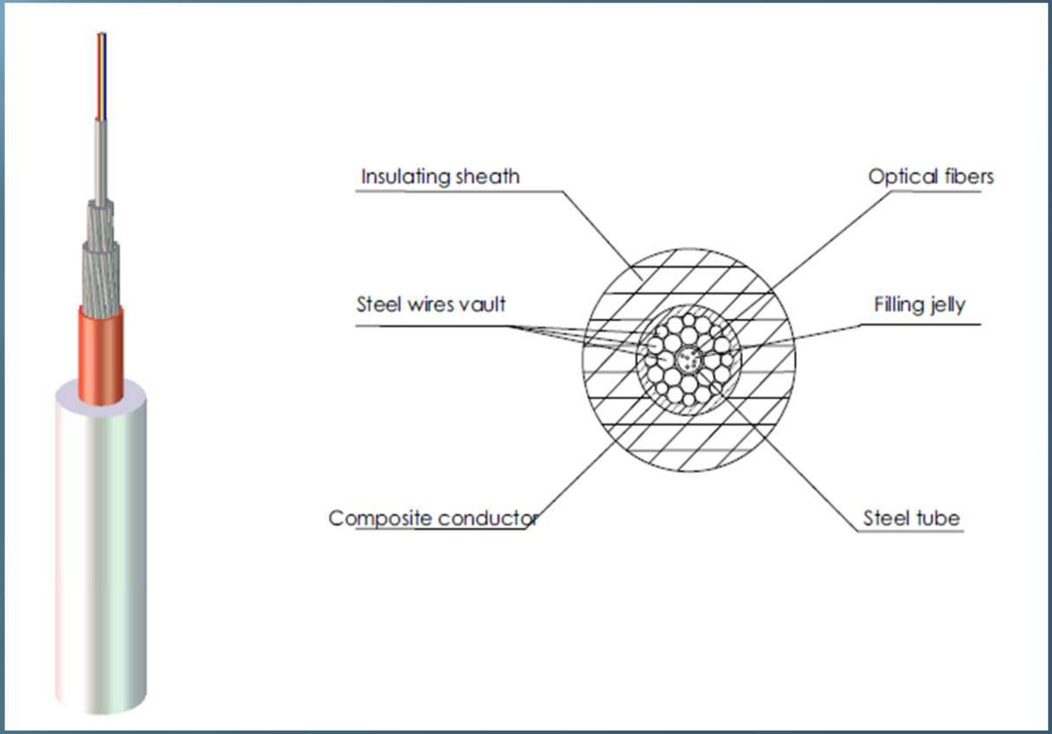
Mechanical requirements:

- **Favourite construction :** Water blocking in the cable to ingress water penetration when cut or damage events. Metallic vault design
- **Armoured section for landing route** (depth < 1000m): Length to be considered: 15km. External diameter non specified. Density>3. Acceptable repeated and storage min bending radius ~ 1.5m. Tensile strength resistance without damage: larger than 1500m of its own weight in water.
- **Light section for layout route** (depth >1000m): External Diameter < 21.5mm. Density >1.1. Acceptable repeated and storage min bending radius ~1m. Tensile strength resistance without damage: larger than 3500m of its own weight in water. Ultimate tensile stress: 3 times the previous figure.

Deep sea cable

Tendering process for manufacturing and laying in progress
Technical specifications written and bid foreseen in March.





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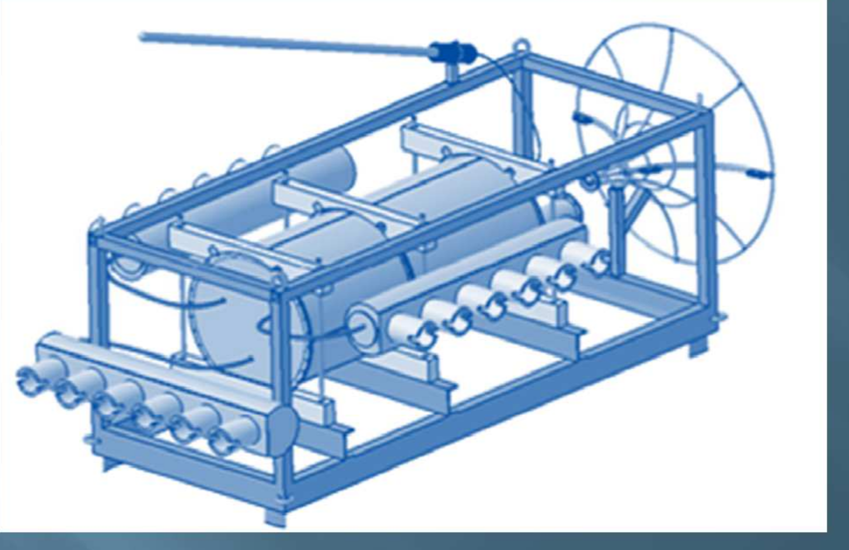
internal node architecture

MEUST
INTERNAL NODE ARCHITECTURE



Node functions

The node holds:

Power for DU's

Infrastructure control/command

Data transmission network for DU's

Junction box characteristics (power distribution)

➢ **Input Characteristics** :

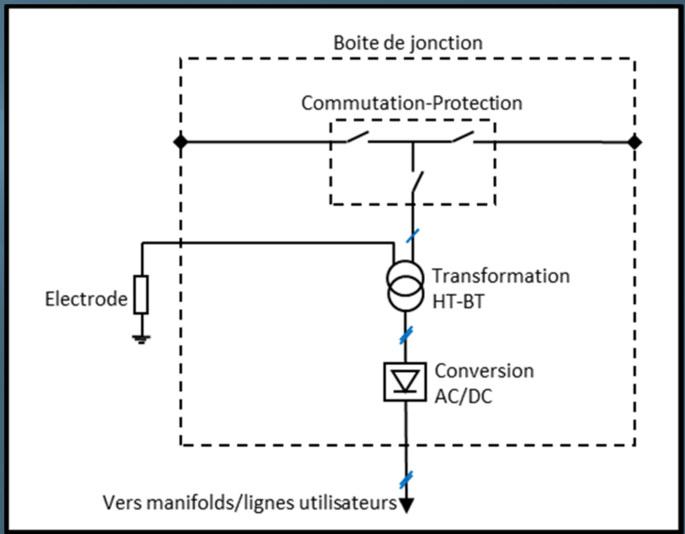
- P_{in} = 9740W_{eff} when P_{charge} = 400W x 18
- P_{in} = 12105W_{eff} when P_{charge} = 500W x 18

➢ **Hypothesis** :

- $\eta_{AC\text{-}DC}$ = 0,8 ; $FP_{AC\text{-}DC}$ = 1
- $\eta_{transformateur}$ = 0,95 ; $FP_{transformateur}$ = 1 (or 0,8 with upstream compensation device)

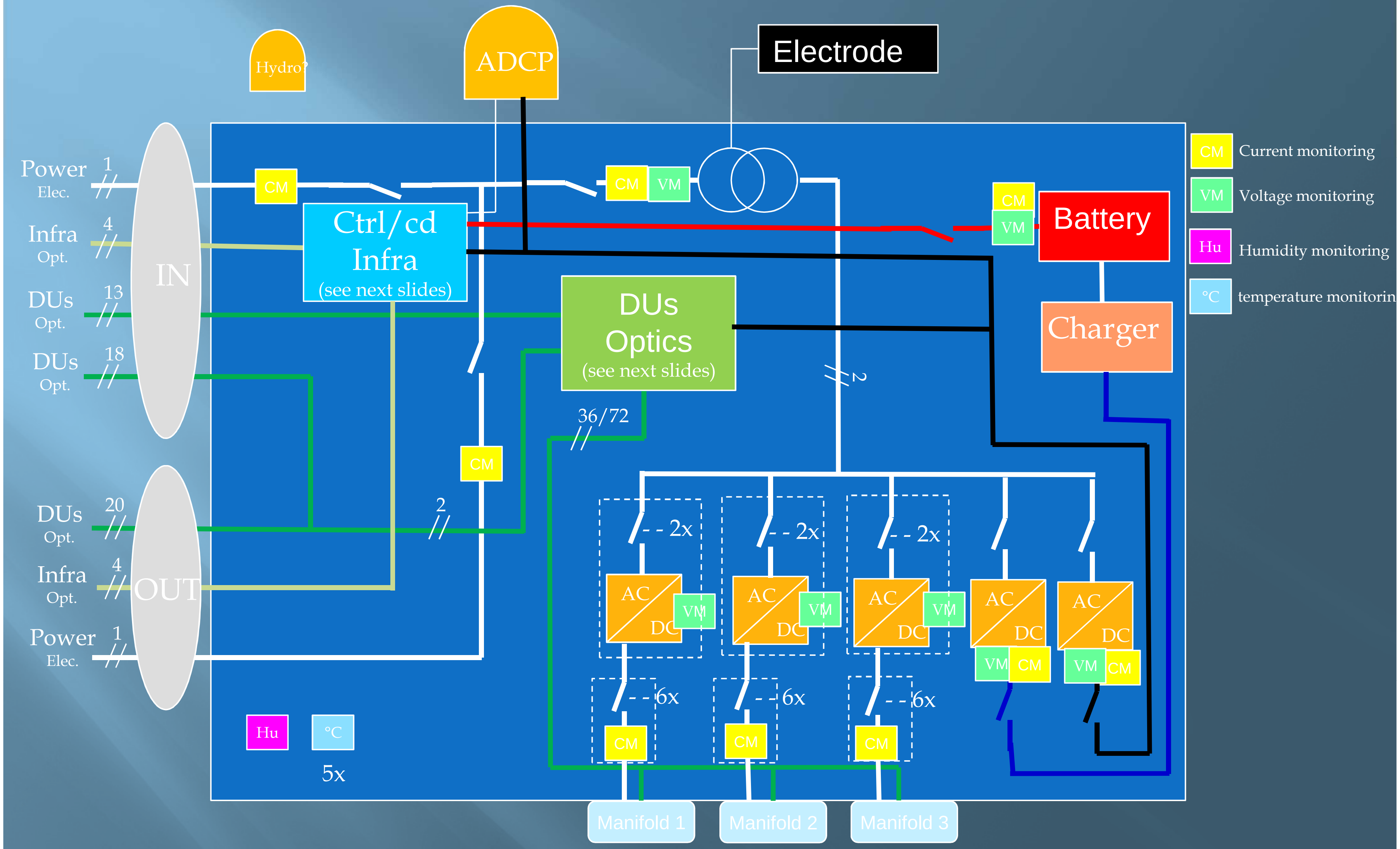
➢ **Output Characteristics** :

- 18 connections users by node (⇔ 3 manifolds of 6 ports)
- Tension available by user : 400V DC
- Variable load acceptable user : 0 (switch off) - 500W permanent nominal mode.

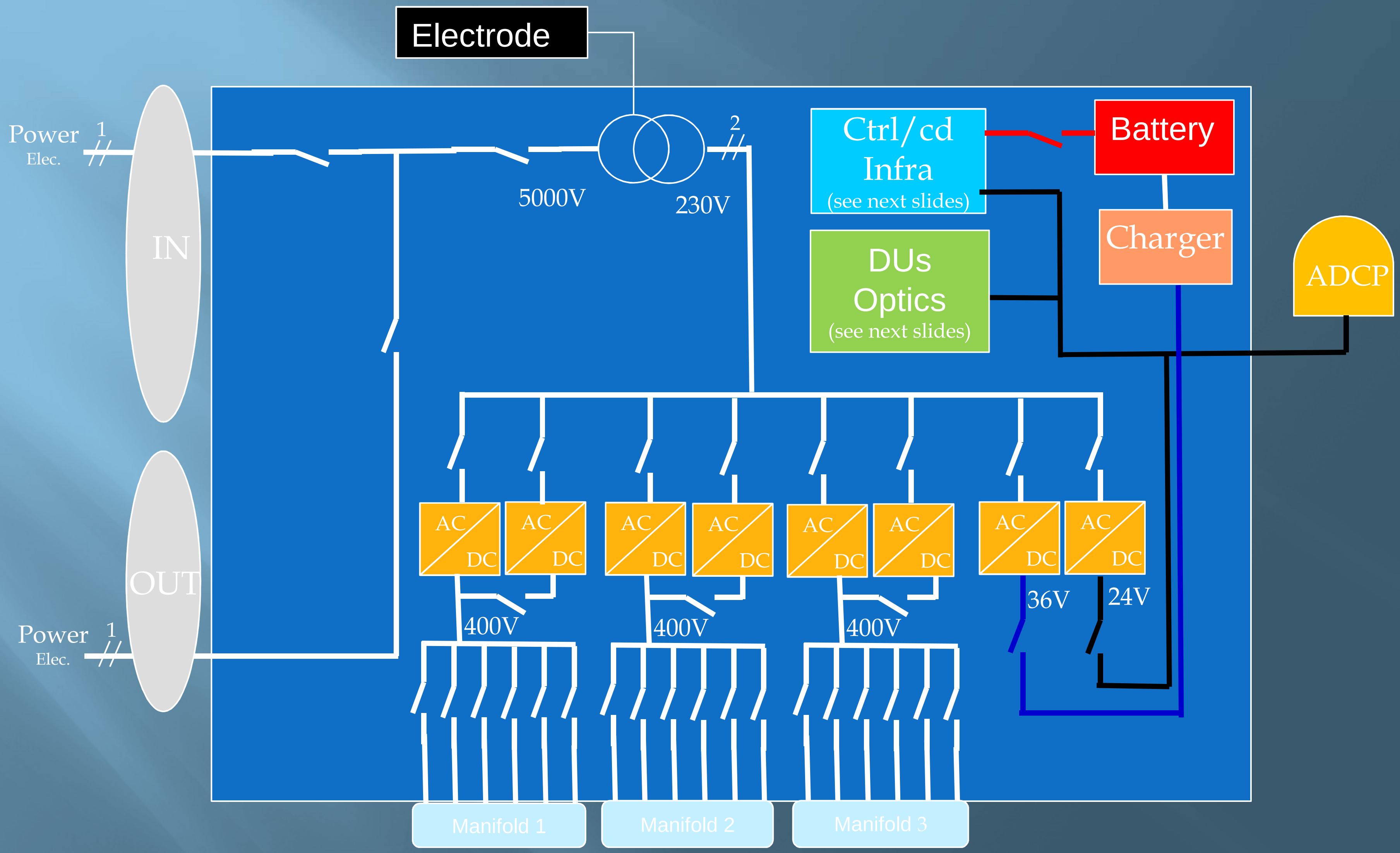


- the system of cut does not play the part of protection

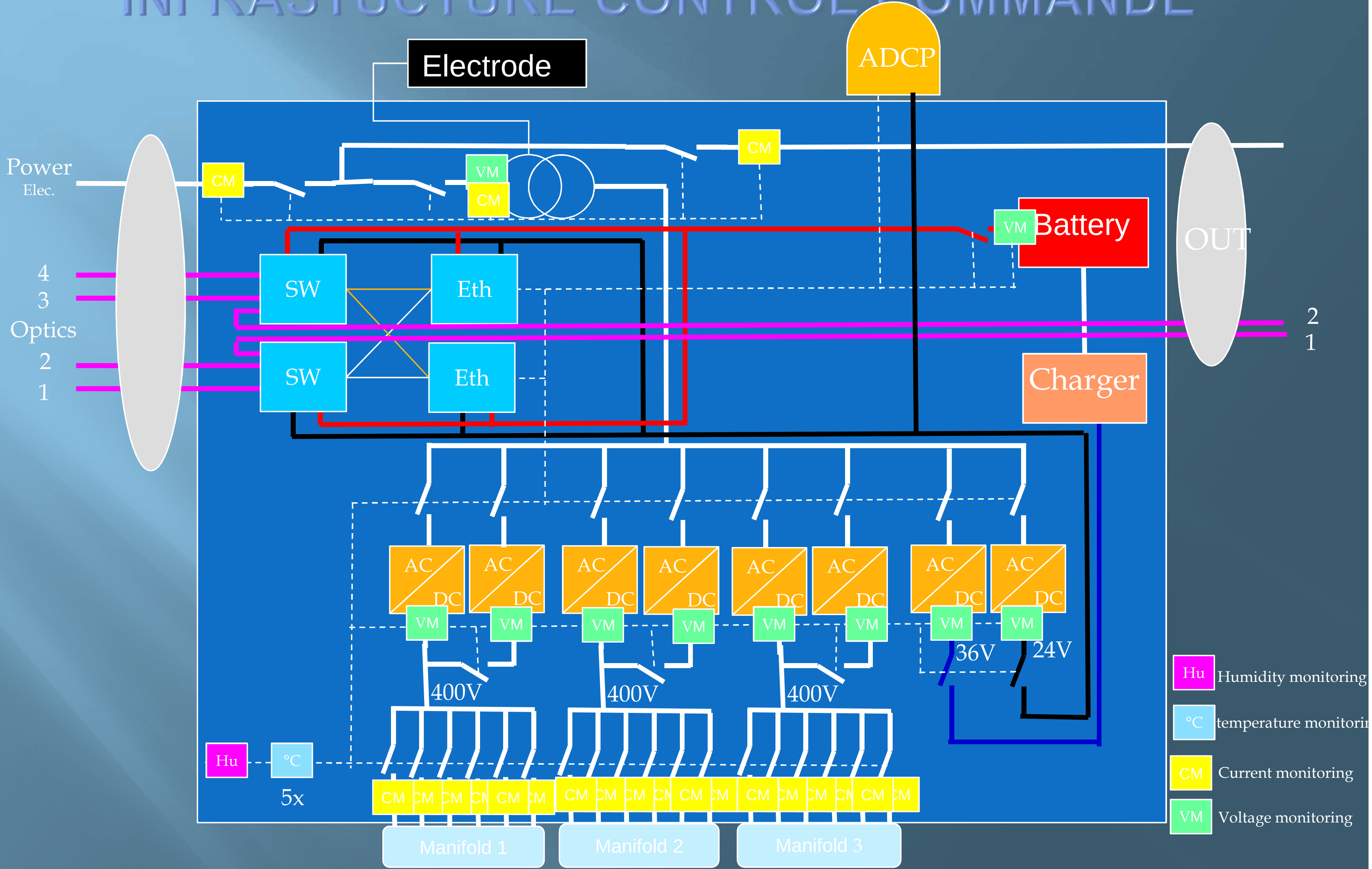
GENERAL SCHEME



POWER


Electrode
Power
Elec.
1
IN
OUT
Power
Elec.
1
5000V
230V
2
Ctrl/cd
Infra
(see next slides)
Battery
Charger
DUs
Optics
(see next slides)
ADCP
AC
DC
400V
400V
400V
36V
24V
Manifold 1
Manifold 2
Manifold 3

INFRASTUCTURE CONTROL COMMANDE



Infrastructure control/command

- No home made electronics, only use certified existing modules
- Operate Antares junction box return of experience as much as possible
- We have now several nodes so introduced network functions
- Network is based on a ring of industrial switches
- Use ethernet modules for all IOs
- All parts are built with redundancy

Contact : Michel Ageron
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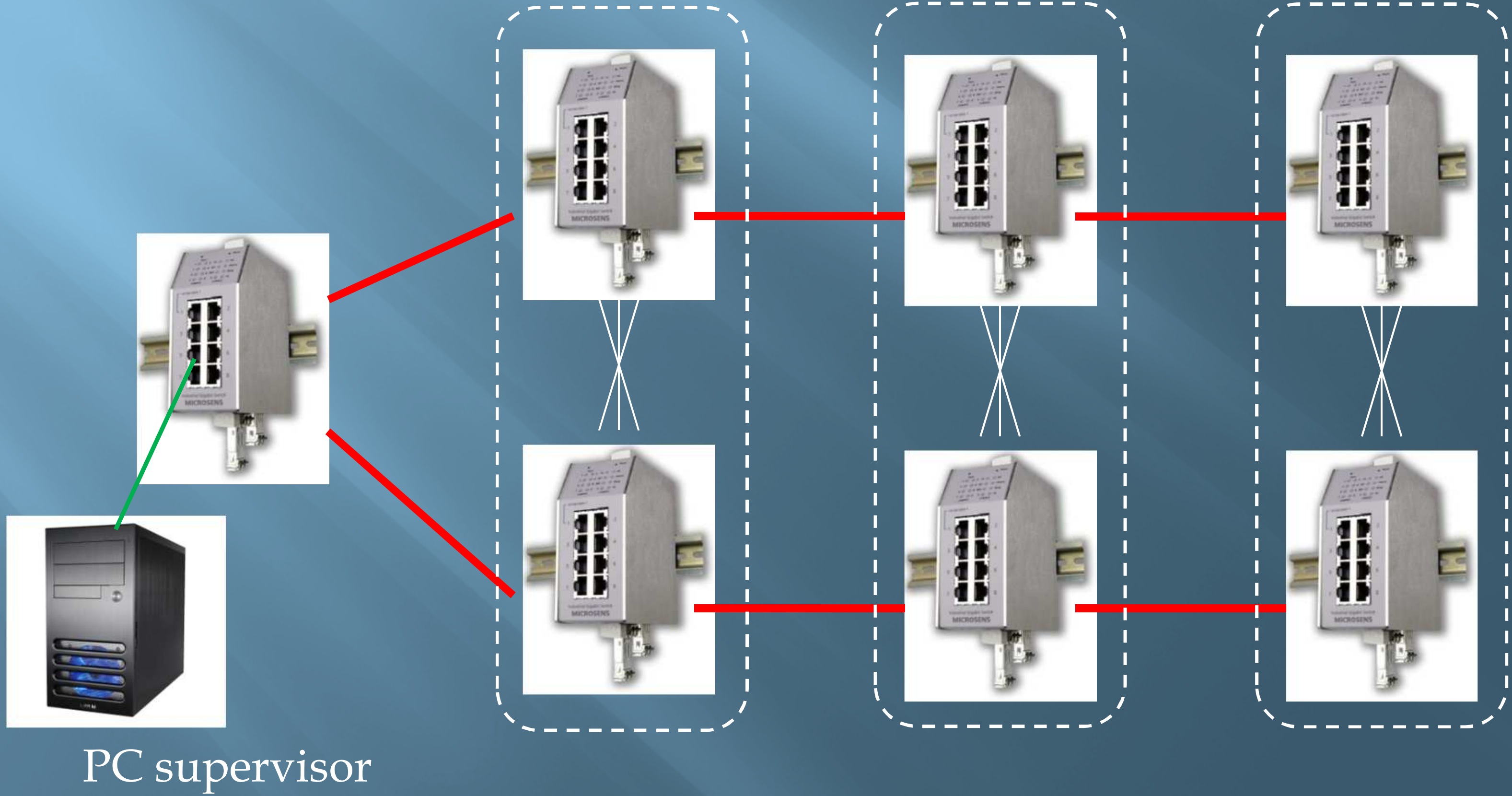
Infrastructure control/command network

- Switches currently being tested : Microsens MS650869M-V2
- 3 optical ports with SFP modules, 8 copper ports, dual supply for redundancy
- Acts as an OSPF (Open Shortest Path First) router so routes are configurable
- Operates in a ring quickly reconfigurable (20 mS) after faulty link
- Added redundancy with 2 switches in one node so more than 1 faulty link is tolerated



Contact : Michel Ageron ageron@cppm.in2p3.fr

Infrastructure control/command IOs

- Dual redondant ethernet port
- Digital IOs, Analog IOs cards
- Galvanic isolation on every IO
- Windows and linux libraries
- Compatible with any SCADA

Master block

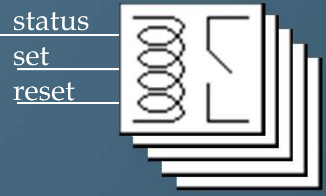
Additionnal cards

As in Antares (fortunately), IO channels are doubled so 2 such modules per node

IO cards summary

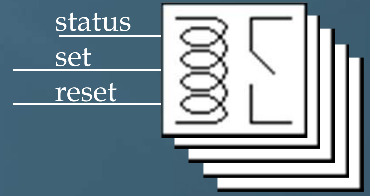
6 Outage artery (2x3 relays) 6 Breaker before AC/DC 3 Switches 18 Breaker after AC/DC	33 relays

33 x 24V inputs sink or source



Cards : 5 M18xx (8in) or 3 M16xx (16in)
24v (11 to 28,8V)
Min off state voltage : 5V
On state current : 6 mA
Input impedance : 5,1 K

66 x 24V outputs sink or source



Cards : 5 M26xx 16 outputs 24V
On state min current 1 mA
Off state leakage current 50 uA
Output current 0,3 A

31 x analog inputs

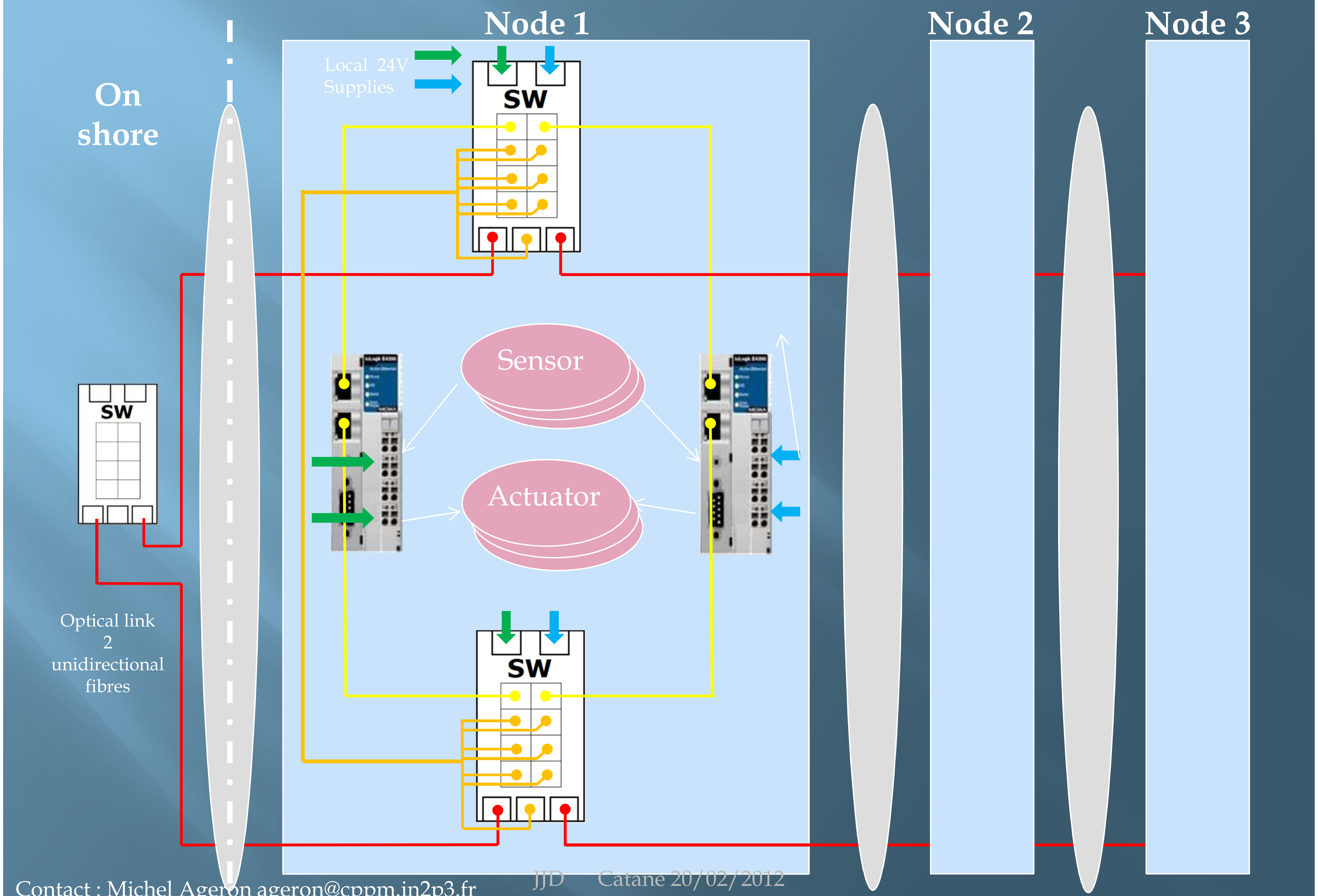
3 Outage artery : voltage, input and output current 2 Environnement : temp, hygro 24 DC outputs : 18 current, 6 voltage	31 analog inputs

2 Local supply . Current, voltage

Cards : 4 M3810 0=>10V 12 bits
Input impedance : 500 K
Opto isolated

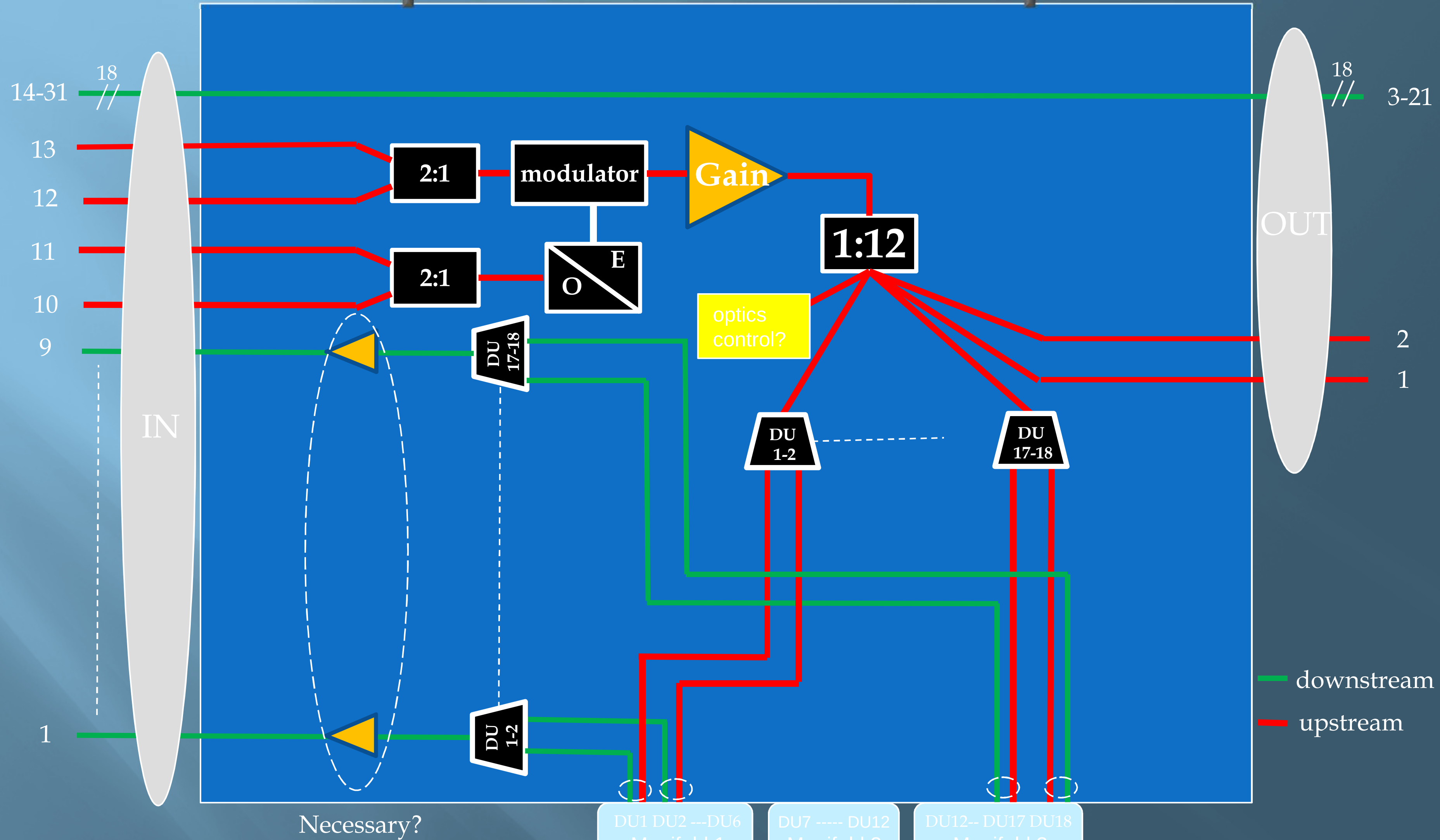
Contact : Michel Ageron ageron@cppm.in2p3.fr

Detailed internal organisation

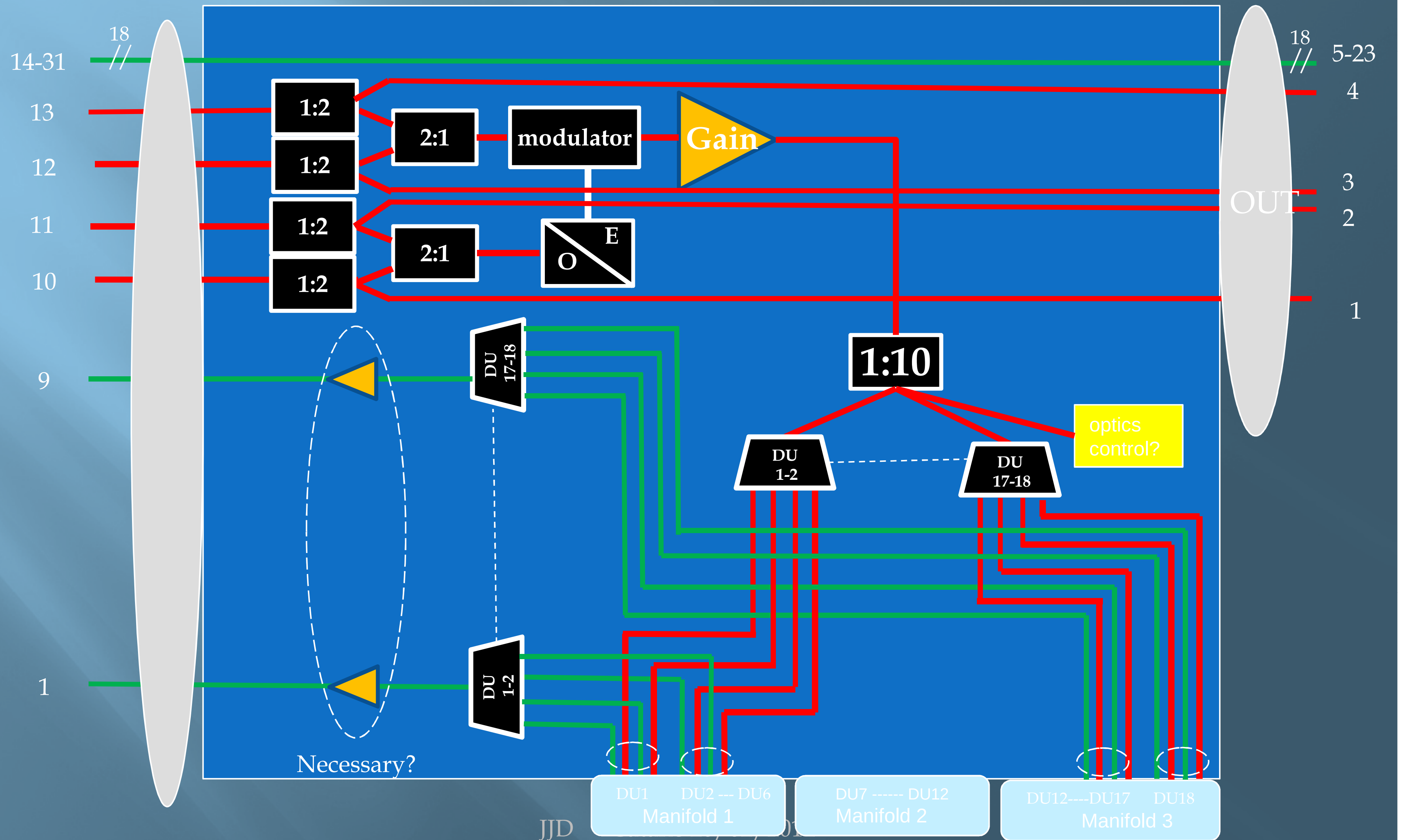


Contact : Michel Ageron ageron@cppm.in2p3.fr

DUs optics node 1 - option 1



DUs optics node 1 - option 2



JJD

node architecture progress report

- Functional analysis > 13 external functions,15 principal internal functions, 35 secondary functions.

- Simulations and cots (components on the shelves) characterizations and inquiries (KN systemes company)

- Experimental technological model designed and under construction (all components already purchased and available) AC/DC 3kW converters under development (Oleane Company)

- planned next months

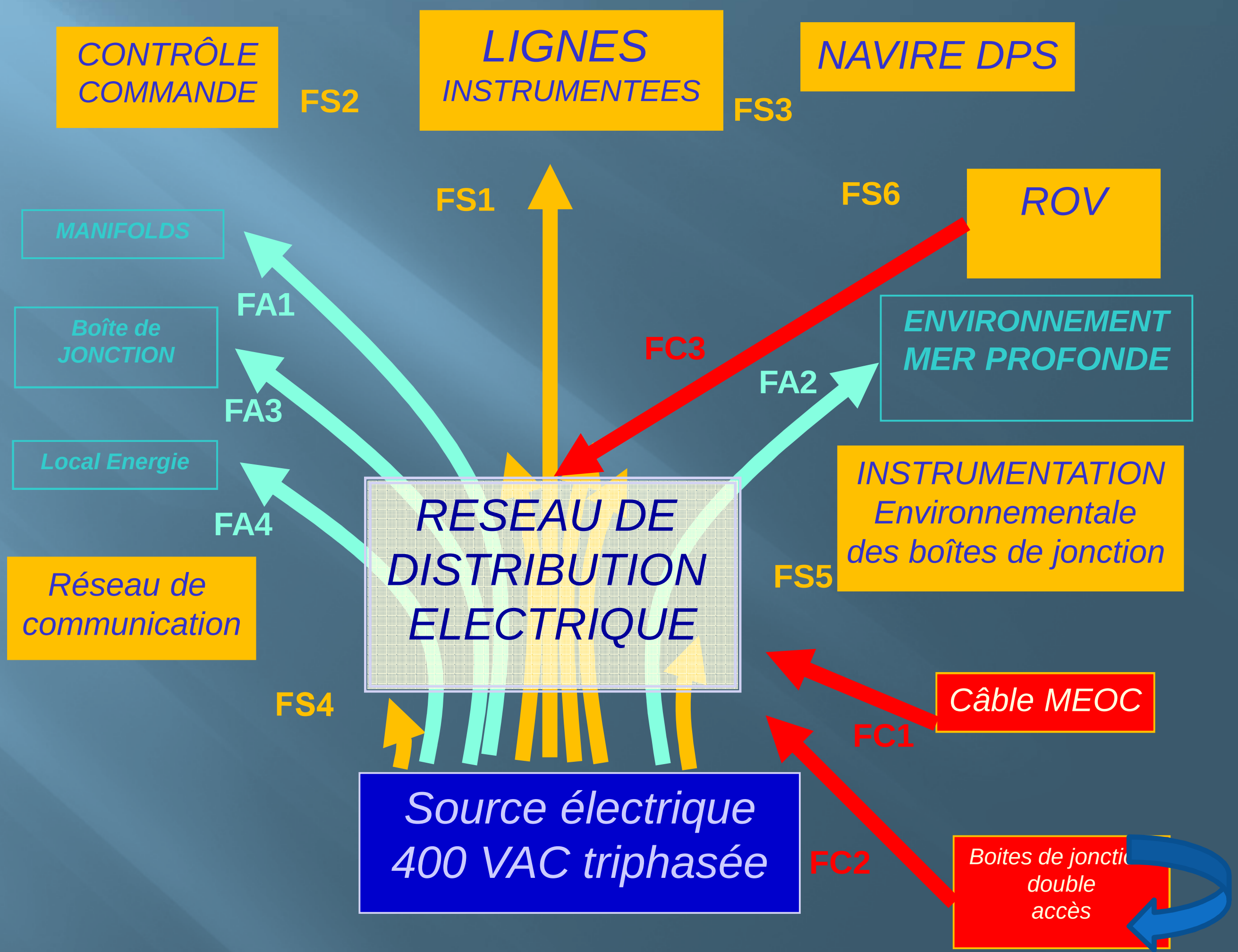
  Functional tests and reliability studies (bench of tests on building)

  Test pressure-balanced campaigns (IFREMER- Brest facility)

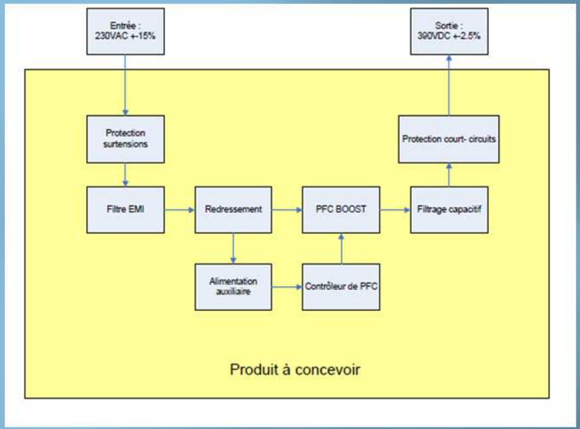
  High Voltage network tests

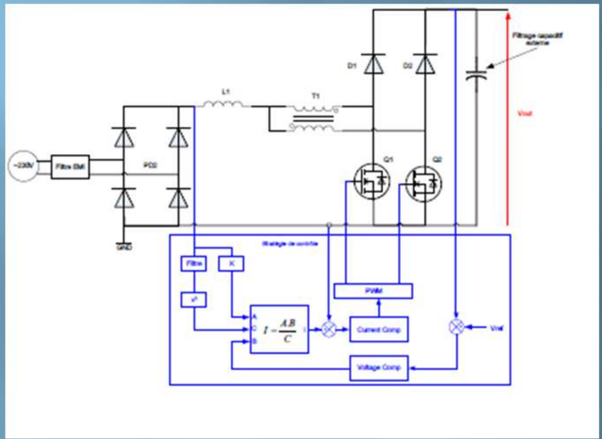
Analyse fonctionnelle externe du réseau d'alimentation électrique

13 fonctions externes
15 fonctions internes principales
35 fonctions secondaires



AC/DC converters





INPUT :

- Tension : 230VAC @ 15%, 50Hz
- Surtension : +25% pendant 1s
- CEM : EN55022 classe A
- Courant d'appel : <50A.

OUTPUT :

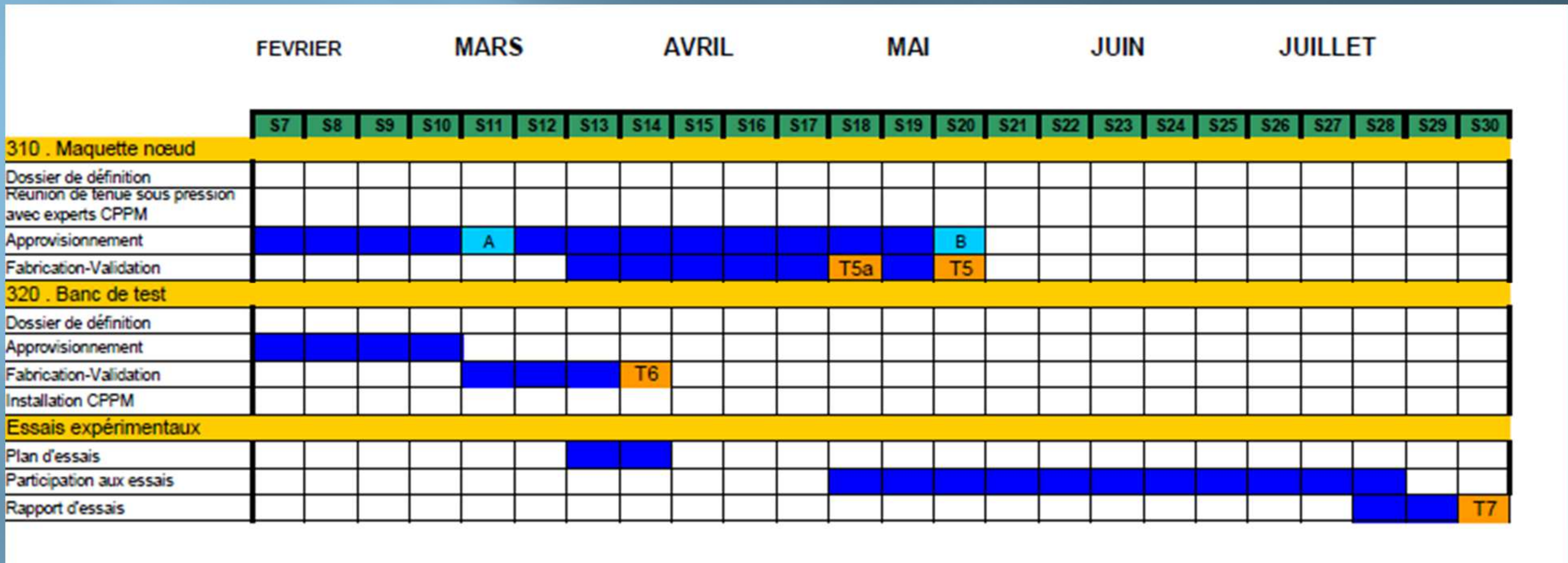
- Tension : 390VDC @ 2,5%
- Puissance : 3000W
- Output Ripple : 5%
- Load regulation : 380VDC @ 5%
- Contrainte filtrage de sortie : la partie HF sera sur la carte, et les condensateurs de fortes valeurs seront or alimentations à prévoir par le client (besoin à définir).
- Limitation de courant : 19A
- Temps de démarrage : < 10s
- Pas de monitoring de la tension de sortie (or régulation)
- Load : 0% à 100% après démarrage.
- Court-circuit : 500ms sinon pas de protections

GENERAL :

- Facteur de puissance : > 98%
- Rendement : > 90%
- Isolation entre l'alimentation et la masse mécanique (carcasse) : TBD
- Fréquence de découpage : TBD (pas de restriction)
- Dimensions : Exemple 110x60x30mm pour une alimentation 3kW : TBD
- Thermique : fonctionnement permanent. Convertisseur baigné en permanence dans l'huile.
- Durée de vie : 10 ans

A development with Eolane-Combée Company)
Contact : Stephane Theraube : theraube@cppm.in2p3.fr

Next 6 months schedule of works planned with the test model



Infrastructure MEUST

Installation mainly composed by:

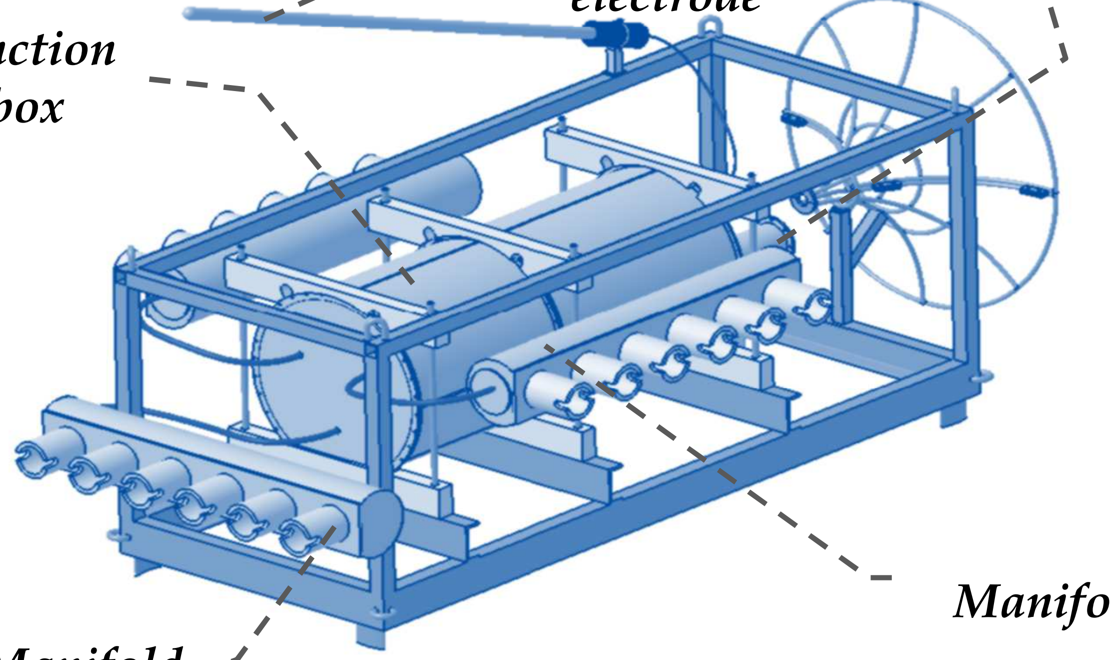
- a station on the shore (power room)
- a cable of telecommunication and power supply
- a network marine resources

inter- connections issues

Node Configuration (inter – connections)

Two main components :

node = Junction box + manifolds

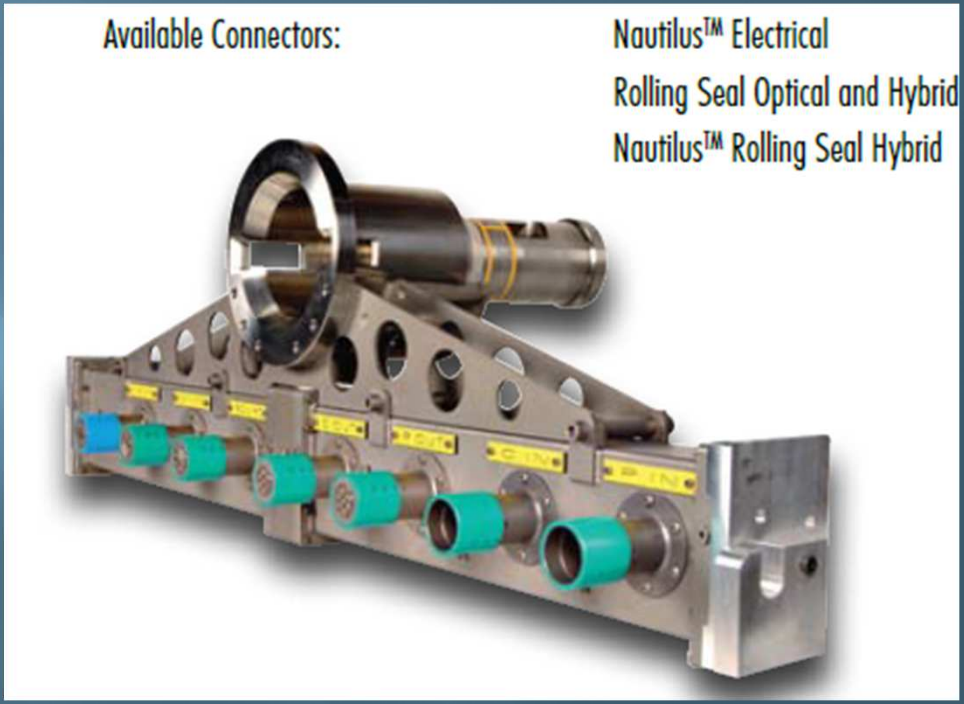


A difficult challenge :

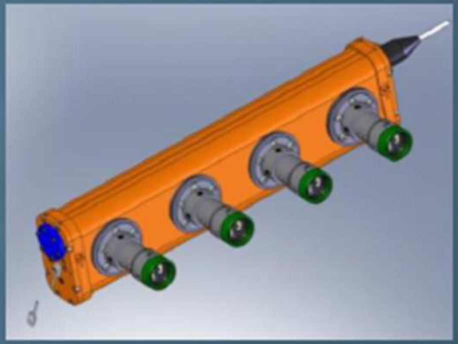
Find an alternative solution to the wet-mateable inter connections used today by ANTARES

BJ/DU ROV wet connection

Distribute signal and power to multiple points



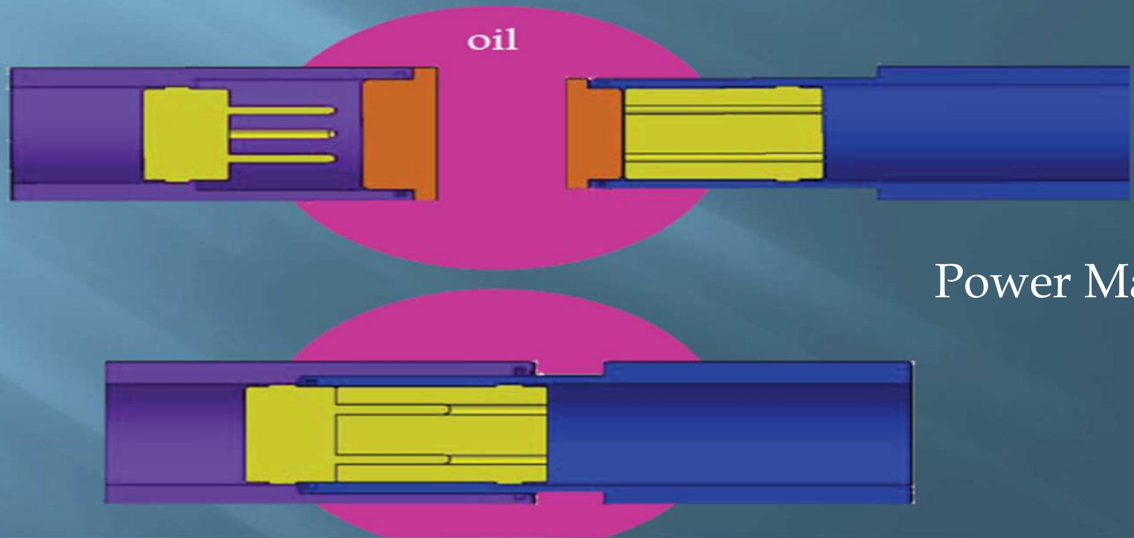
Exemple of very first cotation : 130 k€ per manifold (six ports) > ~ 400 k€ per node !
(without connectors and inter links included !!!) > How unlocking such an economic bolt ?



Exemple of existing manifold

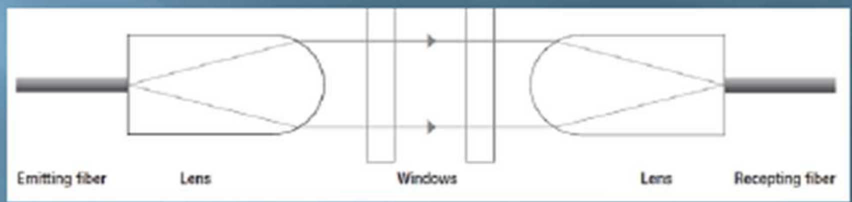
Two ways of solutions

- Industrial R&D Project (EDF+COMEX+CNRS)
  - Standard connectors (marinized) connected in oil



Power Mate Project

- On going R&D 4 beam expanded
  +4 electric contacts



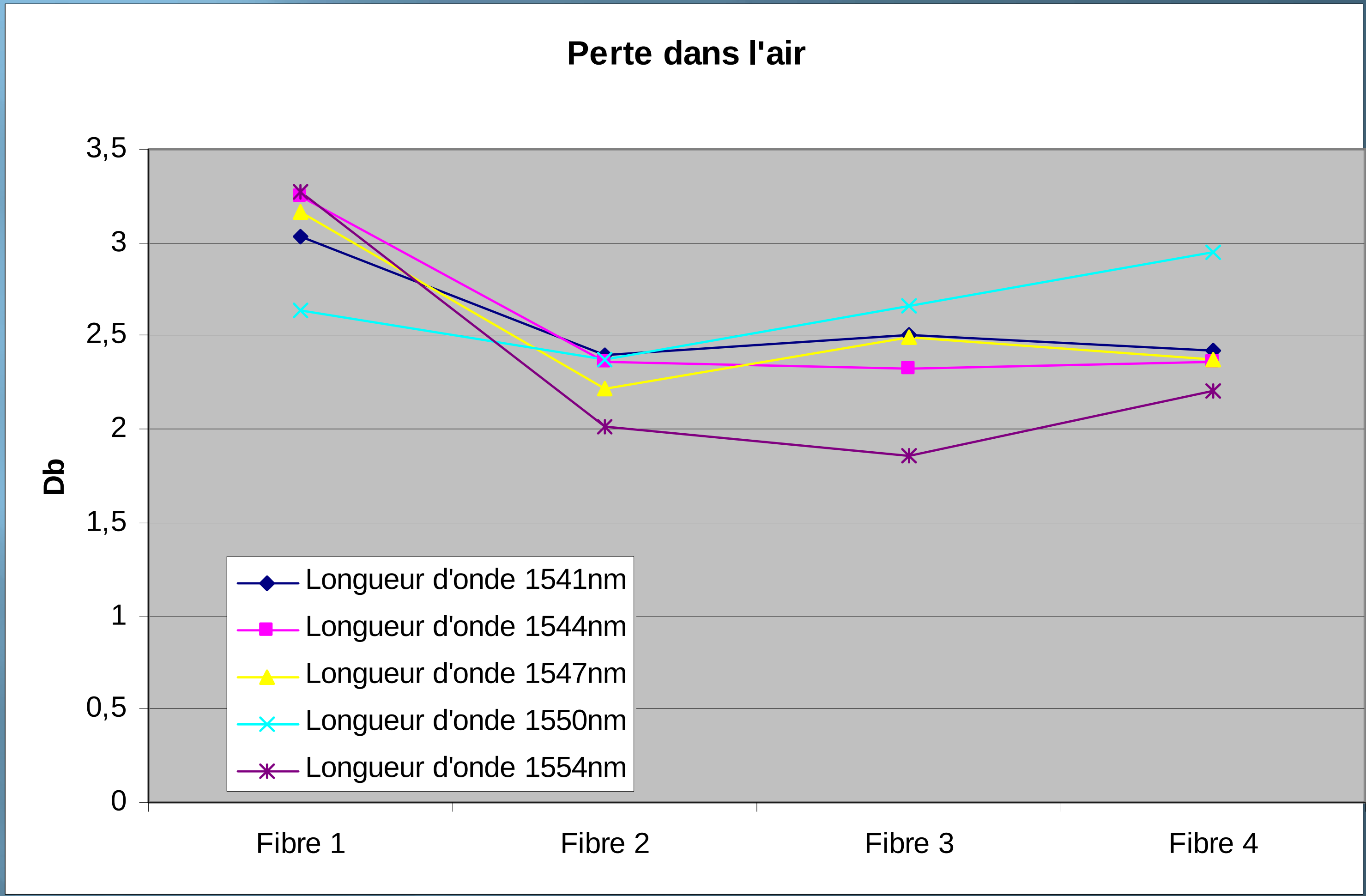
Low cost wetmate connector

Beam expanded Connector
First prototypes in the lab

A seacon development. Contact : Stephan Beurthey beurthey @cppm.in2p3.fr

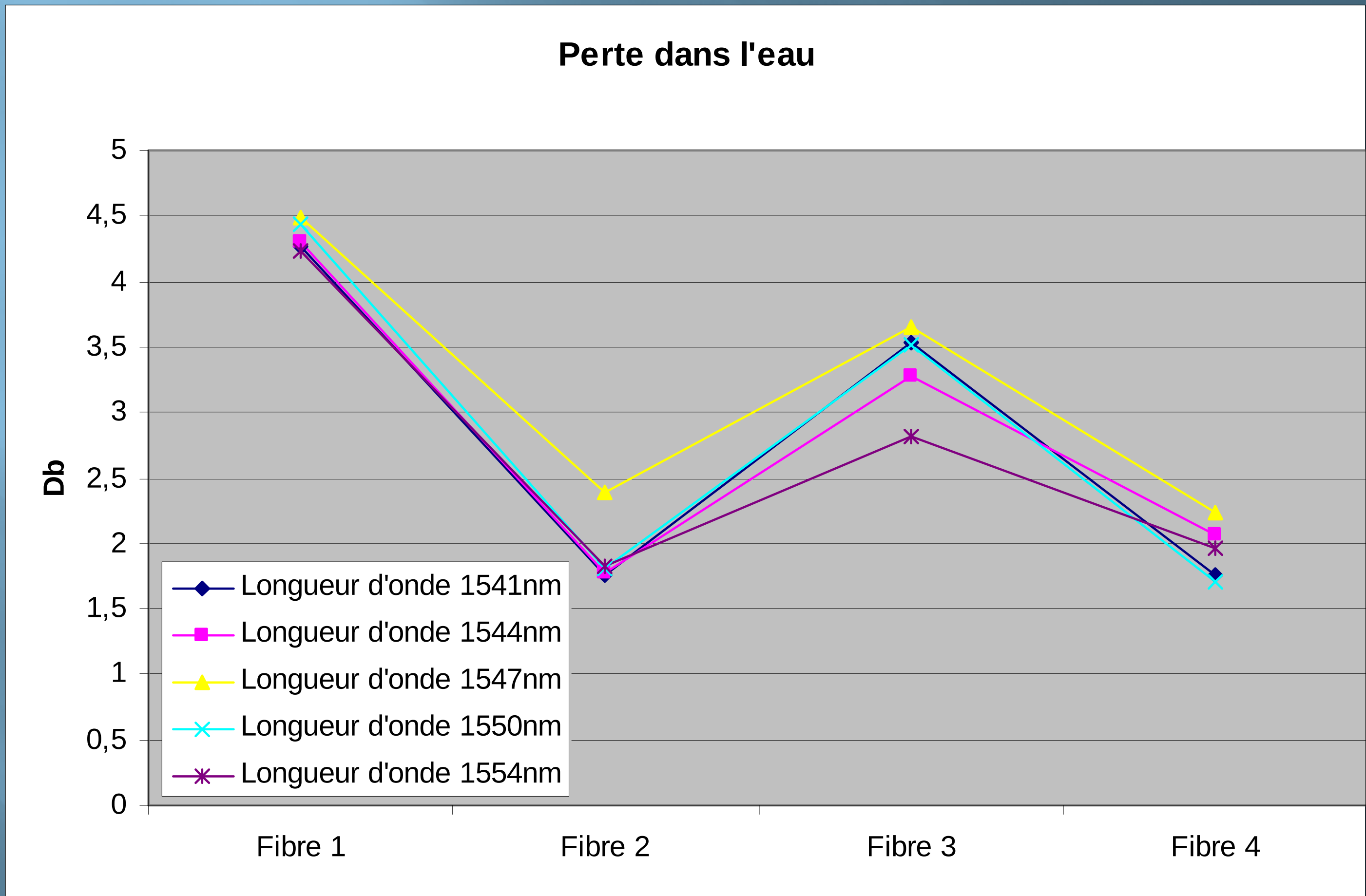
Crate Test

Loss in Air



Crate Test

Loss in Water

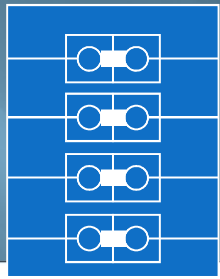


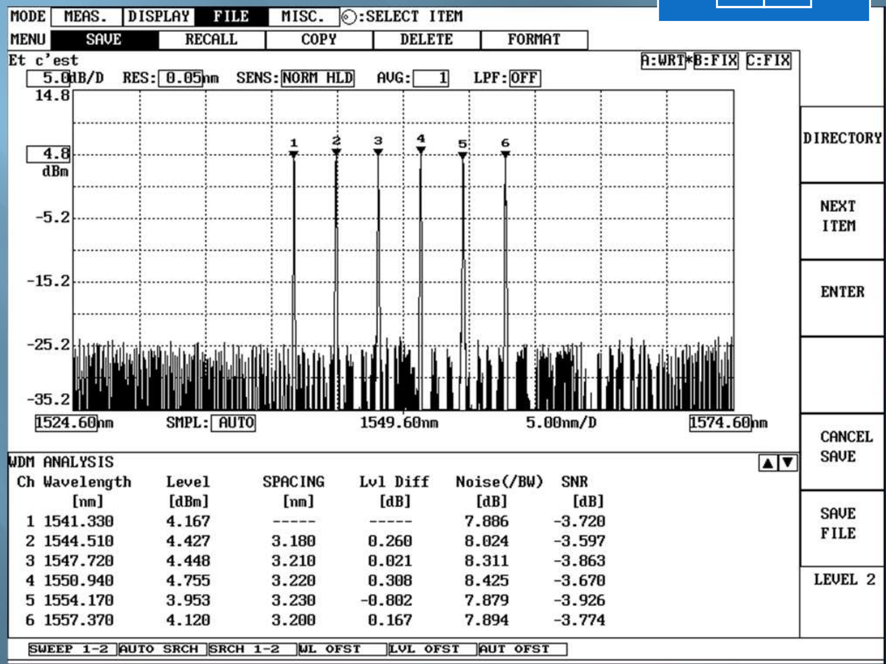
Crate Test

Fiber cross talk

- Signal on one fiber → look for signal on other fibers

λ_i





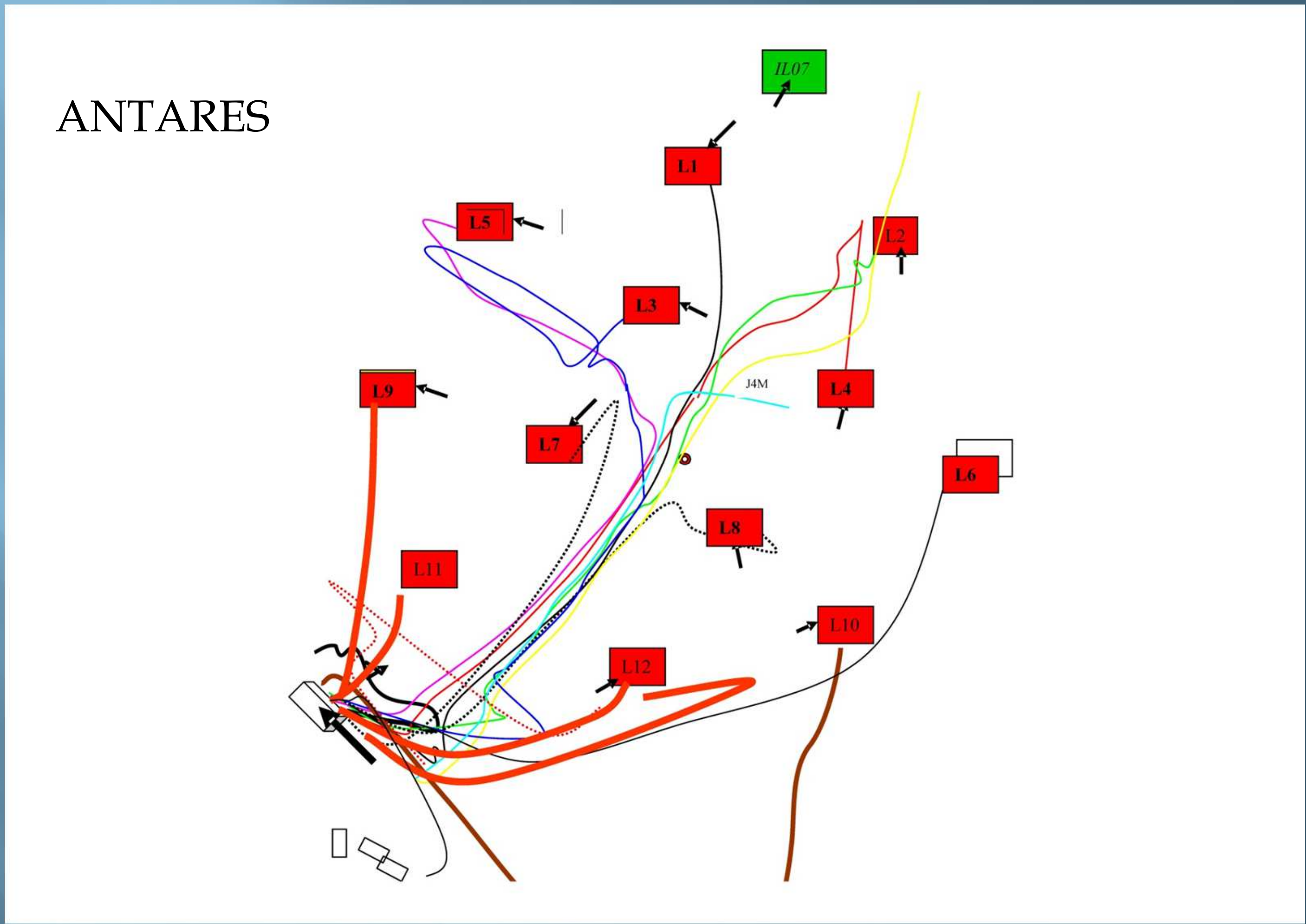
No signal on other fibers (in air and in water)

Crate Test

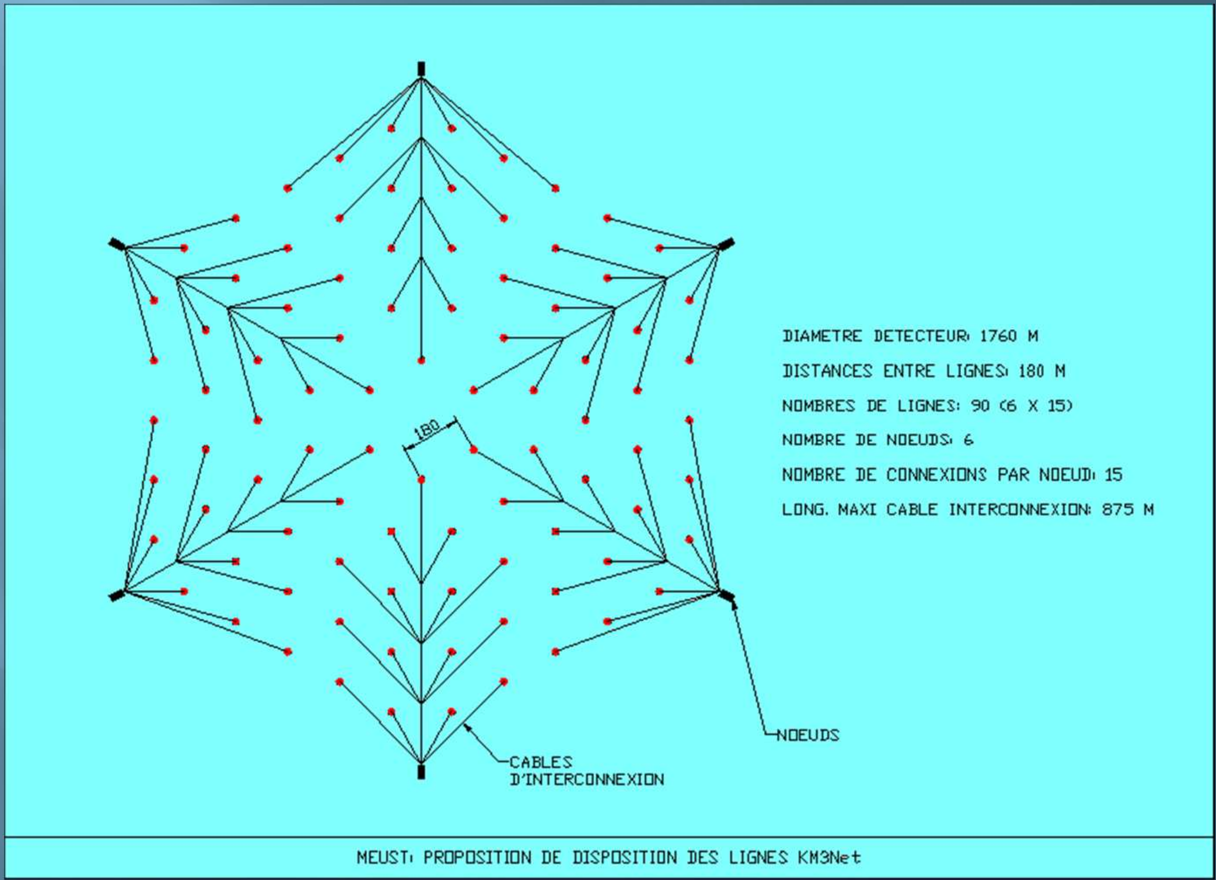
Conclusions

- Power loss still a bit too high:
- Objective: maximum loss 3Db/connector in water
- No λ dispersion: investigation can continue
  - → Bit error rate test to be done
  - → λ reflexion?
  - → Salt water with sediments

ANTARES presents a rather complicate layout !



Proposition of 90 lines layout



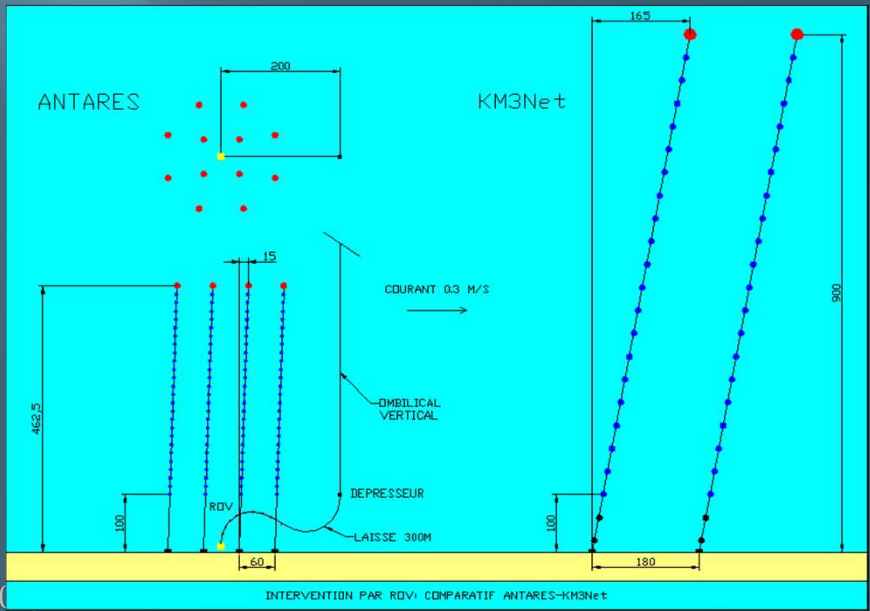
Constraints

When all the lines are deployed the ROV can operate with difficulty inside the field.

So the recovery of a line by release appears very risky !

they are likely to come to cling on an adjacent line

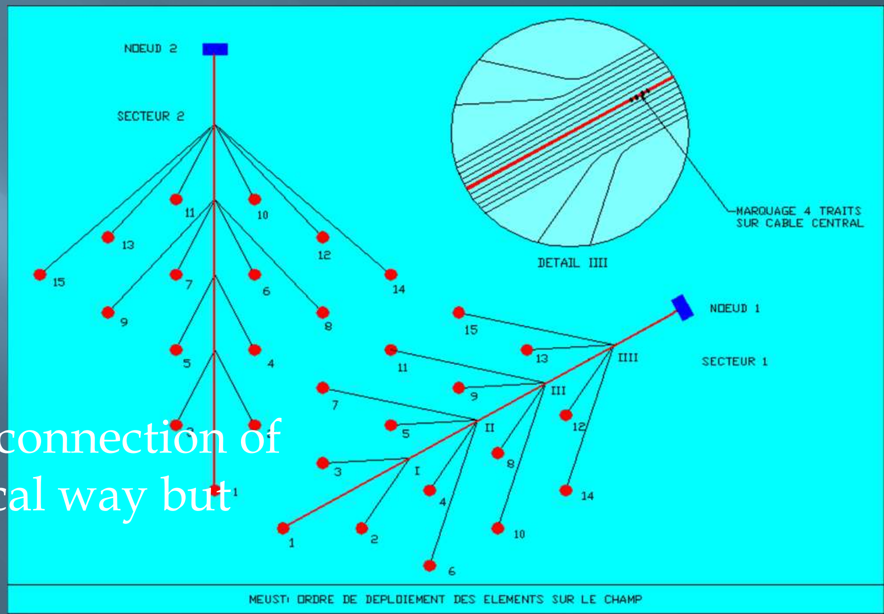
Are the lines thus disposable ?



Exemple of strategy of lines deployment required

The deployment of sector 1 of the field is made interior towards outside in the following order:

- Line 1
- Lines 2.3
- Lines 4,5,6,7
- Lines 8,9,10,11
- Lines 12,13,14,15



The deployment and the interconnection of sector 2 are made in an identical way but in the following order:

- Line 1
- Lines 2.3
- Lines 4.5
- Lines 6,7,8,9
- Lines 10,11,12,13,14,15

Interconnections requirements

We started a broad reflection in order to specify the requirements in interconnections taking into account: node manifold and connectors, interlinks cable, deployment tools and procedures, ROV requirements → Tendering !