DOCTORATE PROGRAM IN ELECTRONIC ENGINEERING

DOCTORAL TRAINING SEMINARS: RESEARCH PROJECTS IN THE DEPARTMENT OF ELECTRONIC ENGINEERING

Marine Instrumentation Technologies. Ocean observatories and underwater vehicles

Spartacus Gomariz & Joaquin del Rio

21/2/2014

PROGRAMA DE DOCTORAT EN ENGINYERIA ELECTRÒNICA

Jornades formatives 2014: Projectes de recerca al Departament d'Enginyeria Electrònica

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament d'Enginyeria Electrònica

PROPOSED OUTLINE:

1.- Introduction to SARTI Research Group

2.- Ocean observatories. OBSEA. Expandable Seafloor Observatory

3.- Unmanned underwater vehicles. GUANAY II.

The School of Engineering

Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú
UNIVERSITAT POLITÈCNICA DE CATALUNYA

Edificio EPSEVG

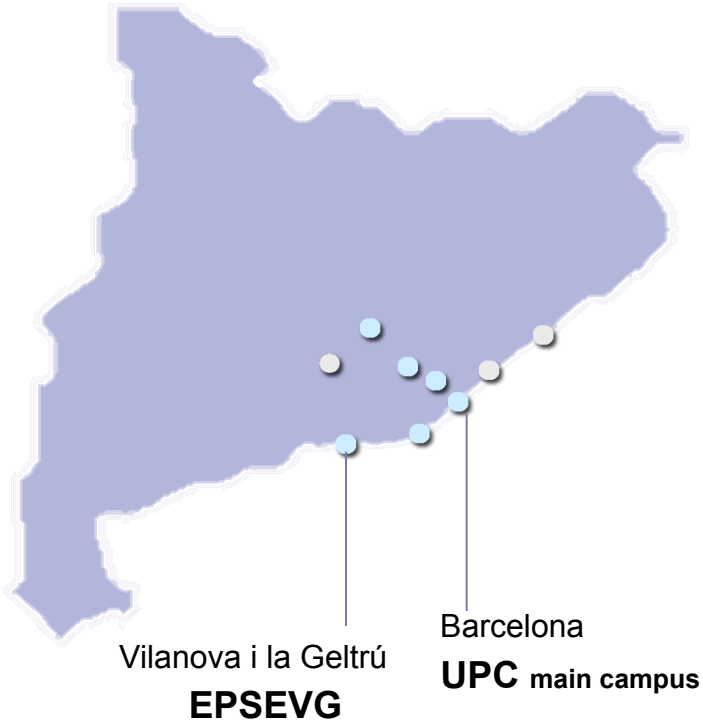
Edificio Centro Tecnológico.
SARTI Headquarters

The School of Engineering

1901 → It was founded as an arts and crafts school

1972 → It became part of the Technical University of Catalonia (UPC)

2001 → The university campus is born with new facilities and services



Main indicators

- 1500 students
- 200 academic and research staff
- 50 administrative staff
- 17 departments

- 14.000 m^2
- 22 lecture rooms
- 22 laboratories
- 8 computer rooms

Studies

Graus d'Enginyeria àmbit TIC:
-Grau en Enginyeria Informàtica
-Grau en Enginyeria de Sistemes Electrònics

Graus d'Enginyeria àmbit industrial:
-Grau en Enginyeria de Disseny Industrial i Desenvolupament del Producte
-Grau en Enginyeria Mecànica
-Grau en Enginyeria Elèctrica
-Grau en Enginyeria Electrònica Industrial i Automàtica

Ensenyaments de 2n cicle d'Enginyeria:
-Enginyeria Superior en automàtica i electronica industrial

SARTI Research group

- Centro de Desarrollo Tecnológico de Sistemas de Adquisición Remota y Tratamiento de la Información (SARTI) de la Universitat Politècnica de Catalunya

➢ Tiene como objetivo fundamental

- El desarrollo científico y tecnológico de equipos y sistemas de adquisición remota de datos, con especial énfasis en la instrumentación virtual y oceanográfica

SARTI Research group: members

Artero Delgado, Carla	Tècnic d'aplicacions hardware
Bghiel, Ikram	Becaris i Doctorands
Cadena Muñoz, Javier	Tècnic d'aplicacions hardware
Carreras Pons, Normandino	Becaris i Doctorands
del Río Fernández, Joaquín	Cap de projectes electrònics, PDI
Garcia Benadí, Albert	Tècnic d'aplicacions hardware
Hidalgo Castro, Alberto	Tècnic d'aplicacions informàtiques
Mànuel Làzaro, Antoni	Director, PDI
Nogueras Cervera, Marc	Cap de projectes electrònics
Santamaria Català, Josep	Responsable de qualitat
Sarrià Gandul, David	Tècnic d'aplicacions hardware
Toma, Daniel Mihai	Becaris i Doctorands
Vidal Oliveras, Neus	Cap de formació
Spartacus Gomariz	PDI
Rafael Ramos	PDI
Mariano Lopez	PDI
Oriol Pallares	Tècnic
Ivan Masmitja	Tecnic

SARTI Research group

Research

Technology Transfer

Services

Education and Outreach

- Group creation: 1998
- Multidisciplinar:
  electrónics, telecos, mecánicos, físicos, matemáticos, informáticos

SARTI membership

Red AEGIS (Ability Enlargement For Geophysicists and Information Technology Specialists)

Unidad Asociada al CSIC (Consejo Superior Investigaciones Científicas)

Grupo de Desarrollo Tecnológico de Sistemas de Adquisición Remota Aplicado a las Ciencias de la Tierra (Tecnoterra)

Instituto Ciencias de la Tierra, Jaume Almera. CSIC
Instituto Ciencias del Mar. CSIC
Unidad de Tecnología Marina. UTM-CSIC

Red Riscos Naturals (RYSKAT) DURSI

Grupo Investigación Consolidado (DURSI). 00708. Recursos marinos renovables.

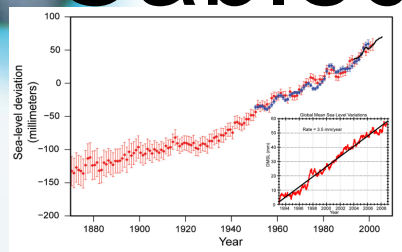
EMPRESA CERTIFICADA
UNE-EN-ISO-9001

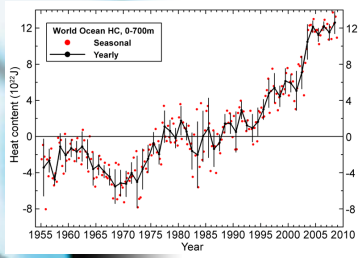
Grupo SARTI: Organización de Congresos

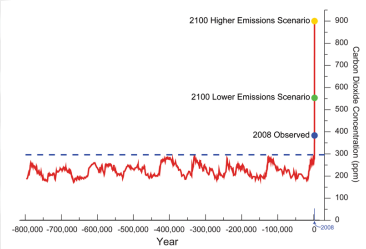
http://www.martech-workshop.org

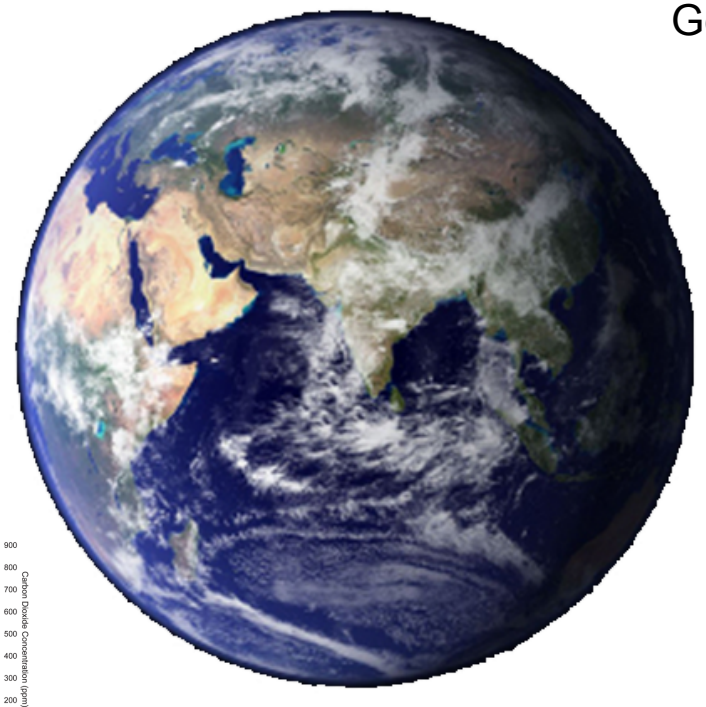
MARTECH, INTERNATIONAL WORKSHOP ON MARINE TECHNOLOGY
1st ,2nd and 3rd took place in Vilanova I la Geltrú. Barcelona.
4th Edition, 2011: Universidad de Cadiz
5th Edition, 2013: Universidad de Girona

Cabled Observatories

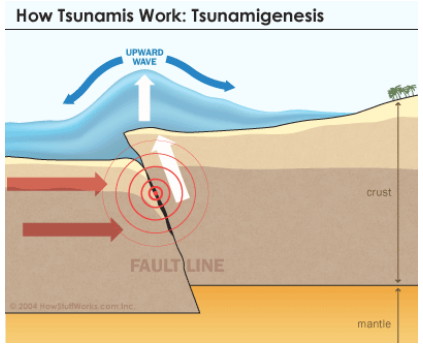








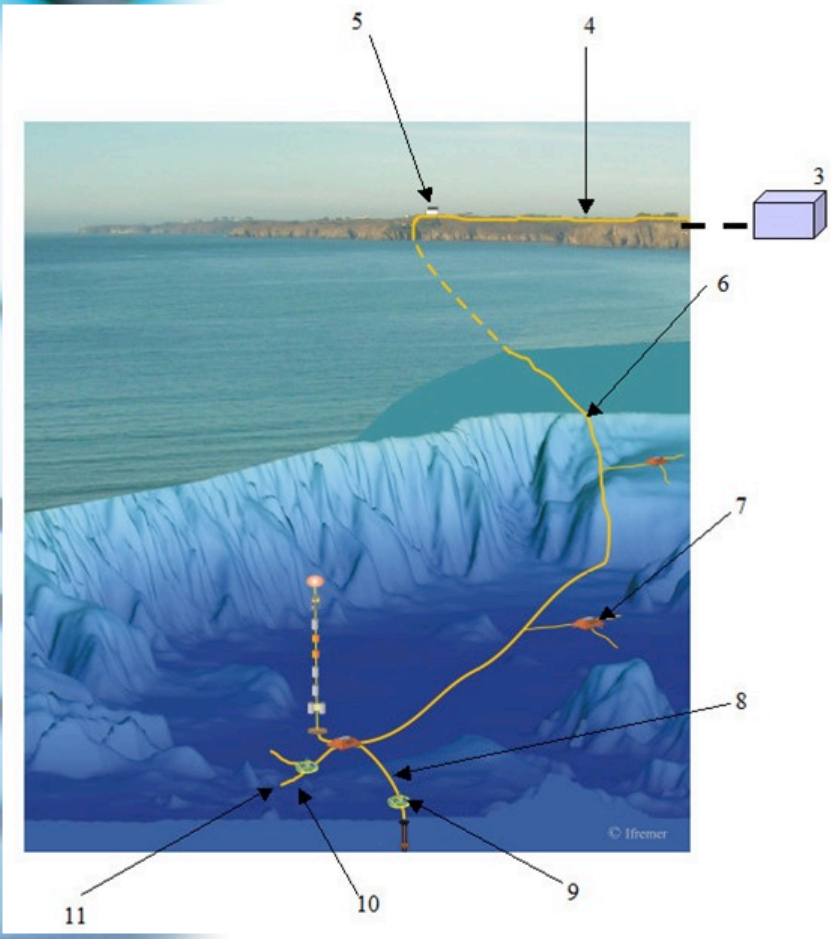
Geohazards early warning systems



Long and continuos time data series

Global Climate Change Indicators. National Oceanic and Atmospheric Administration. National Climatic Data Center. http://www.ncdc.noaa.gov/indicators/

Cabled Observatories

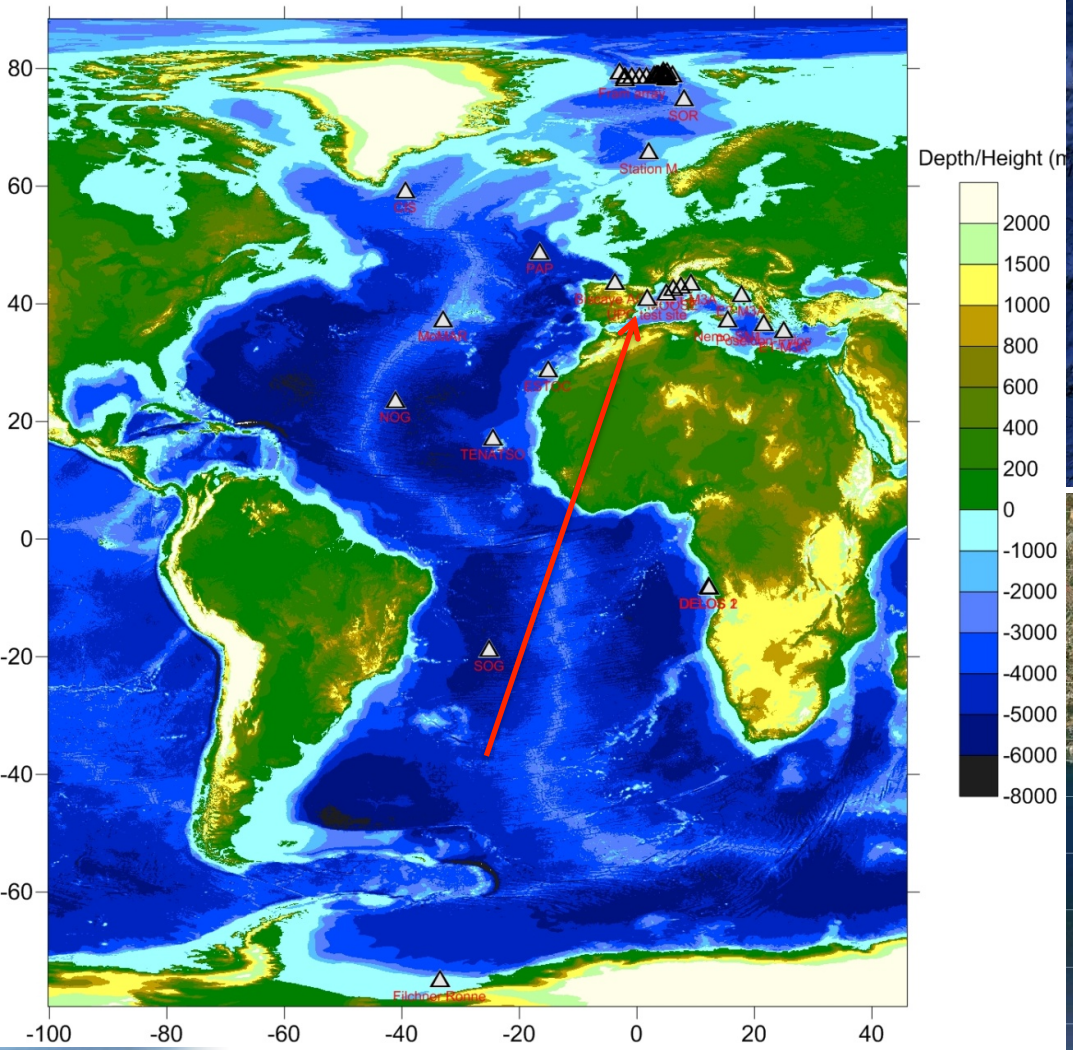


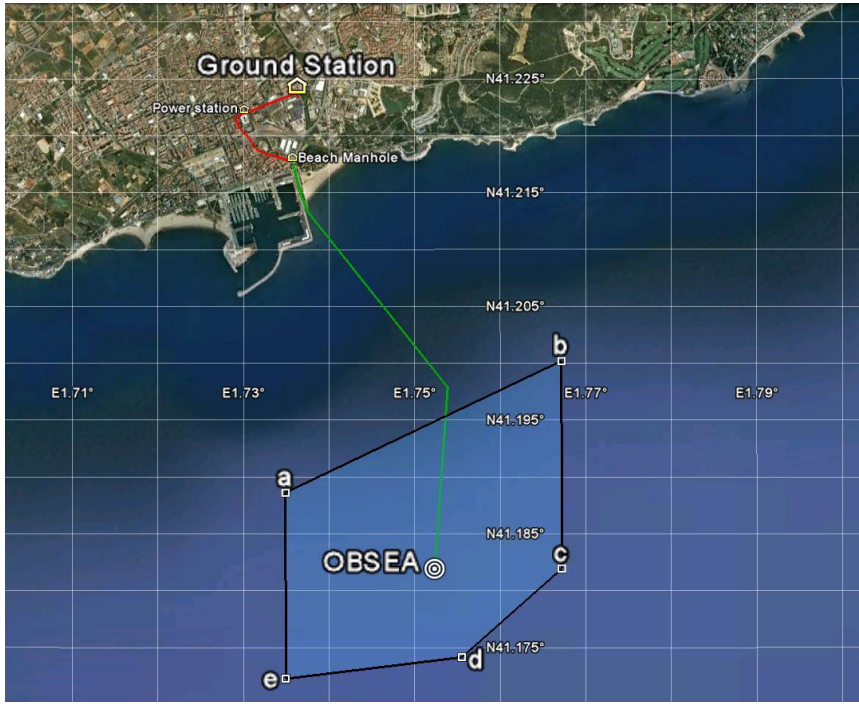
Observatorios Submarinos Cableados

- Monterey Accelerated Research System (MARS), California, USA.
- Victoria Experimental Undersea System (VENUS), Canada.
- Neptune Canada Cabled Observatory (NEPTUNE), Canada.
- Aloha Observatory (ALOHA), Hawai.
- Astronomy with a Neutrino Telescope and Abyss environmental RESearch (ANTARES), Francia
- Dense Oceanfloor Network System for earthquake and Tsunamis (DONET), Japon.
- Neutrino Ettore Majorana Observatory, NEMO-SNI (NEMO), Italia.
- Marine e-Data Observatory Network (MEDON), Francia.
- Martha's Vineyard Coastal Observatory, (MARTA), Massachusetts, USA.
- Marine Cable Hosted Observatory (Hsu,S.-K. et al.2007), Taiwan.
- New Millenium Observatory (MILLENIUM), Oregon, USA.
- Observatorio Submarino Expandible OBSEA, (Mànuel A. et al 2010), España.

Leyenda
3 - Estación Terrestre
4 - Red terrestre
5 - Terminación de la Estación Terrestre. Inicio infraestructura submarina.
6 - Cable de comunicación y alimentación submarino
7 - Nodo o extensión de una ramificación del Cable de comunicaciones submarino
8 - Ramificación de la red
9 - Junction box (nodo de conexión)
10 - Enlace a un instrumento
11 - Instrumentos

Figura Cortesía de Ifremer, Instituto Francés de Investigación para la Explotación del Mar.





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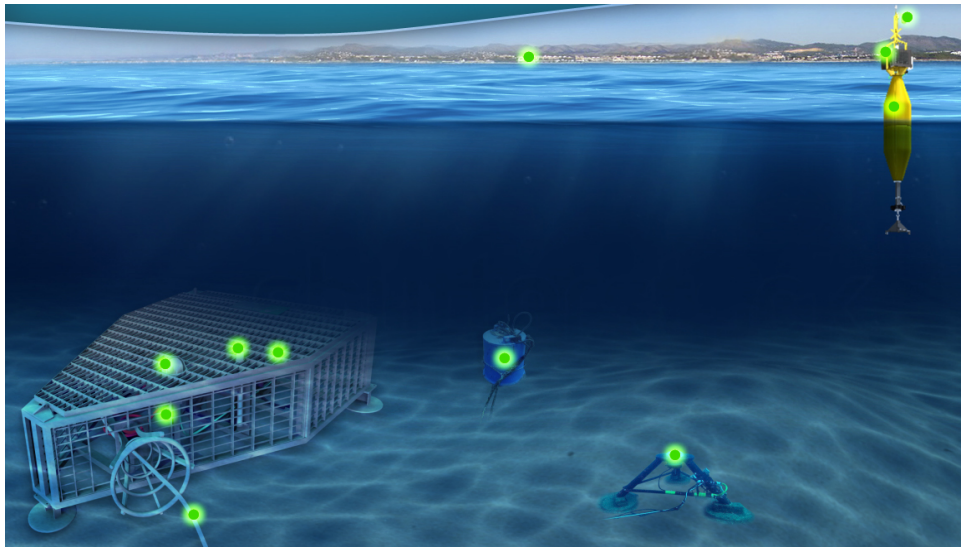
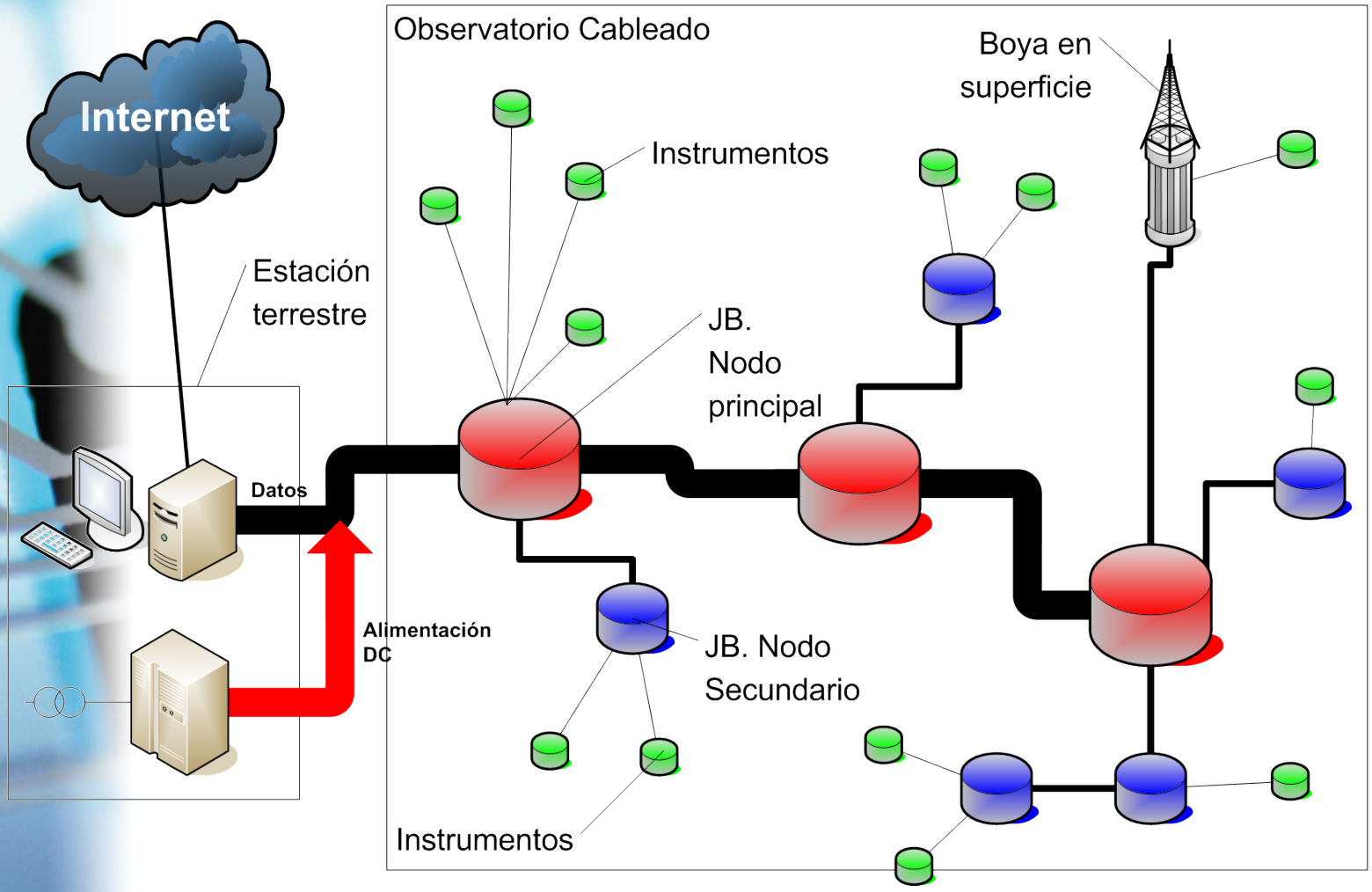
OBSEA schema

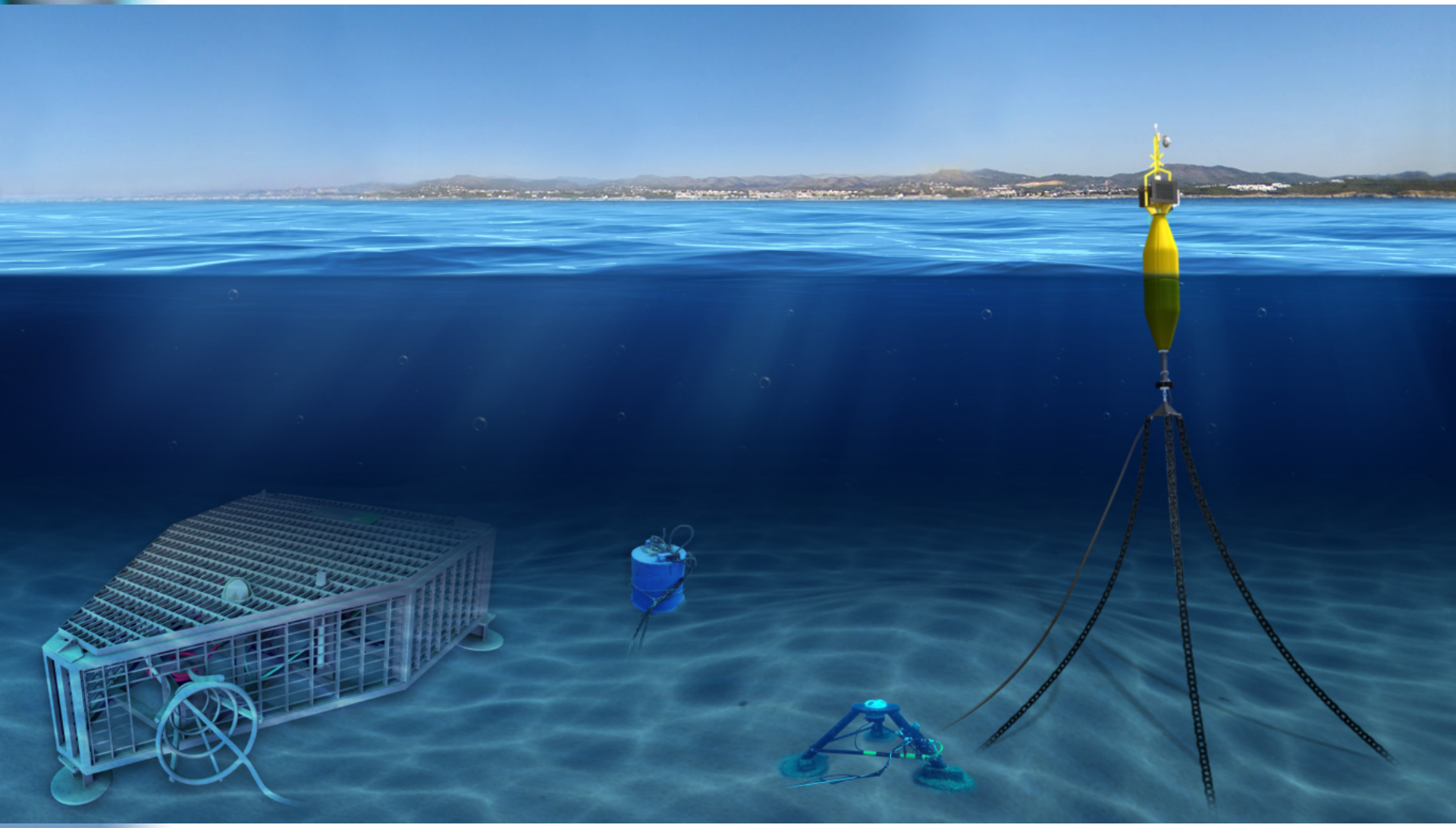
- 20m depth, 4km offshore, 16 wetmate connectors for instrumentation (power, communications, synchronization)
- Operations by scuba divers and small boats.
- The infrastructure is offered under transnational access (TNA).



OBSEA schema



OBSEA schema



OBSEA

OBSEA is a project whose objective is to install a cabled seafloor observatory 4 kilometers away from the Vilanova I la Geltru coast in a fishing protected area, 20m depth.

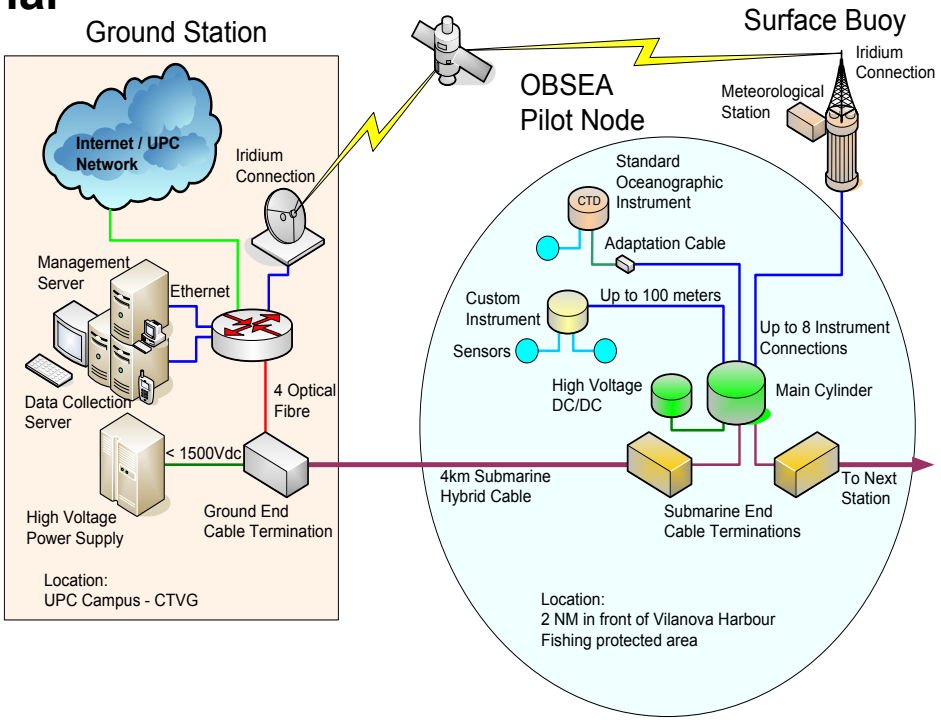
The objective of this project is to have a test-bed for the development of oceanographic instrumentation and at the same time to have an observatory that provides valuable information to the scientific community

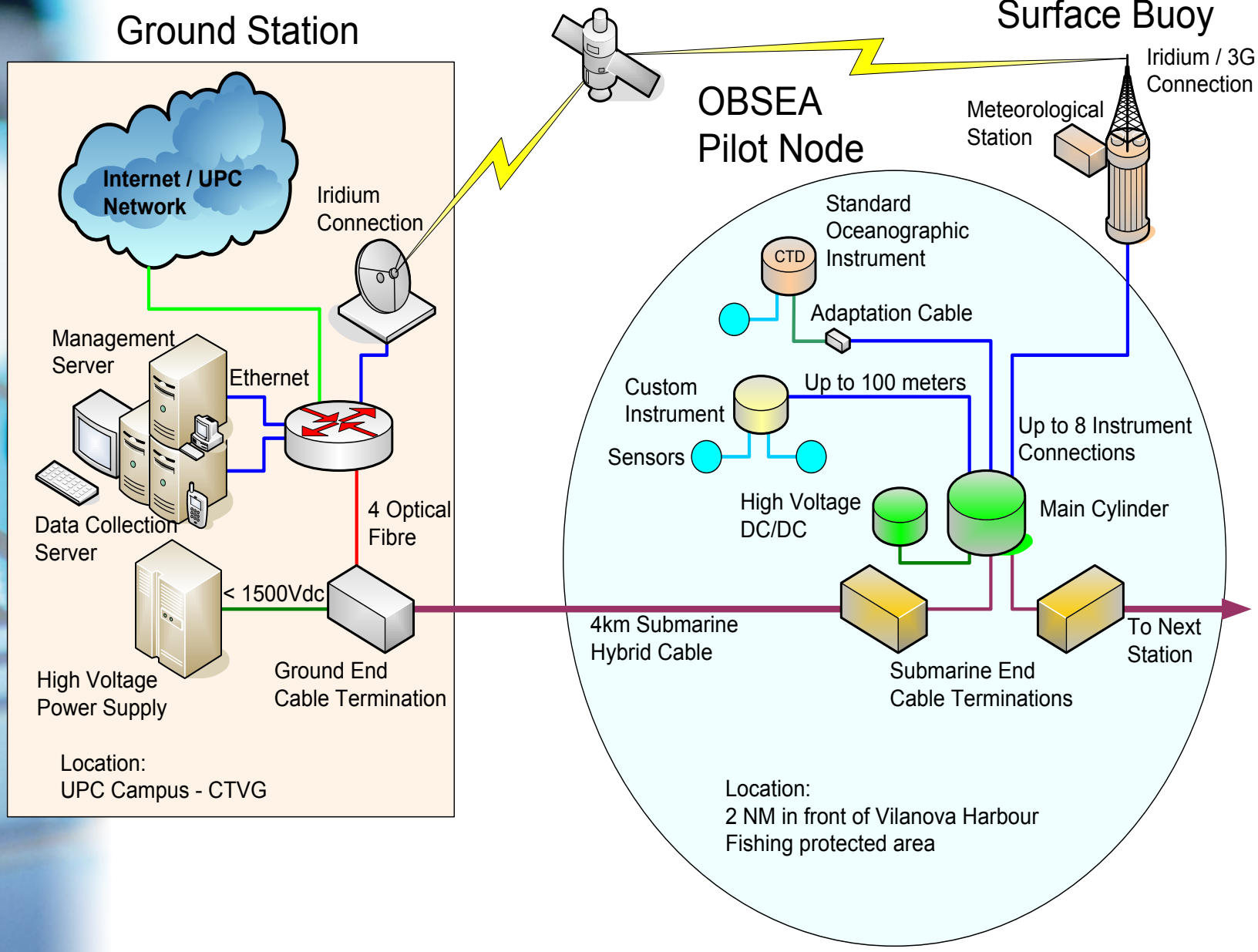
OBSEA will be extended in the future in order to form a seafloor observatory network that covers several interesting sites. Every node will provide connectivity to several instruments (at least 16) as well as a link to other nodes.

Observatorio Submarino OBSEA

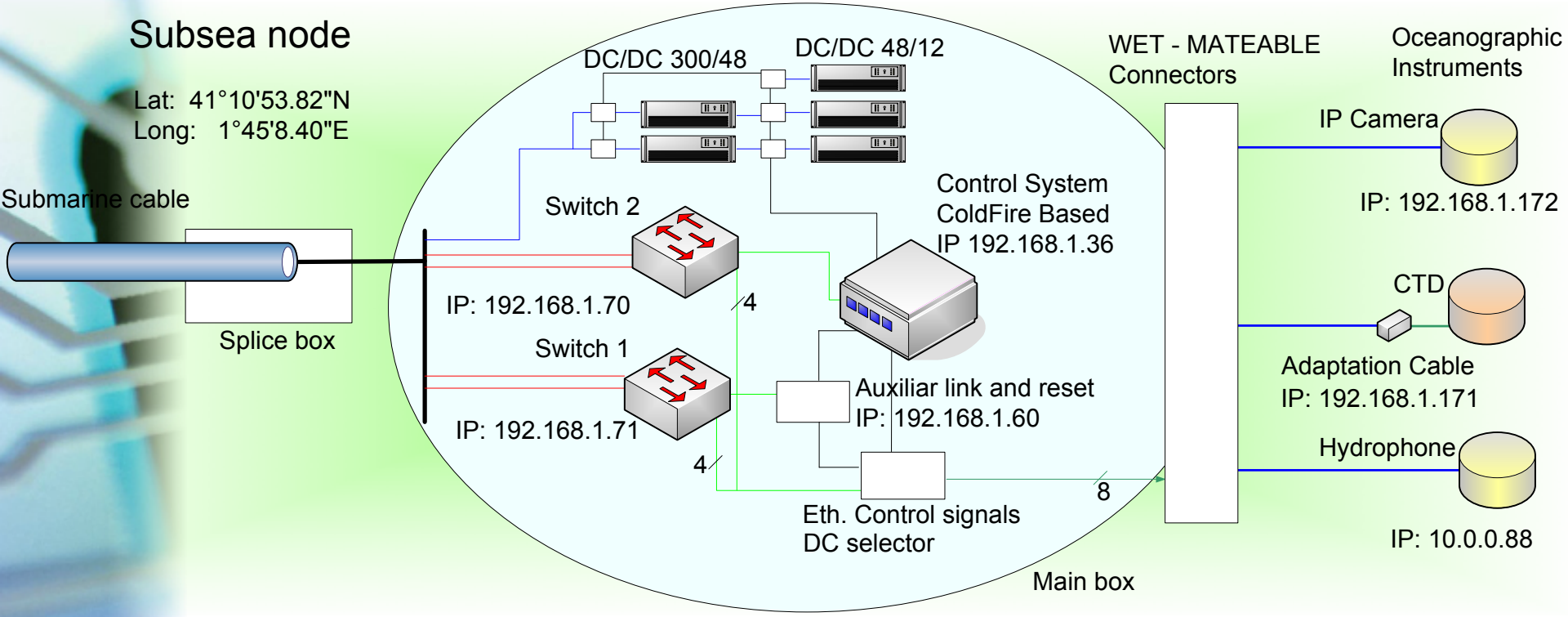
Temas de Interés. Proyecto Multidisciplinar

- Diseño Mecánico
- Sistema de Alimentación
- Conectores
- Diseño Electrónico del Nodo Submarino
- Sistema de Comunicaciones
- Gestión Administrativa del Observatorio
- Permisos
- Colocación del Observatorio
- Instrumentación
- Transmisión y Gestión de los datos
- Accesibilidad de los datos
- Mantenimiento
- Ampliaciones

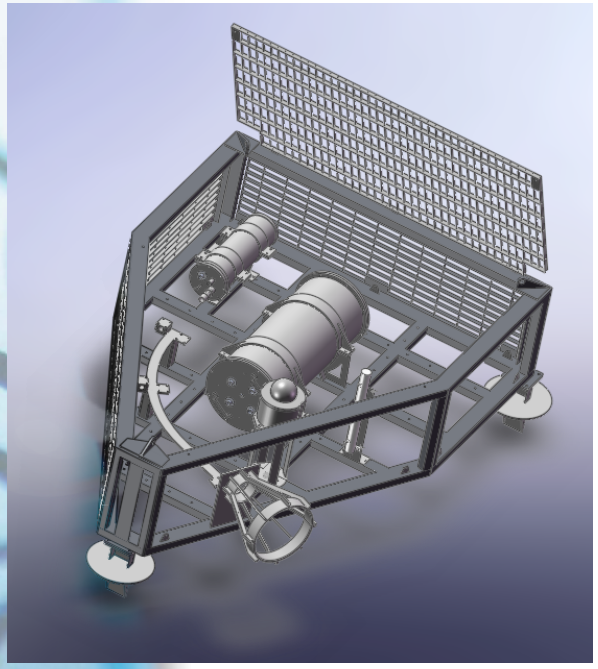


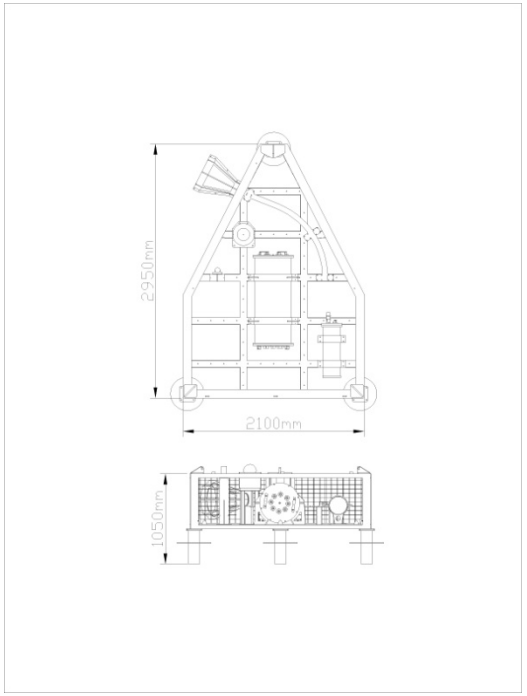

Ground Station
Internet / UPC Network
Iridium Connection
Management Server
Ethernet
Data Collection Server
4 Optical Fibre
< 1500Vdc
High Voltage Power Supply
Ground End Cable Termination
Location:
UPC Campus - CTVG
Surface Buoy
Iridium / 3G Connection
Meteorological Station
OBSEA Pilot Node
Standard Oceanographic Instrument
CTD
Adaptation Cable
Custom Instrument
Up to 100 meters
Sensors
Up to 8 Instrument Connections
High Voltage DC/DC
Main Cylinder
4km Submarine Hybrid Cable
Submarine End Cable Terminations
To Next Station
Location:
2 NM in front of Vilanova Harbour
Fishing protected area

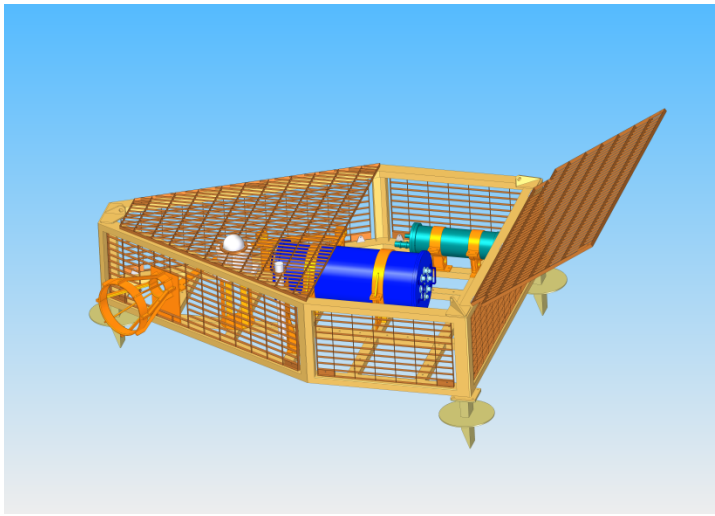
OBSEA: Junction Box



OBSEA: Mechanical protection



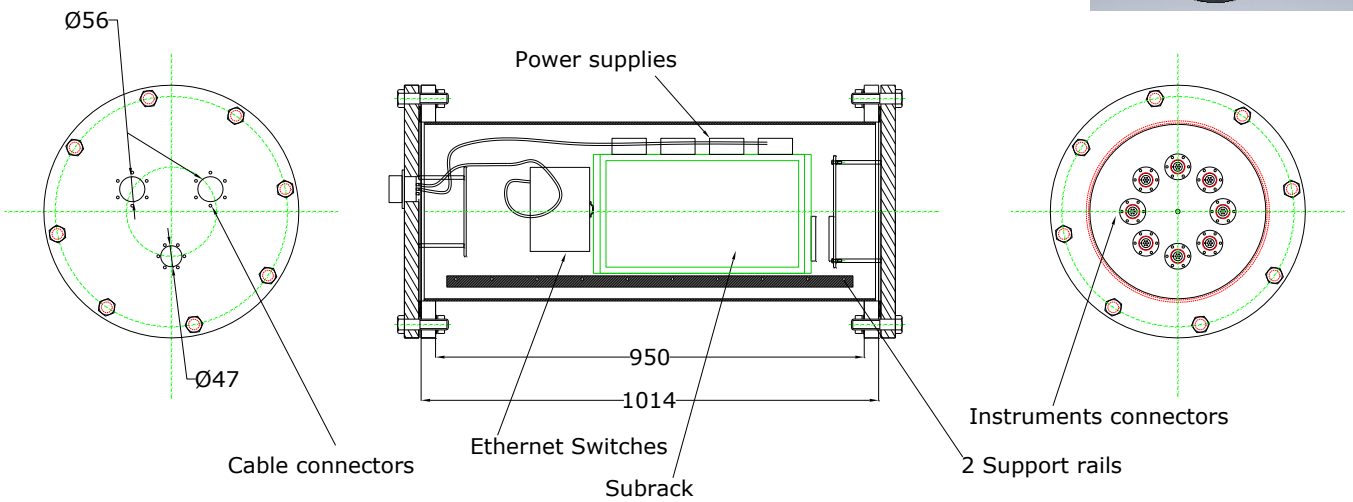




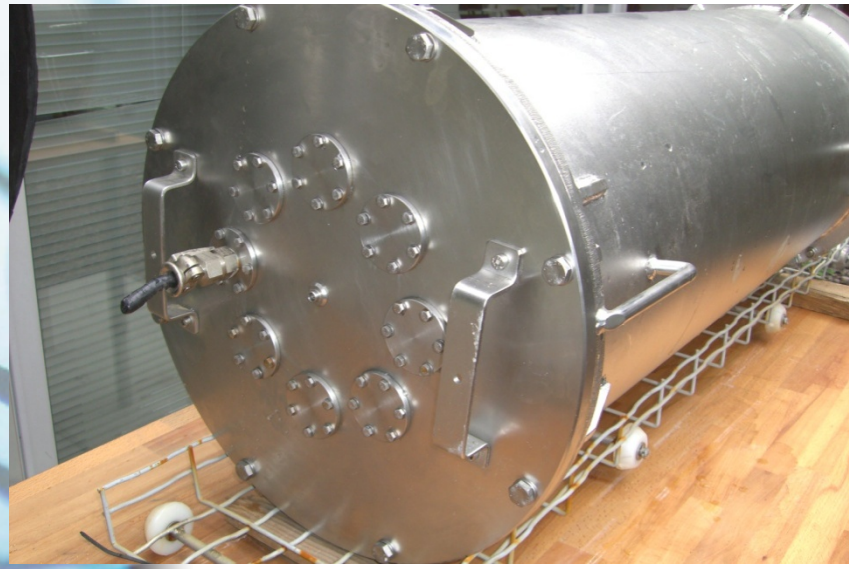
OBSEA: Mechanical Protection

OBSEA: Junction Box

- AISI Type 316L Stainless Steel
- Designed for 300 meters depth
- Up to 8 instrument ports
- 2 ports for trunk cable connection
- One sub-rack for 16 100 x 160mm PCB cards
- 150 watt redundant 1+1 power supply at 48Vdc
- 100 watt redundant 2+1 power supply at 12Vdc
- 1+1 redundant gigabit Ethernet switch

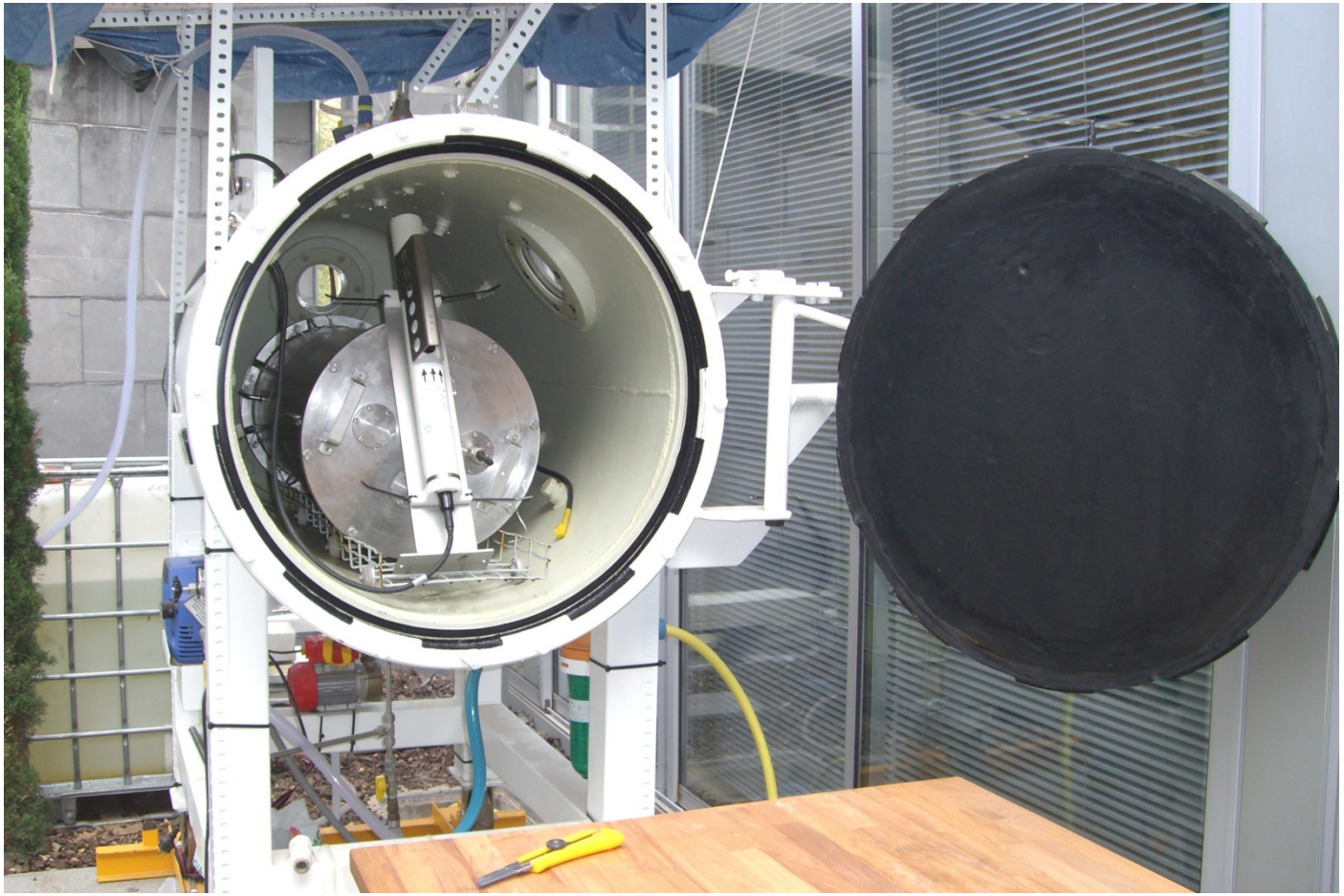


OBSEA: Junction Box



OBSEA: Hyperbaric chamber

OBSEA: Hyperbaric chamber

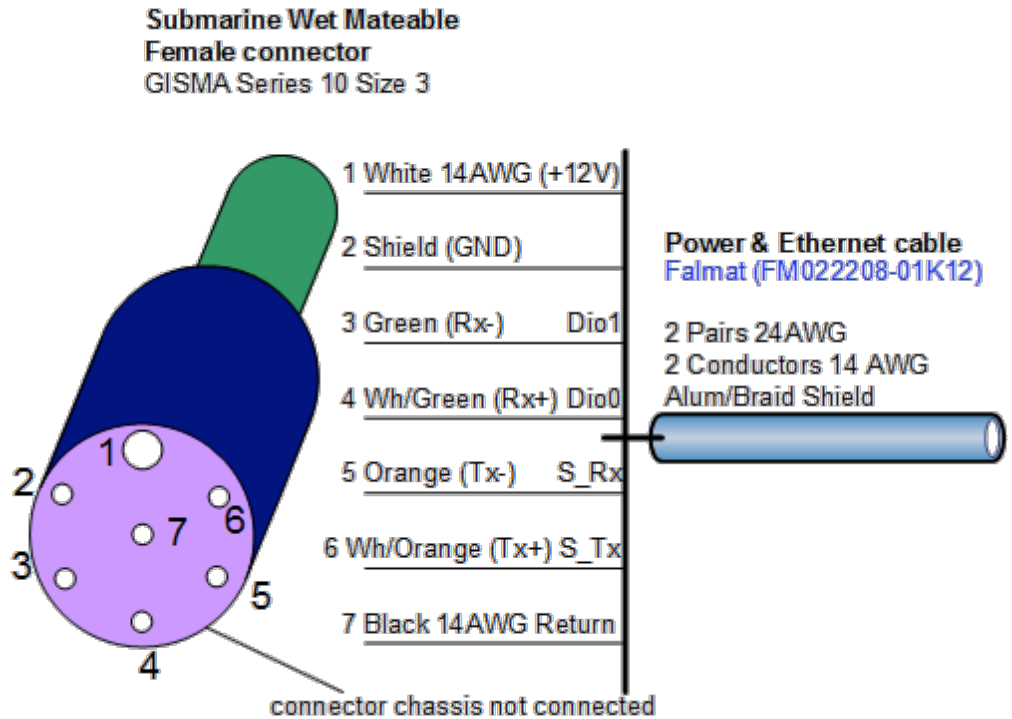


OBSEA: wetmate connectors

(Ethernet+Power)

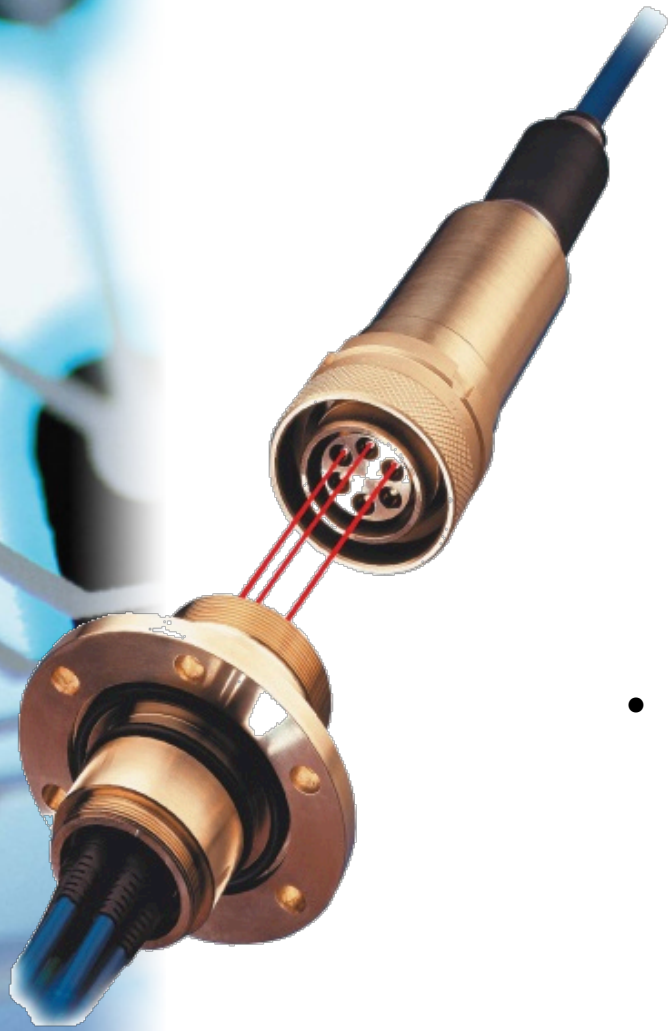
Gisma

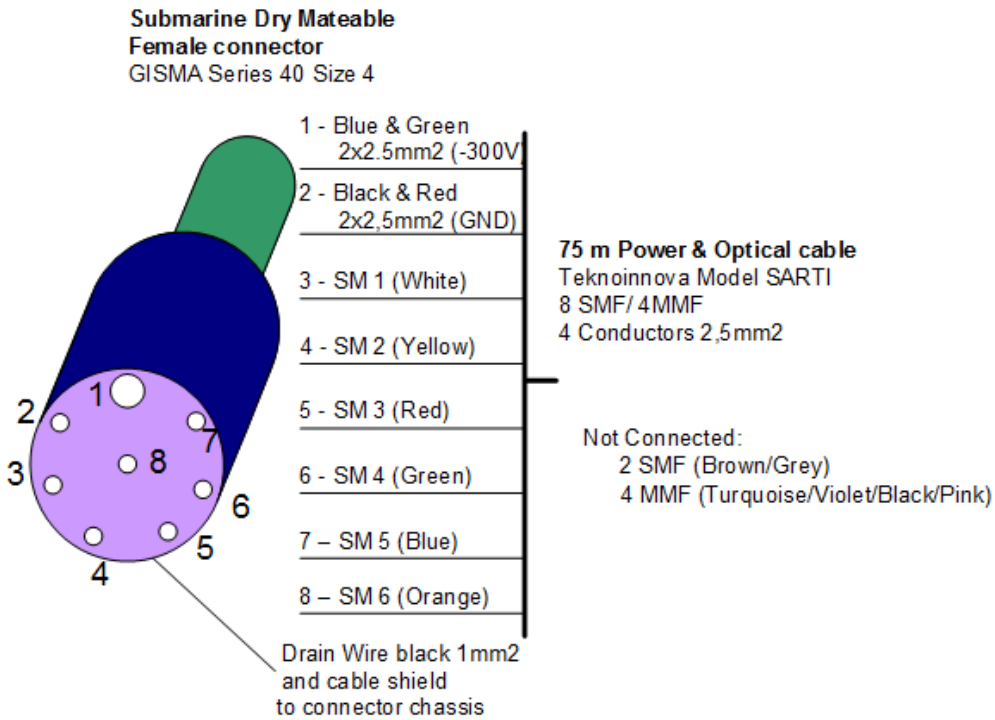
Instrumentation Connector



- GISMA series 10 size 3
  - 7 contacts Ø 1,5mm (max 250V & 15A)
  - Shell Material: Stainless steel 316L
  - Max working pressure 500bars
  - Wet mateable up to 100 meters depth
  - Min 200 mating operations

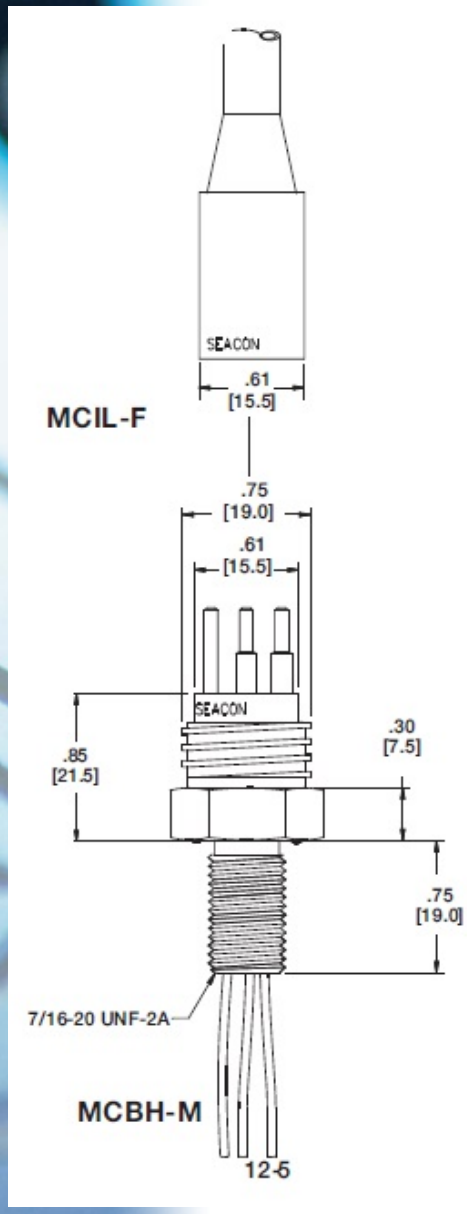
Trunk Connector





- GISMA series 40 size 4
  - 6 singlemode optical contacts (< 1dB atenuation)
  - 2 electrical contacts Ø 1mm (max 1000V & 8A)
  - Shell Material: Stainless steel 316L
  - Max working pressure 350bars
  - Dry mateable
  - Min 1000 mating operations

Auxiliar Connector



MCIL8M

300V 3 Amp
(w/20 AWG Cab)

MCIL8F/MCDLSF Pin	Function (color)	Cable "G"	GISMA Series 10 Size 3 Pin
1	Tx+ (Wh/Orange 24 AWG)	←	6
2	Tx- (Orange 24 AWG)	→	5
3	Power + (White 14 AWG)	←	1
4	GND (Alum Shielding)		2
5	Rx+ (Wh/Green 24 AWG)		4
6	Rx- (Green 24AWG)		3
7	GND (Alum Shielding)		
8	Out Power (Black 14AWG)	→	7

- SEACON
  - 8 electrical contacts (max 300V & 3A)
  - Material: Neoprene & Stainless Steel or Brass
  - Max working pressure 700bars
  - Wet mateable
  - Min 500 mating operations

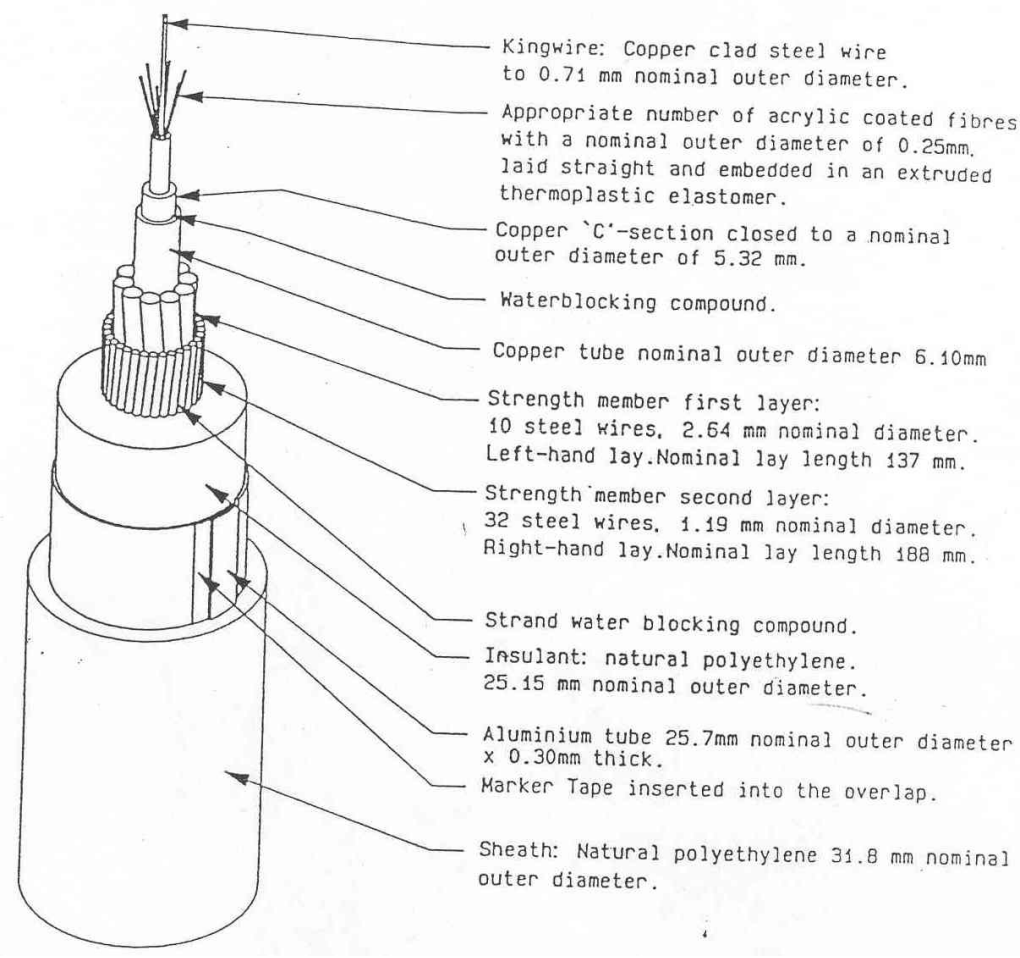
OBSEA: Cable

Cable submarino cedido por Telefònica:

- 5km, 6 F.O. 2 conductores

Cable terrestre

- 1 km, 8 fibras monomode
- 1 km, 3 conductors de 10mm2 de cobre



OBSEA: Power supply on-shore

300V – 11A. Suministro de potencia al nodo submarino a través del cable. Un PLC gestiona el número de fuentes en serie necesarias para suministrar la potencia suficiente. El PLC es controlado y monitorizado via Eth mediante protocolo SNMP

OBSEA: Electronics at Junction Box

-Sistema basado en microprocesador de 32bits ColdFire de Freescale:
-Gestión de las fuentes de alimentación y relés que dan potencia a los instrumentos.
-Gestión Baterías. Estado
-Información de Temperatura y Humedad interior del cilindro
- Conectores con comunicación Ethernet : Switch Industrial Moxa.
-Comunicación Ethernet sobre protocolo SNMP (Single Network Managment Protocol)

OBSEA: Instrumentation

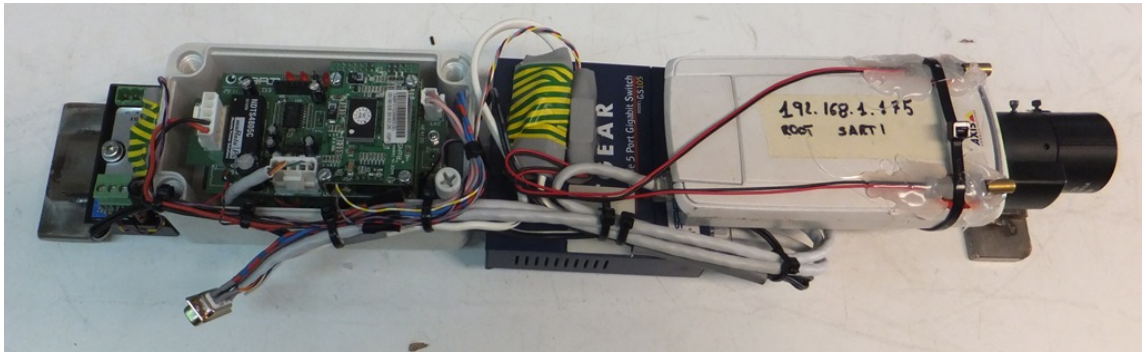
COBS, pH, meteo…

Observatory. OBSEA, UPC Test Site

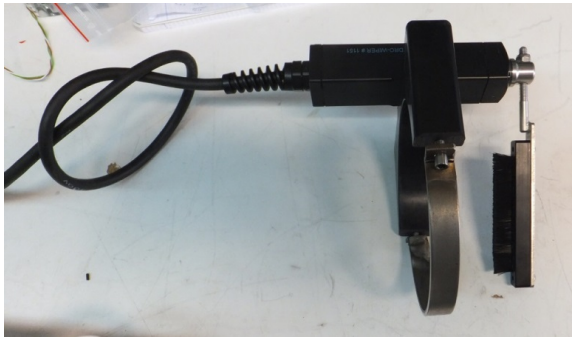
- Possibility to deploy new instrumentation for testing: installation procedures, data communication, data management, performance, robustness, etc…
- Real-time access to data instrumentation.
- Present instruments: **Underwater**: CTD, seismometer, ADCP, hydrophone, pH, video camera. **Surface buoy**: meteo station, video camera.

Early 2014 expand Obsea with a deployment of a 2nd junction box to increase instrument ports

Deploy a new video camera with a custom housing and a wipper to avoid biofouling

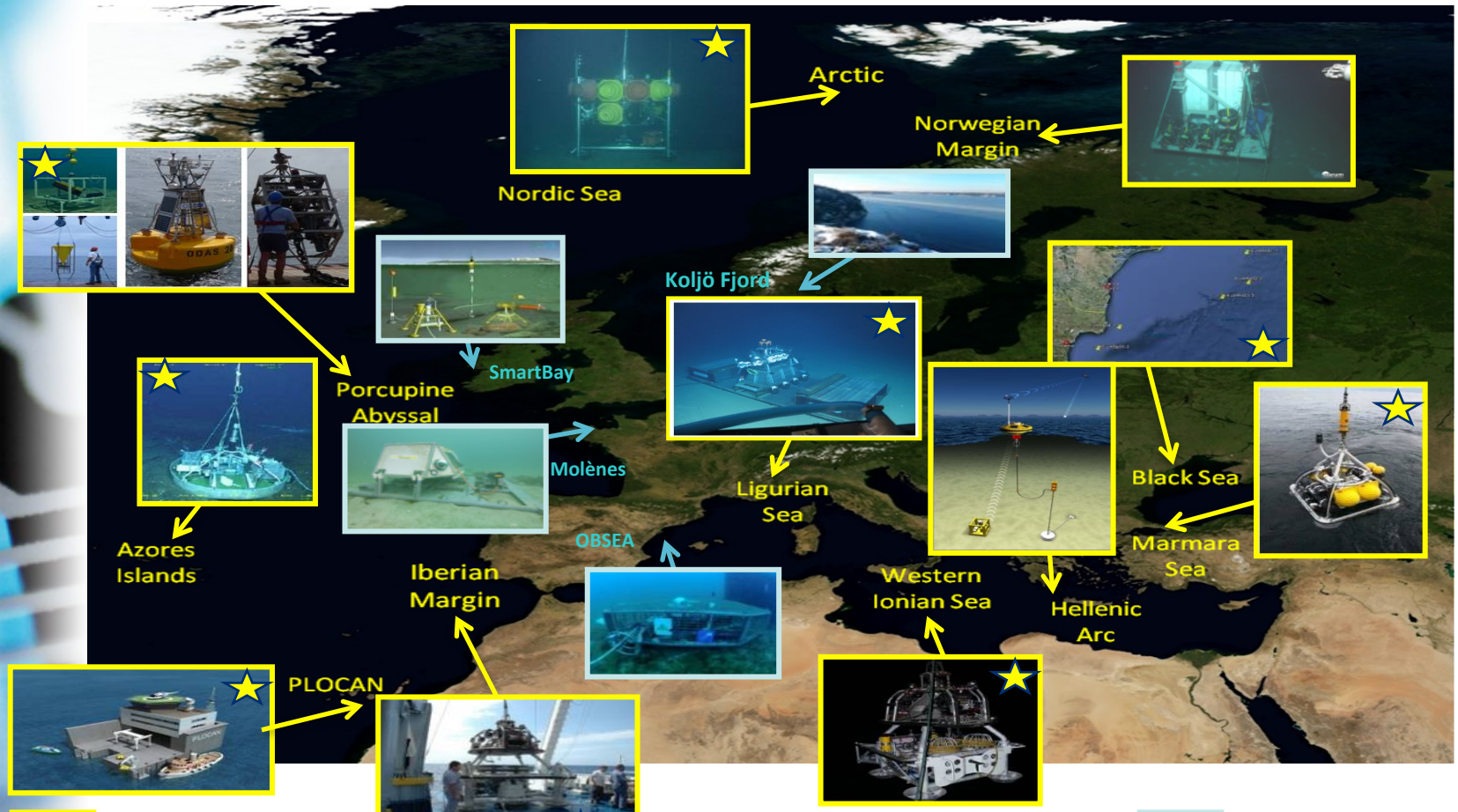


Maintain present services as a data provider for UPC, CSIC, IGN, IGC and new institutions trough TNA calls



EMSO nodes: European Multidisciplinary Seafloor and Water-Column Observatory

european multidisciplinary seafloor & water column observatory



nodes

operating nodes

test sites

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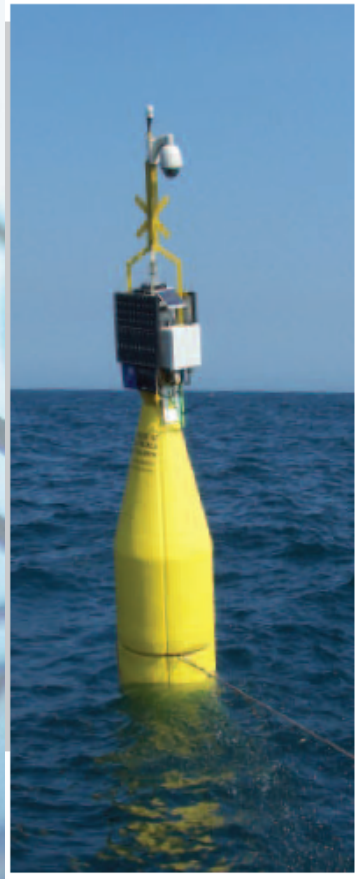
OBSEA: Buoy



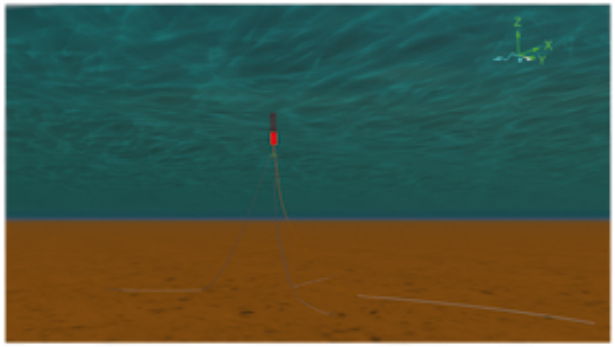
IP Camera: 704x576 pixels; 25 fps; 10x Optical Zoom
Solar panels: 4 x 20W
Weather station:
- Position, velocity and GPS time
- Speed and wind direction
- Pressure and temperature
- magnetic compass
- 3-axis accelerometer for Pitch and Roll angles

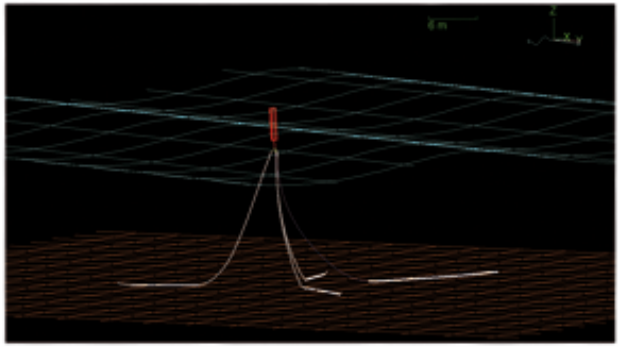
Buoy signalling light, self-powered:
- High efficiency yellow LED light
- Reach 3 nautical miles

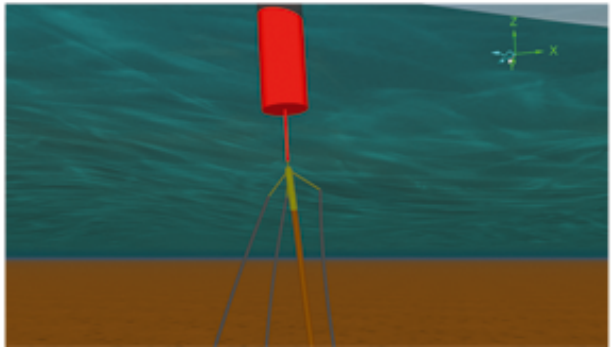
Junction box
- Electronic Control
- 3G Modem Communication

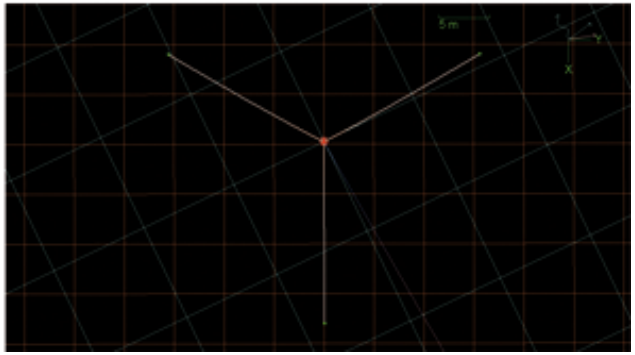
Battery Box
- Battery: 12v & 65Ah
- Solar charge controller: 6A

OBSEA: Boya, fondeo









Orcaflex Software. Orcina.

Challenges for Time Synchronization

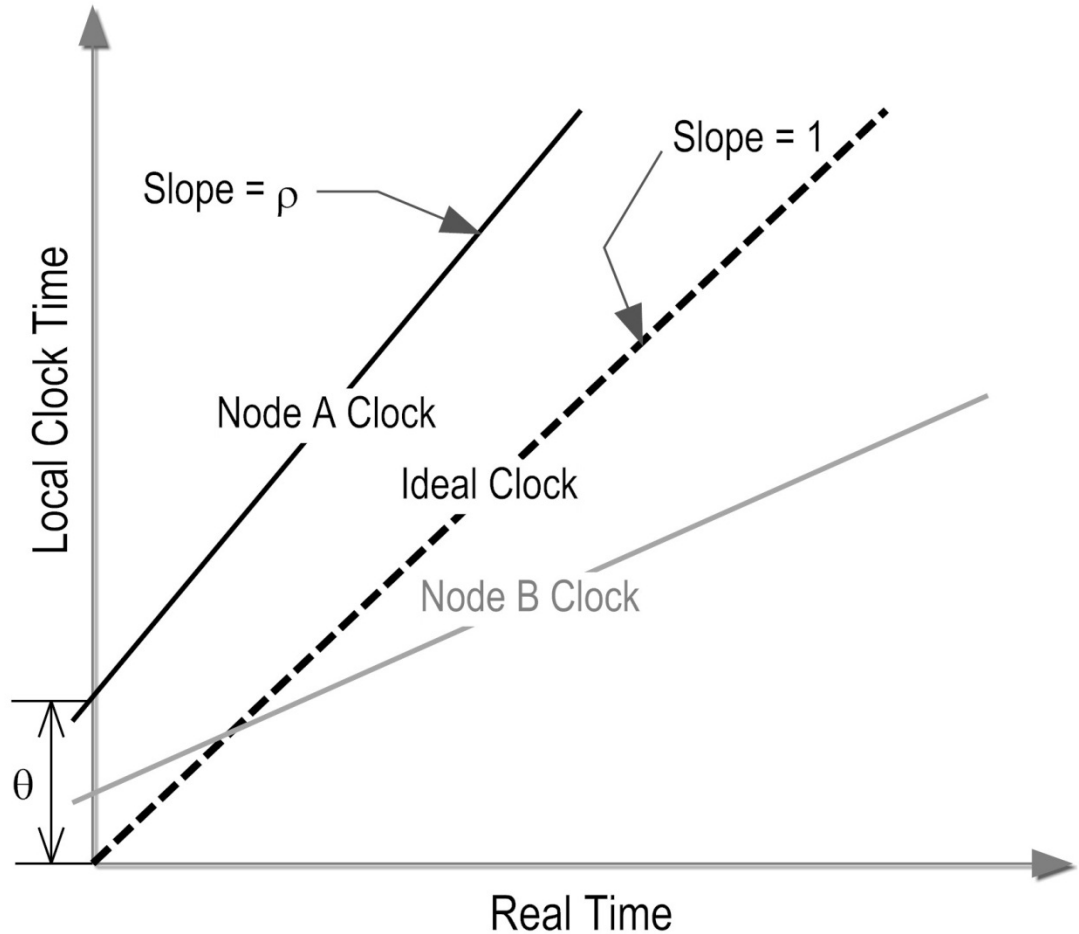
1. Clock Inaccuracies:

Local clock of each sensor ***i*** is a function of time, ***t*** and depends on the ***clock offset (phase difference)*** and ***clock skew (frequency difference)***:

$\tau_i(t) = \theta + \rho \cdot t$

clock of a Node B relative to Node A

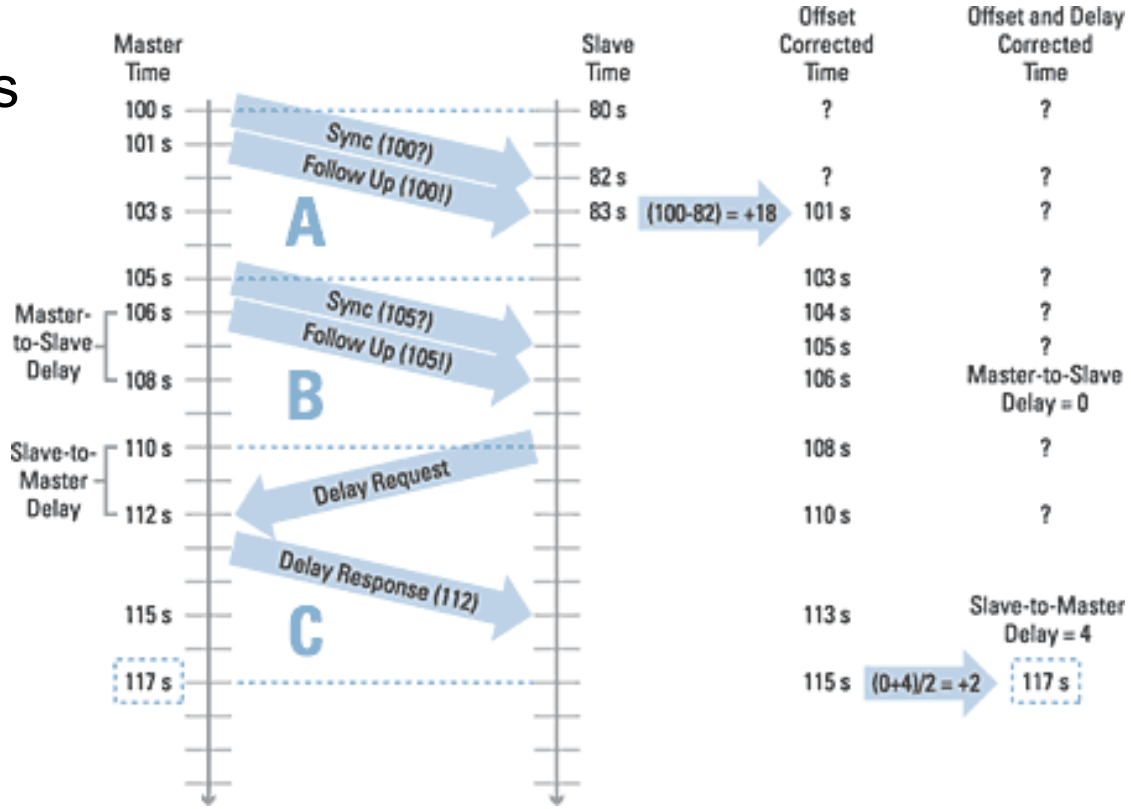
$\tau_B(t) = \theta_{AB} + \rho_{AB} \cdot \tau_A(t)$



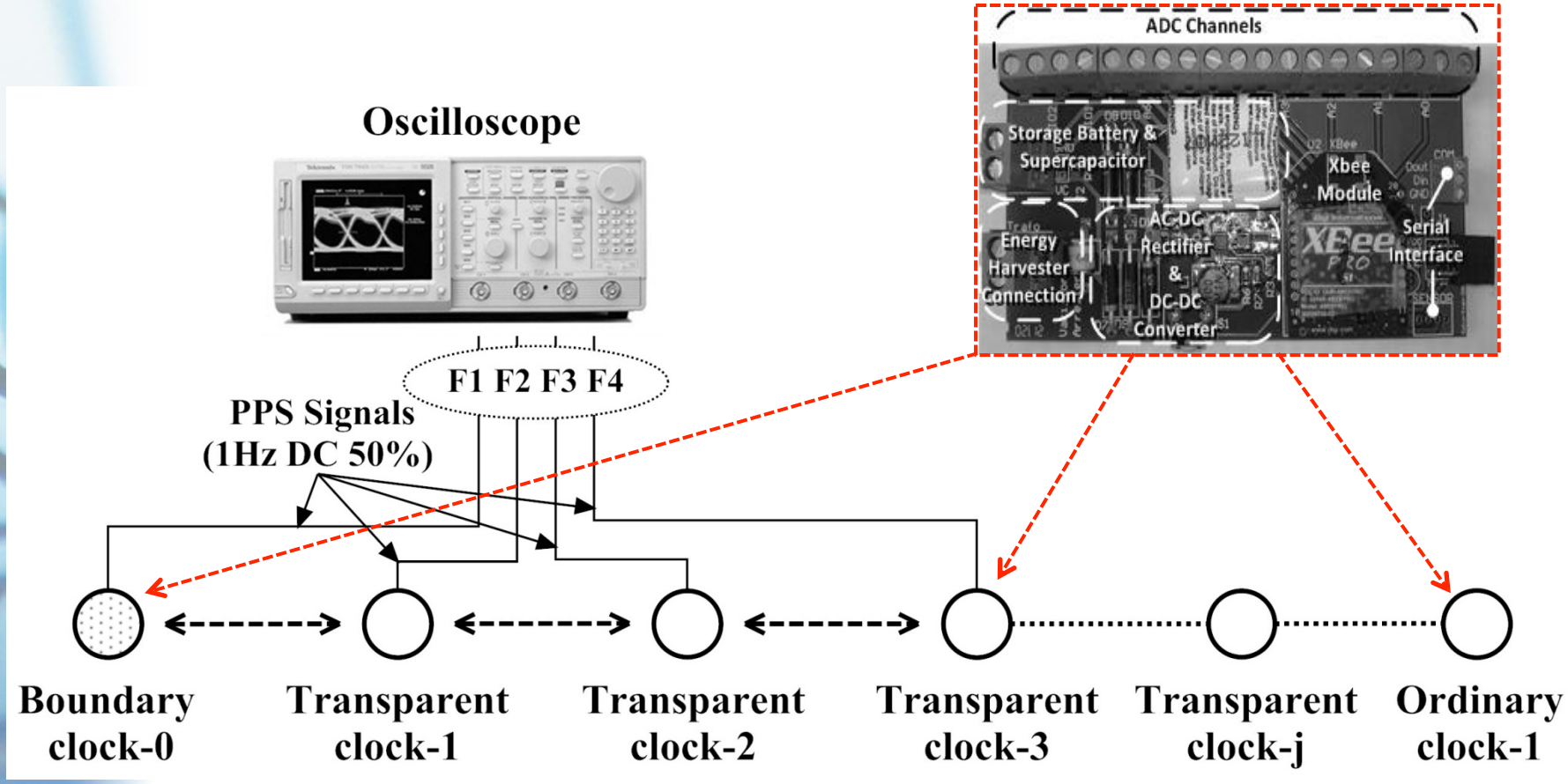
Typical crystal-quartz oscillator commonly used in sensor networks provide a source frequency with a total accuracy up to +/- 40 ppm, which means clocks of different nodes can lose as much as 40 μs in a second causing a clock error of about 3.5 seconds per day.

Synchronization protocol – IEEE1588

- Synchronization Master-Slave
- Exchange of two types of frames
  - Synchronization
  - Time Stamp
- Two sync. Stages
  - Offset compensation
  - Delay compensation

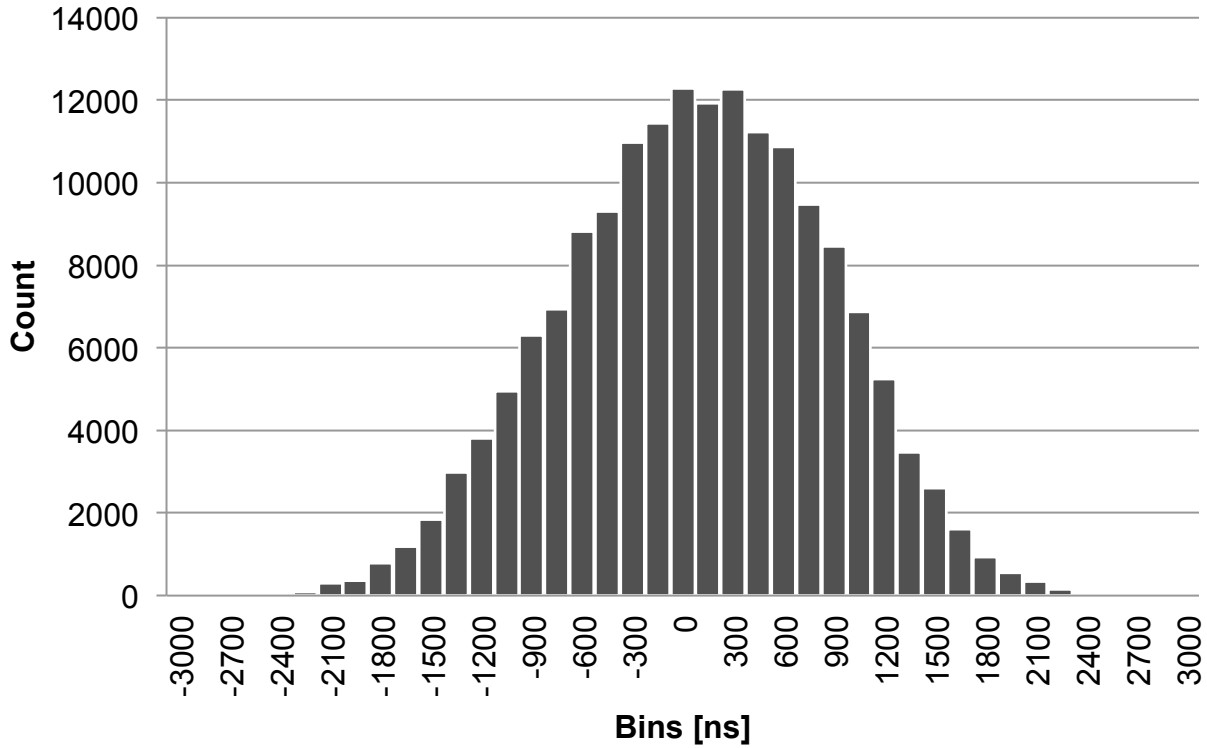


PTP Implementation in WSNs



Performance Evaluation

Pairwise synchronization

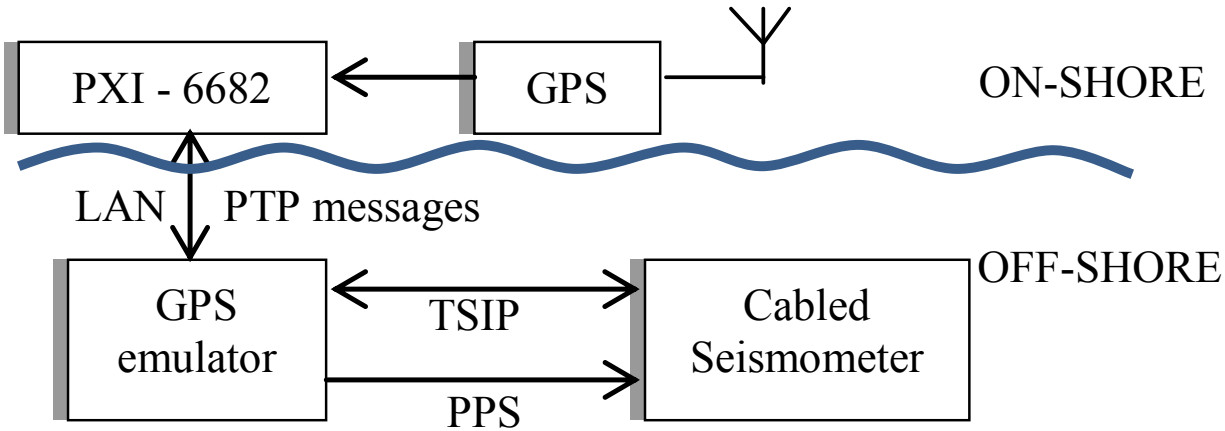


2 patentes

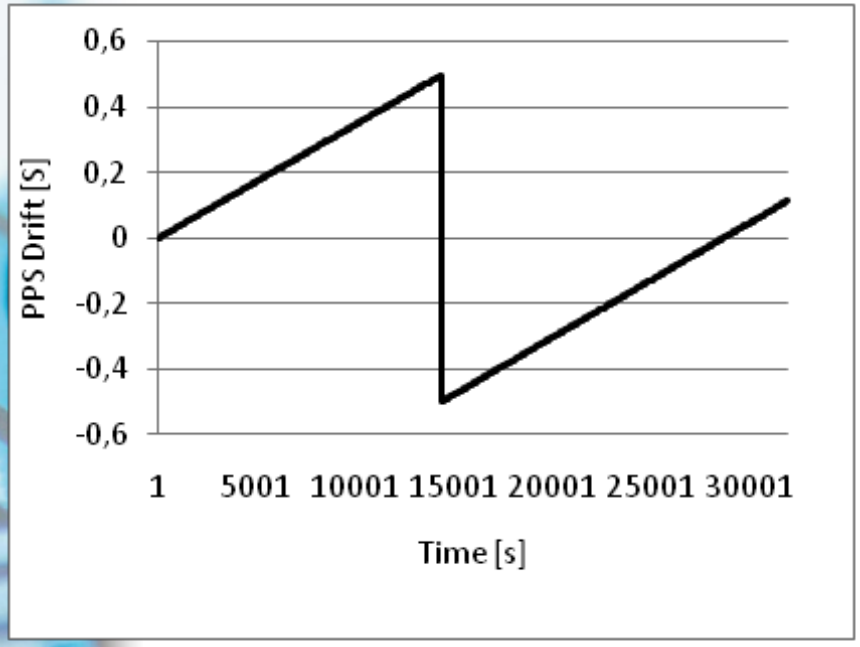
The mean time delay is 481.19 ns, with a standard deviation of 350.62 ns and a maximum value of 2283 ns.

Hardware modifications

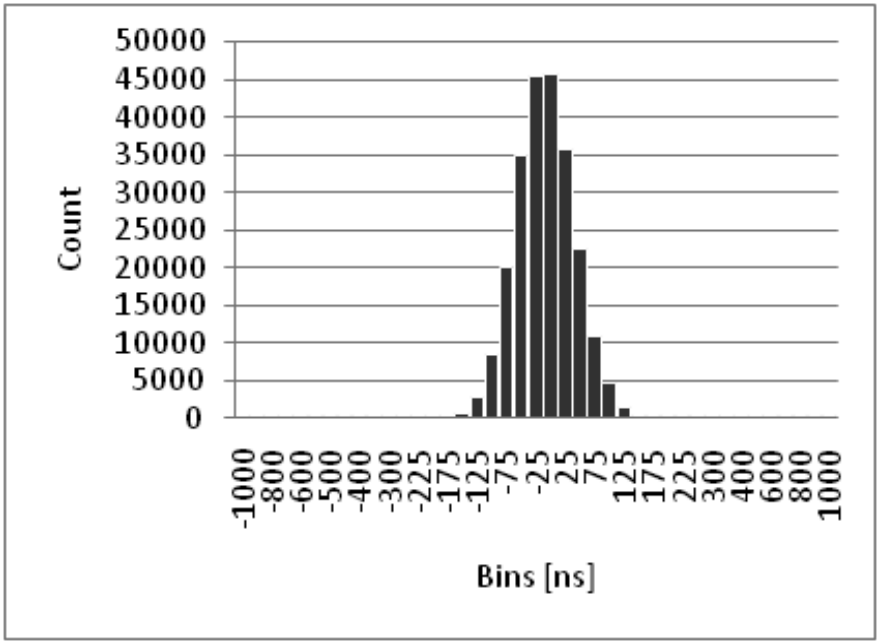
- HW modifications are necessary in order to provide synchronization to COTS seismometer



Deriva de las señales PPS (F1-F2) en ausencia de sincronización



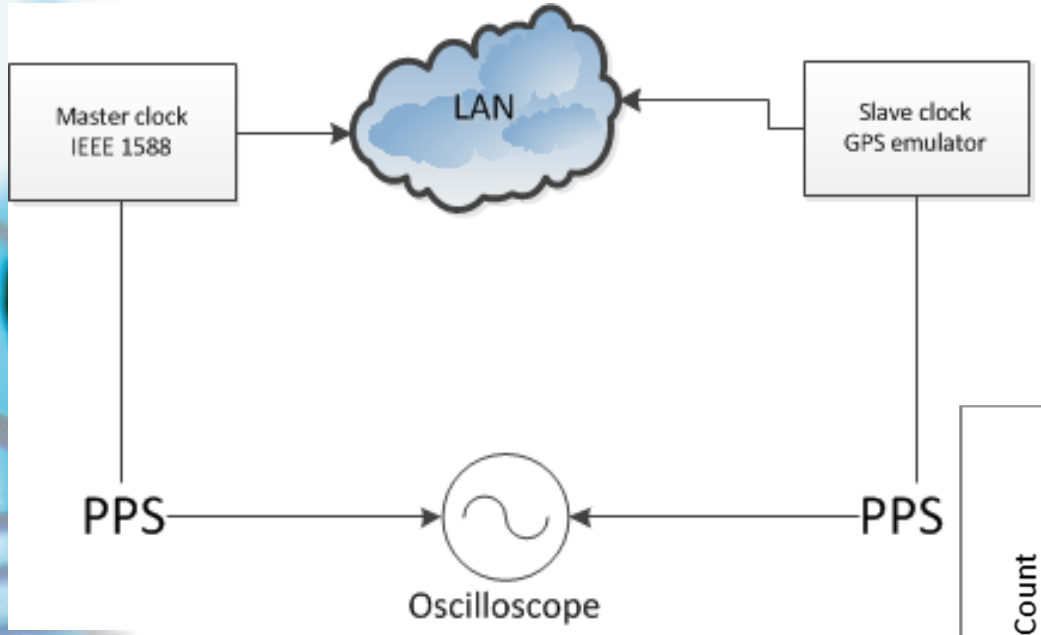
Histograma medidas desfase con el protocolo PTPd activo, sin tráfico

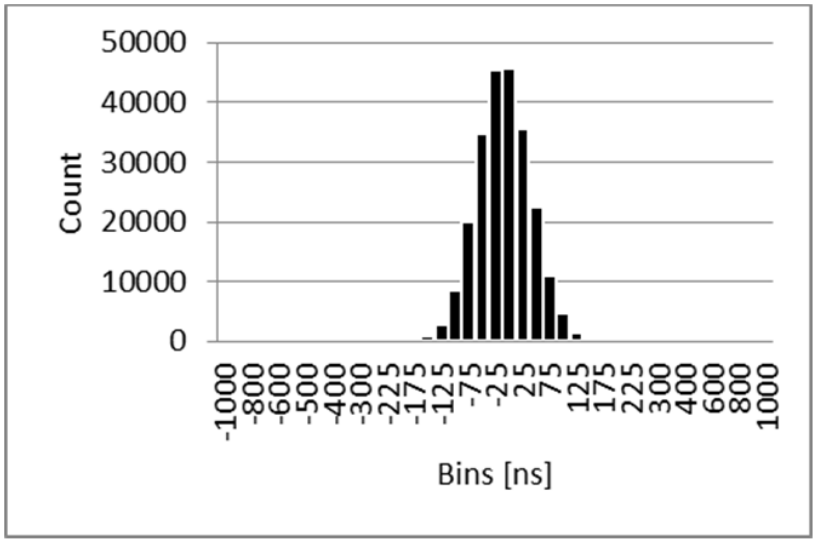


Deriva de 34 µs por segundo

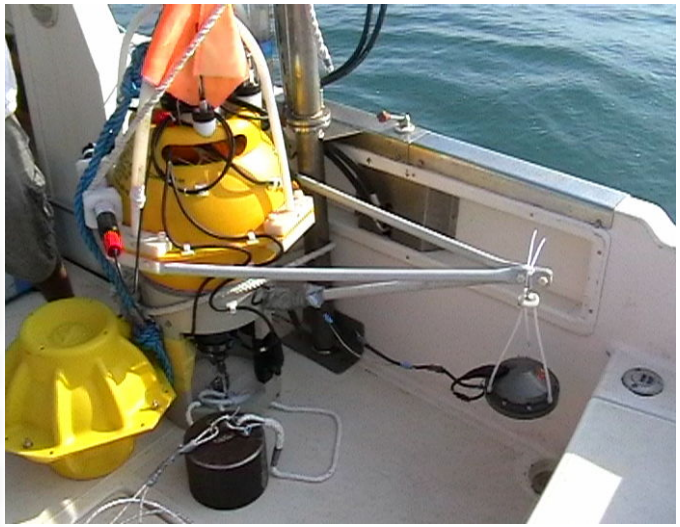
Seismic timing compliance

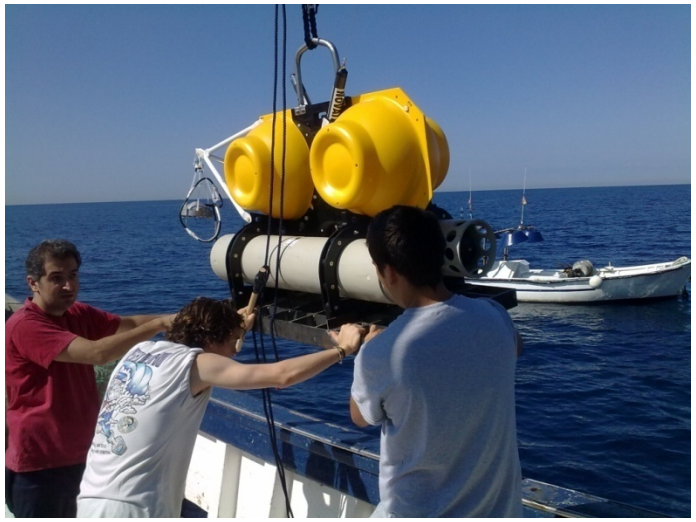
- Laboratory test < 75 ns



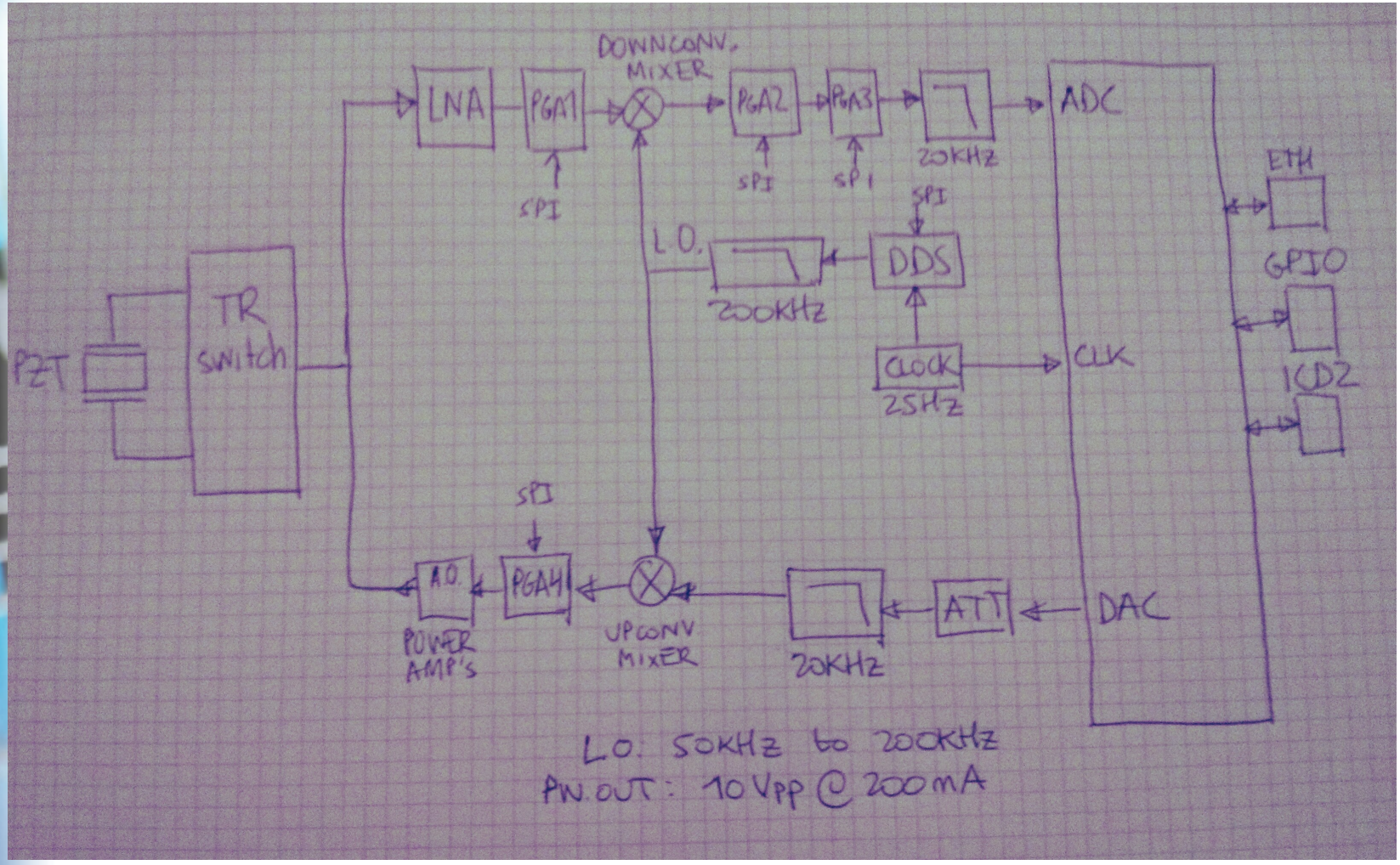


Proyecto Sismómetros Marinos, OBS

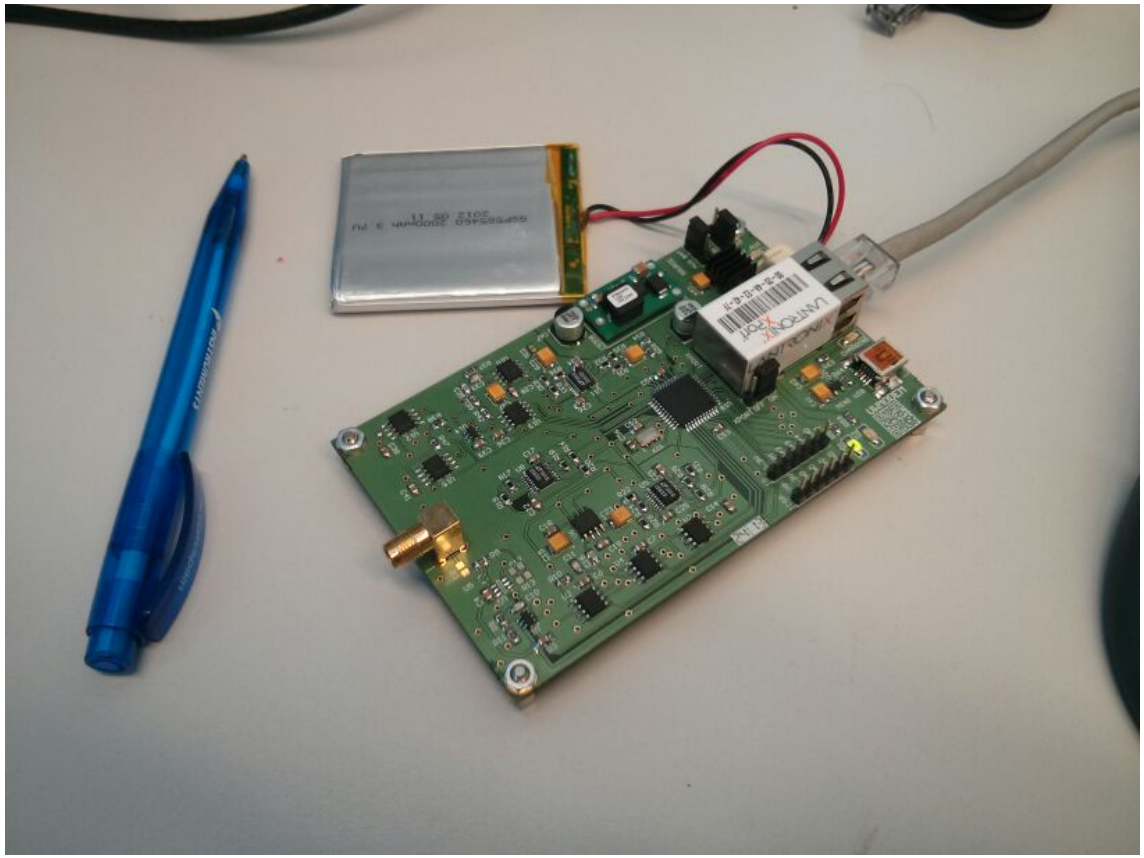




Low cost OFDM based transmitter for underwater acoustic communications



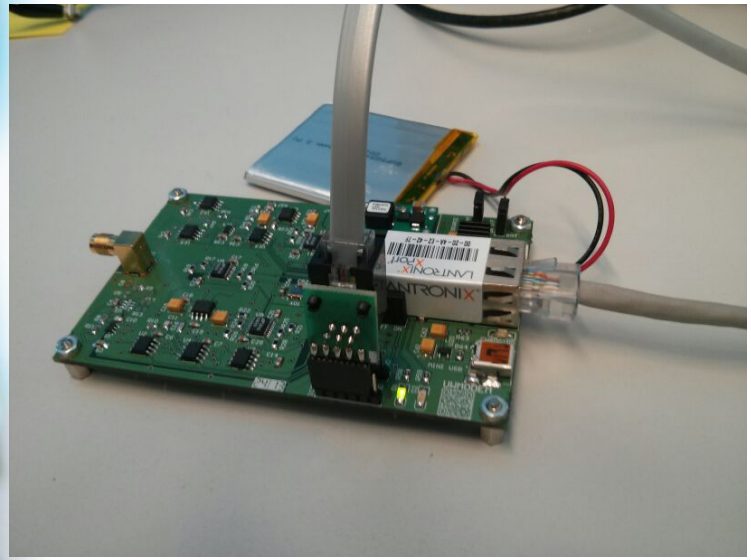
Low cost OFDM based transmitter for underwater acoustic communications

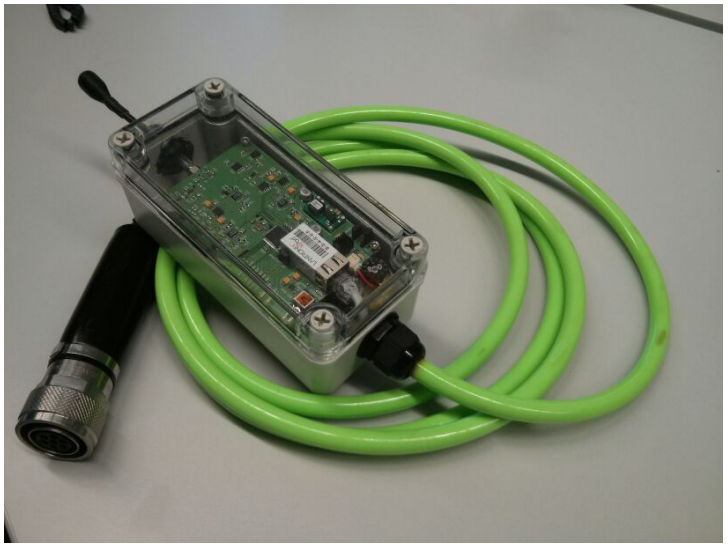


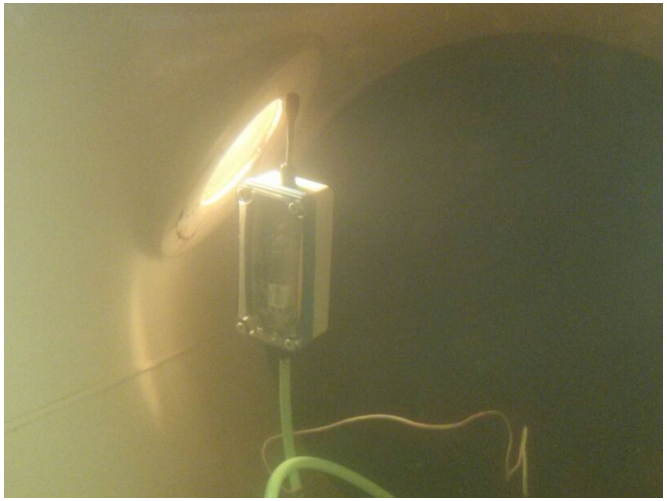
PROGRAMA DE DOCTORAT EN ENGINYERIA ELECTRÒNICA

Jornades formatives 2014: Projectes de recerca al Departament d'Enginyeria Electrònica

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament d'Enginyeria Electrònica







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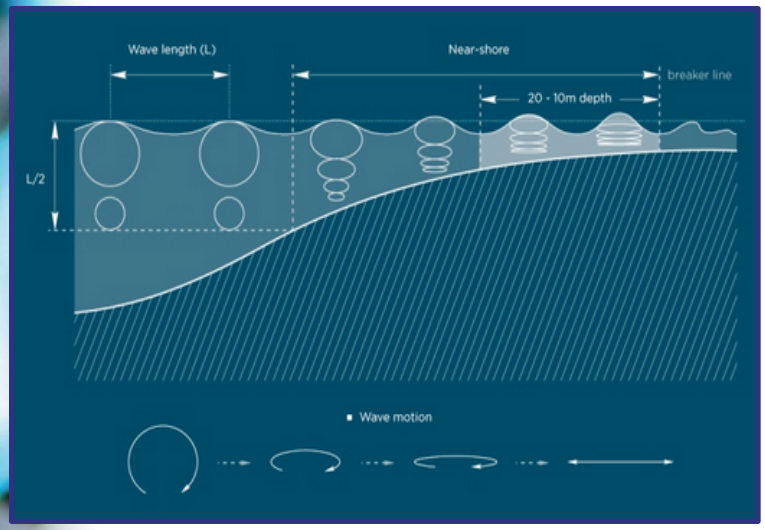
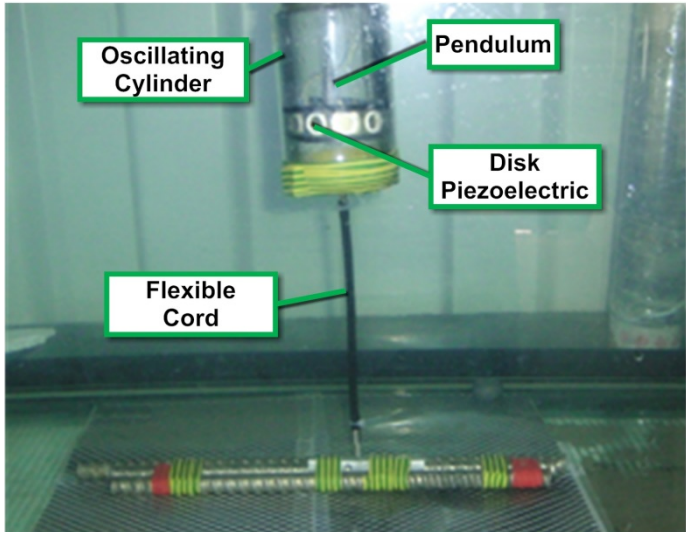
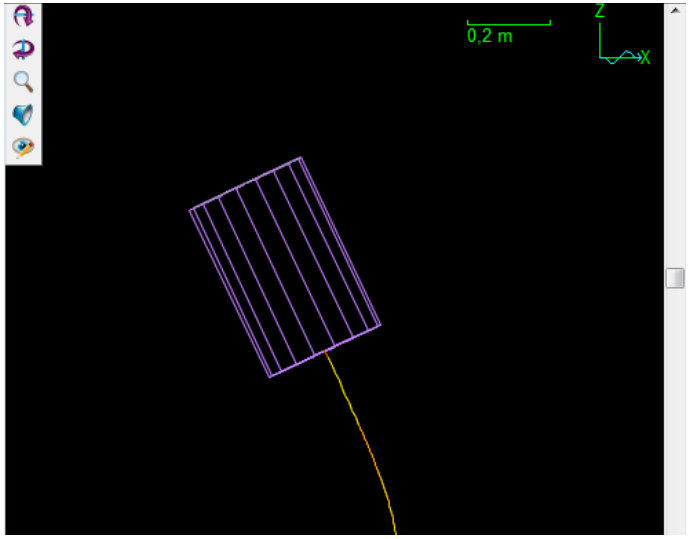
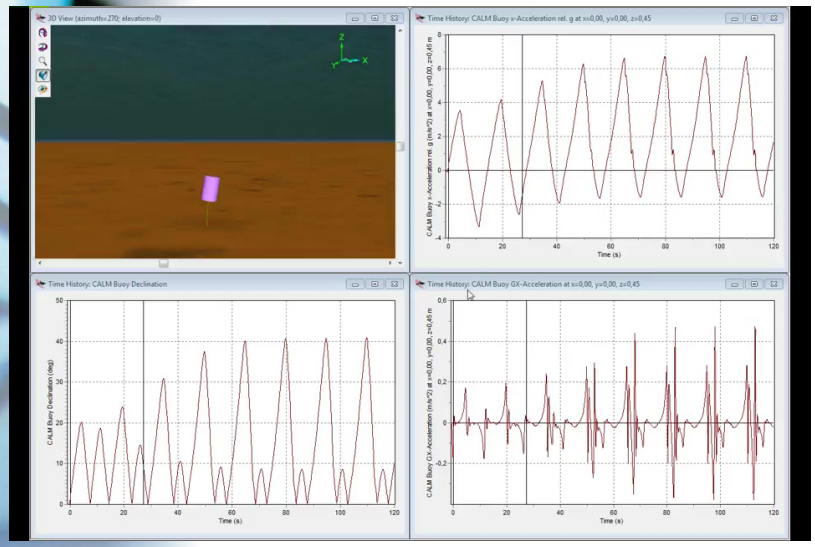
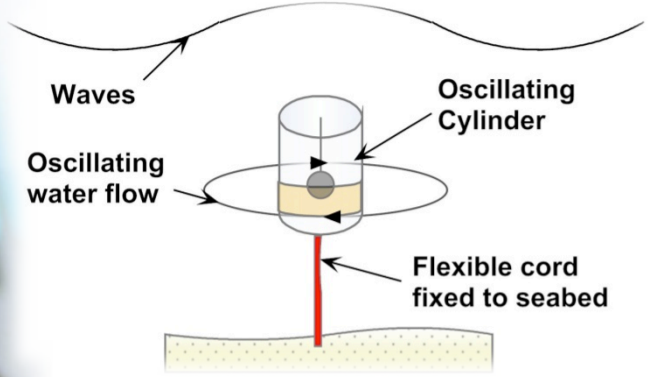

Wave length (L)
Near-shore
breaker line
20 - 10m depth
L/2
Wave motion

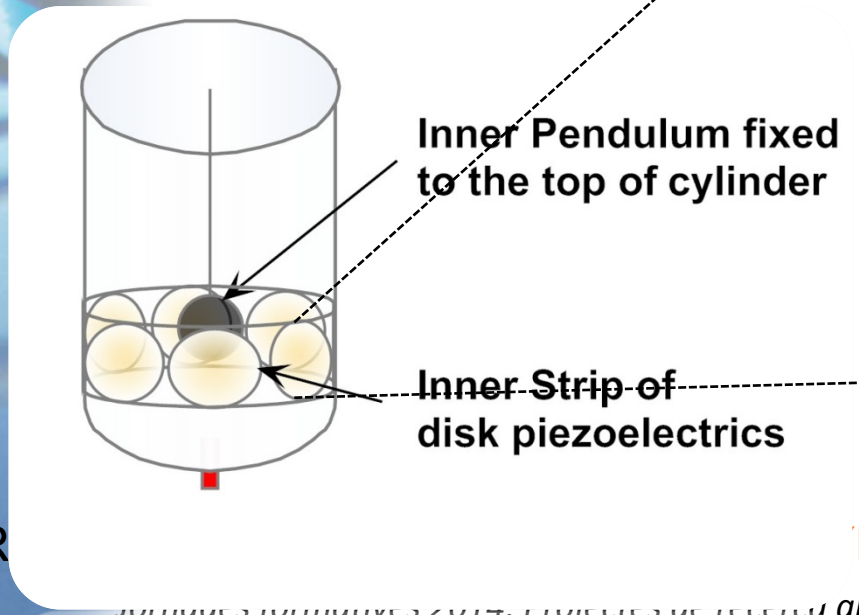

Oscillating Cylinder
Pendulum
Disk Piezoelectric
Flexible Cord

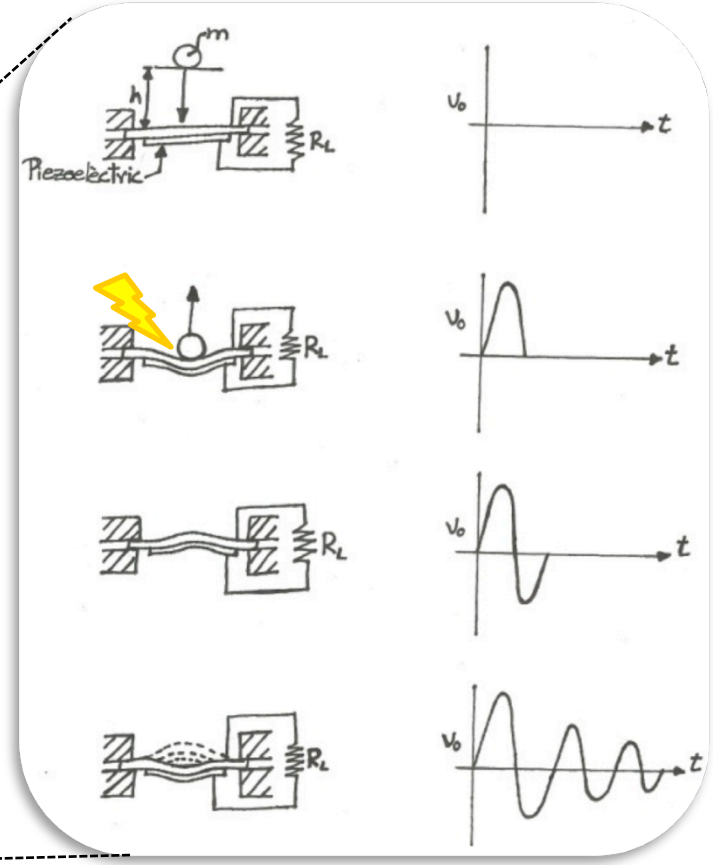

0,2 m
Z
X


3D View (azimuth=270; elevation=0)
Time History: CALM Buoy x-Acceleration rel. g at x=0,00, y=0,00, z=0,45
Time History: CALM Buoy Declination
Time History: CALM Buoy GX-Acceleration at x=0,00, y=0,00, z=0,45
Time (s)

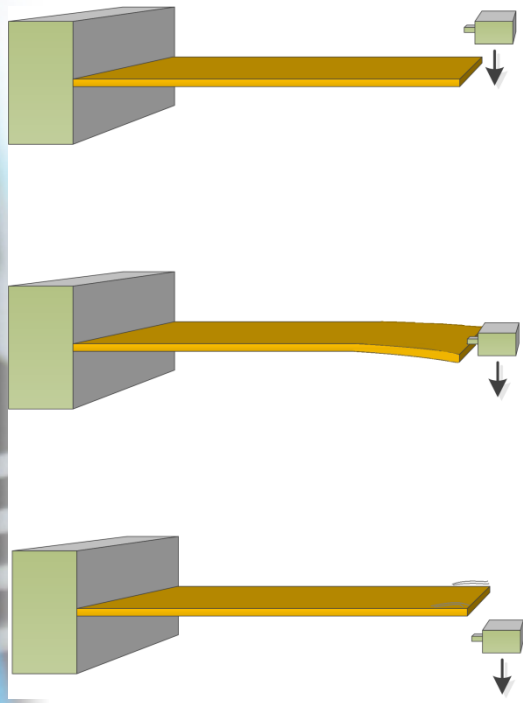
EH based in impacts to disk-PZT





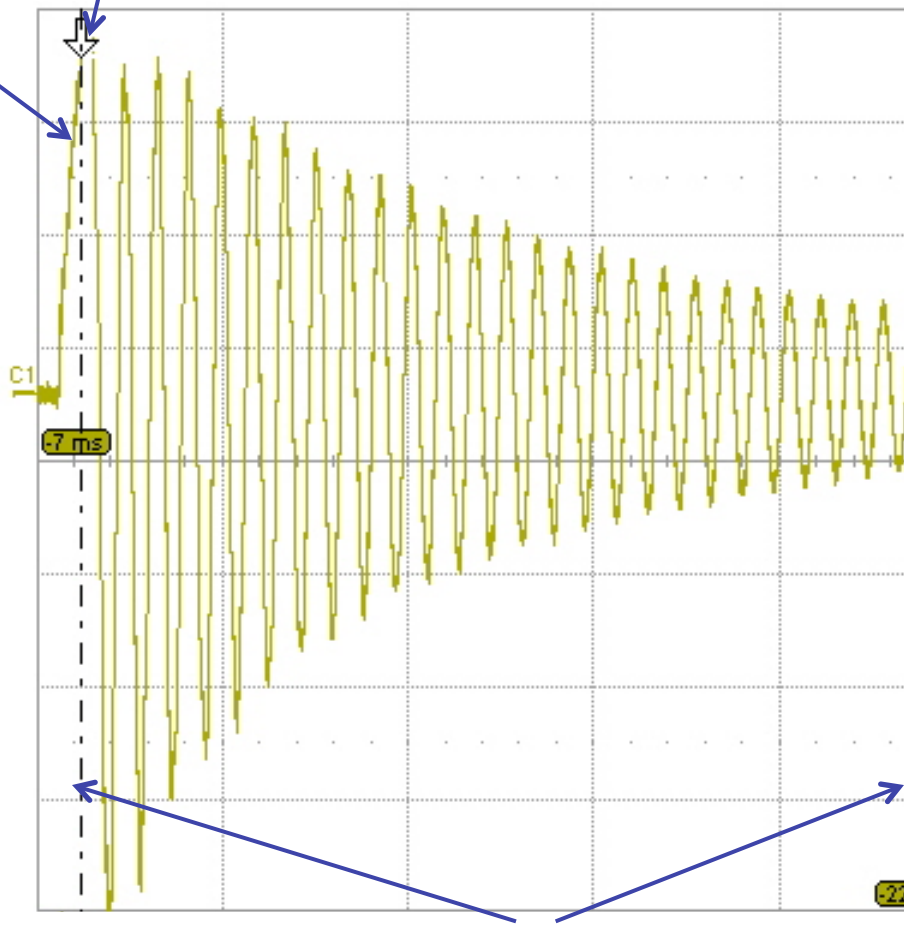


Piezo Excitation by flexion



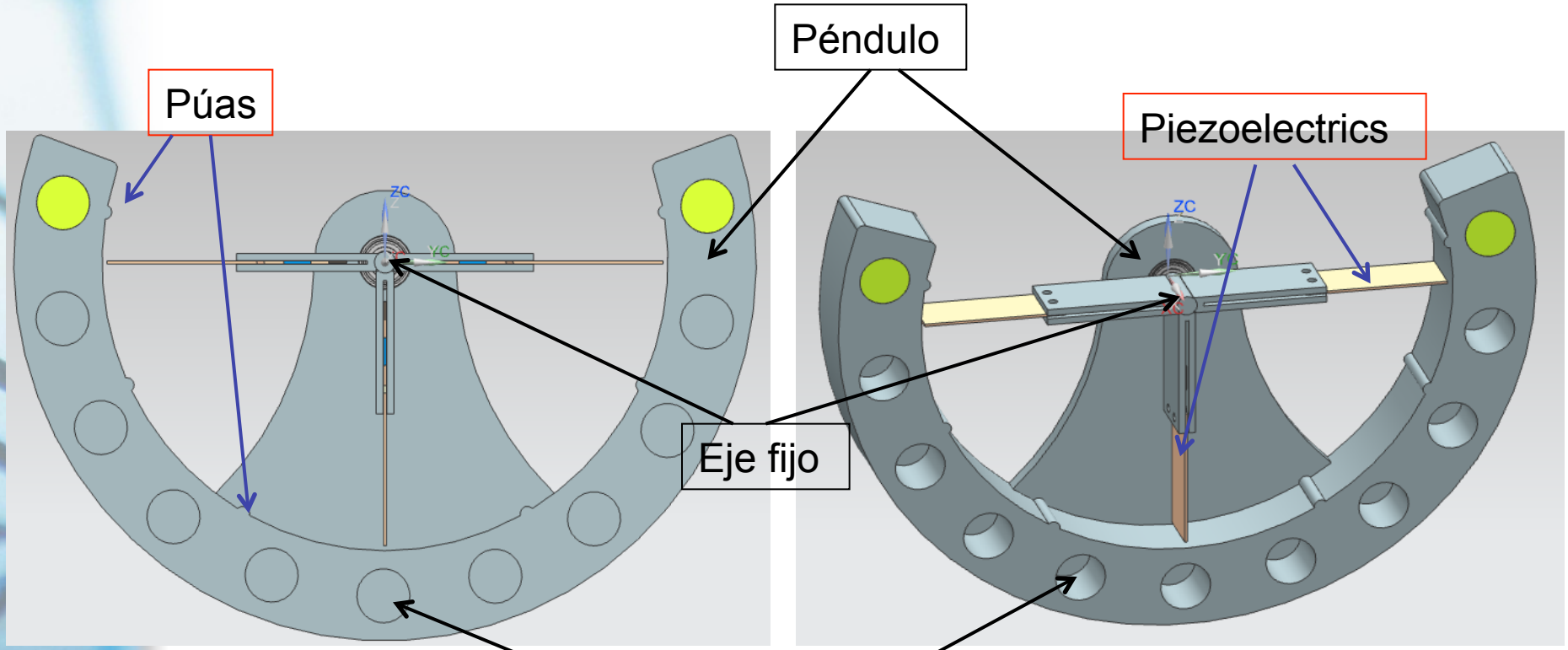
Punto de liberación

Fuerza aplicada

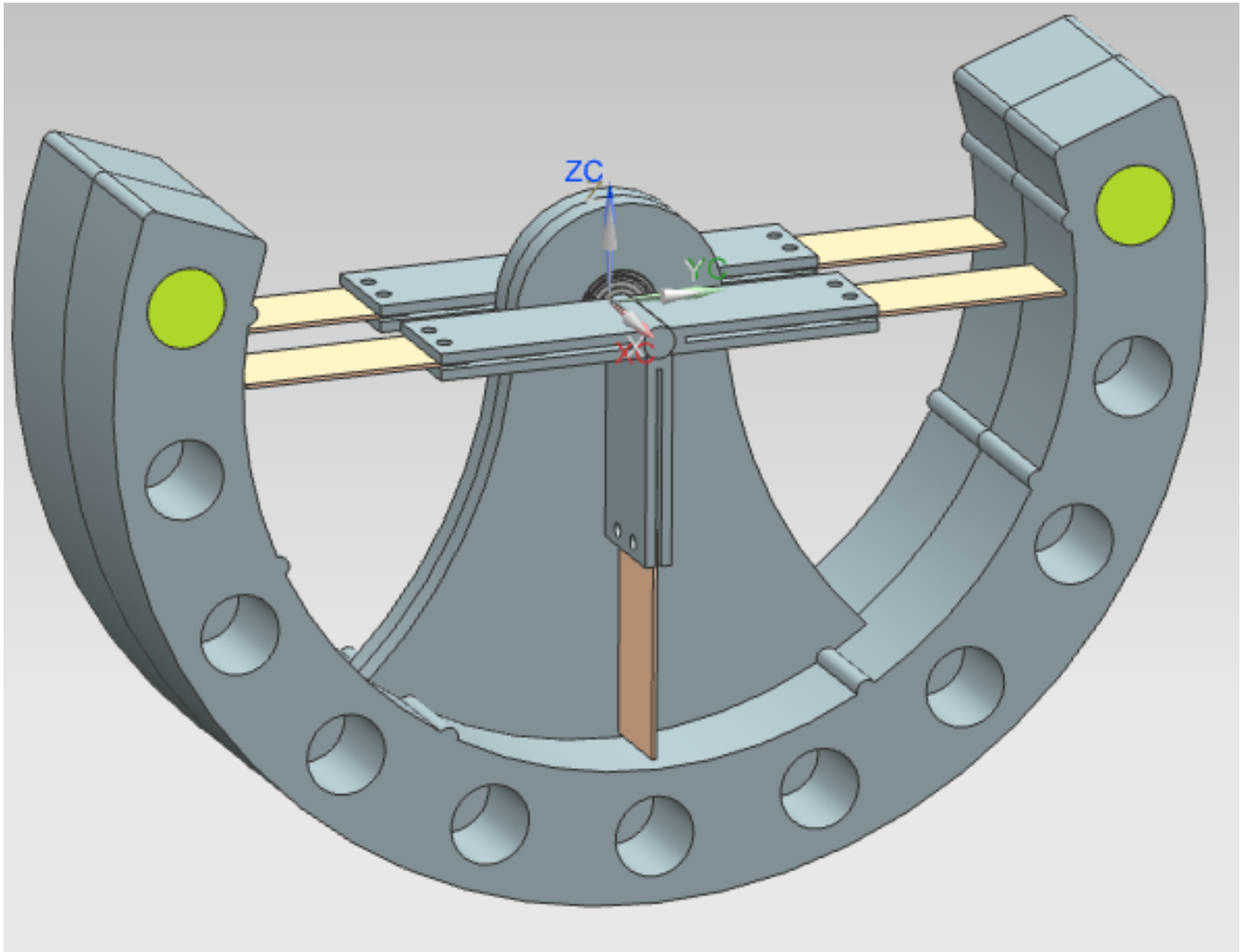


Vibración libre

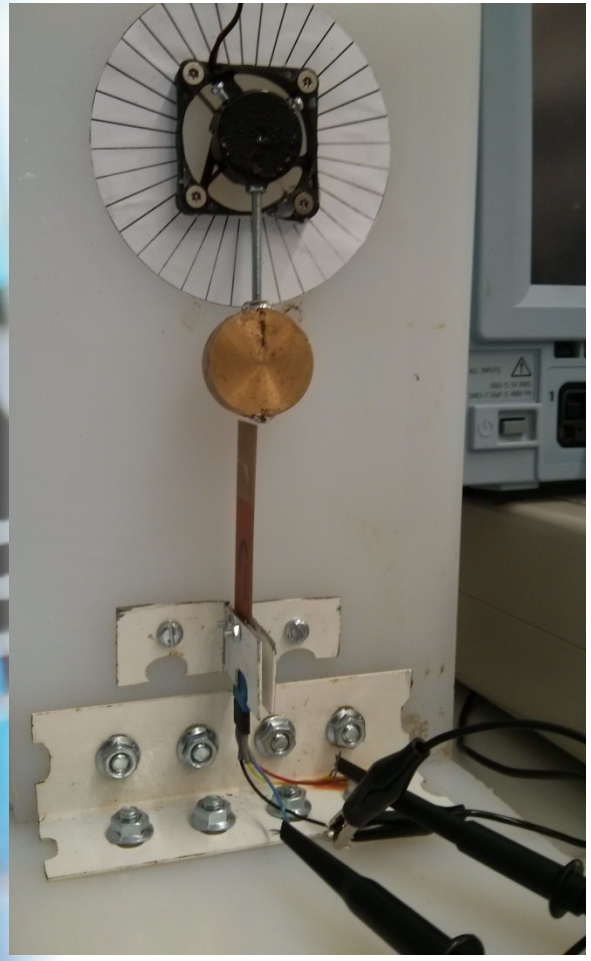
Design



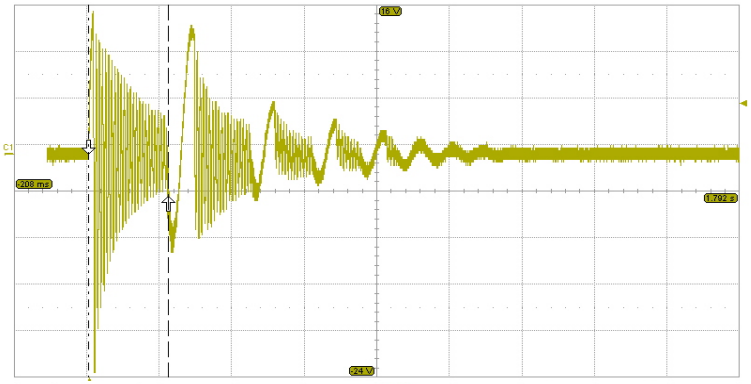
3D Harvesting



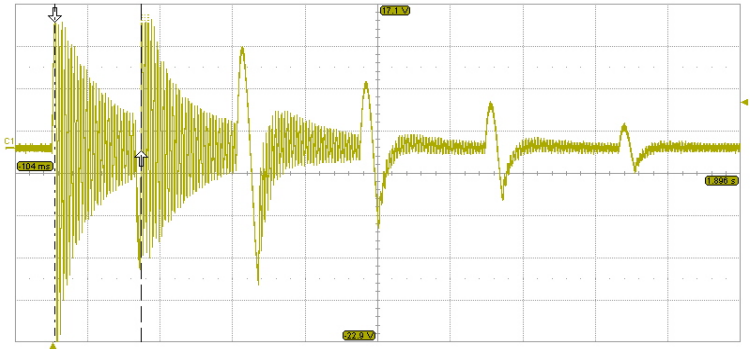
Tests



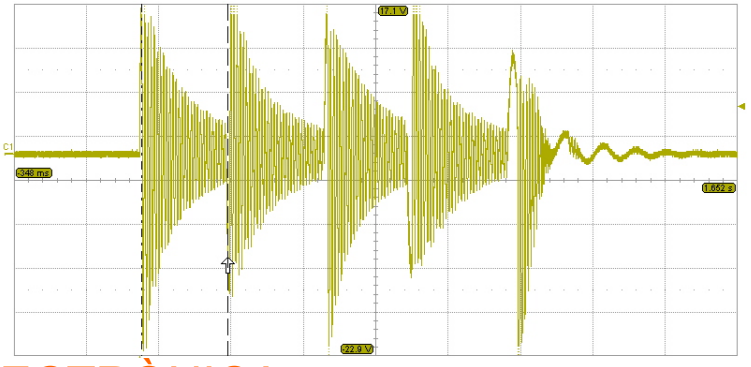
15º

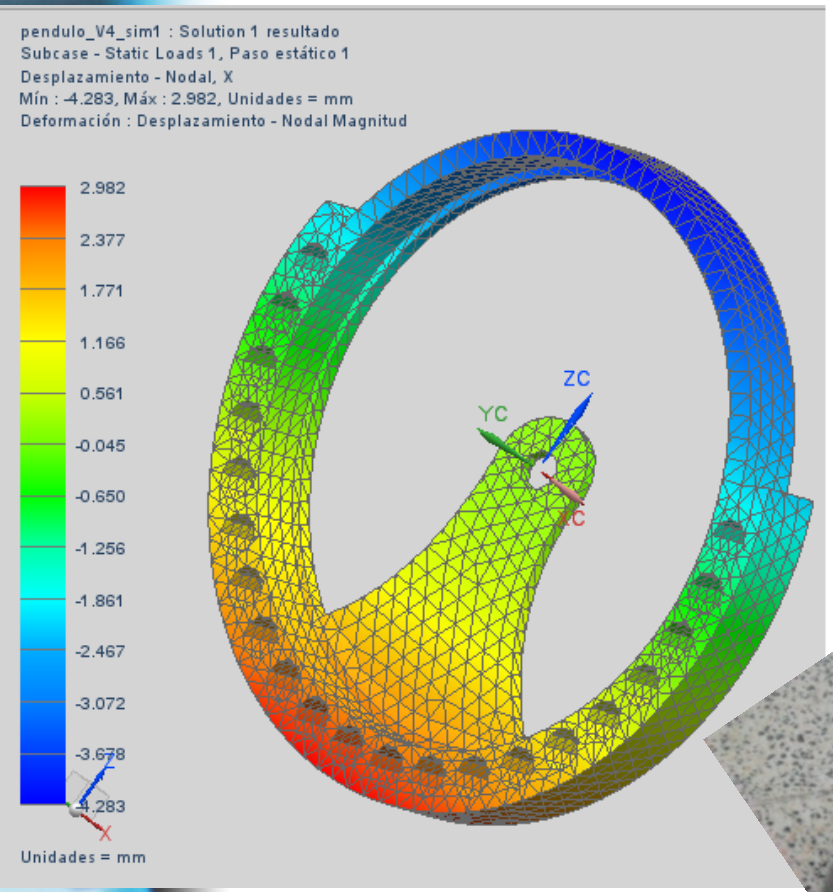


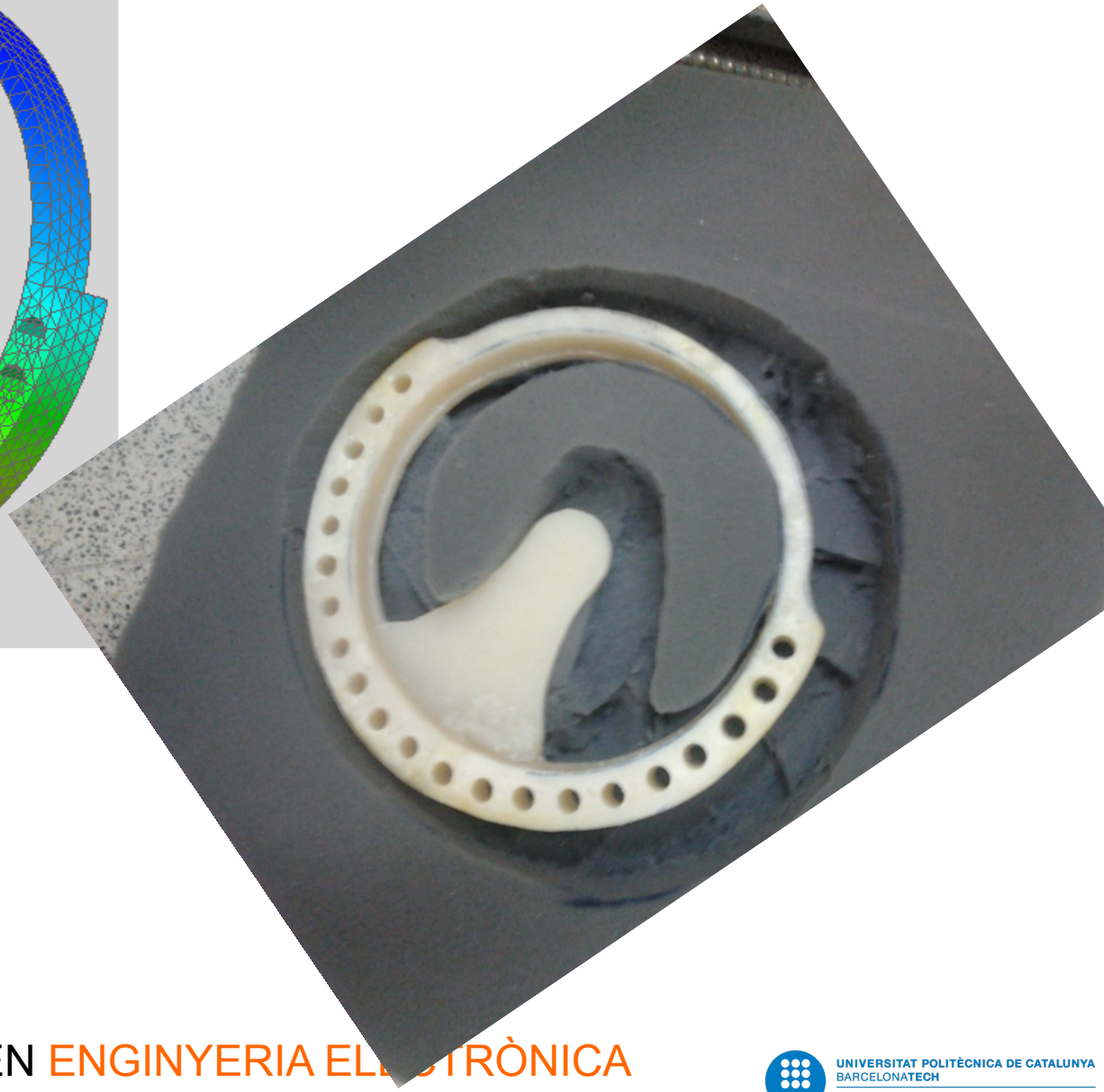
25º



35º







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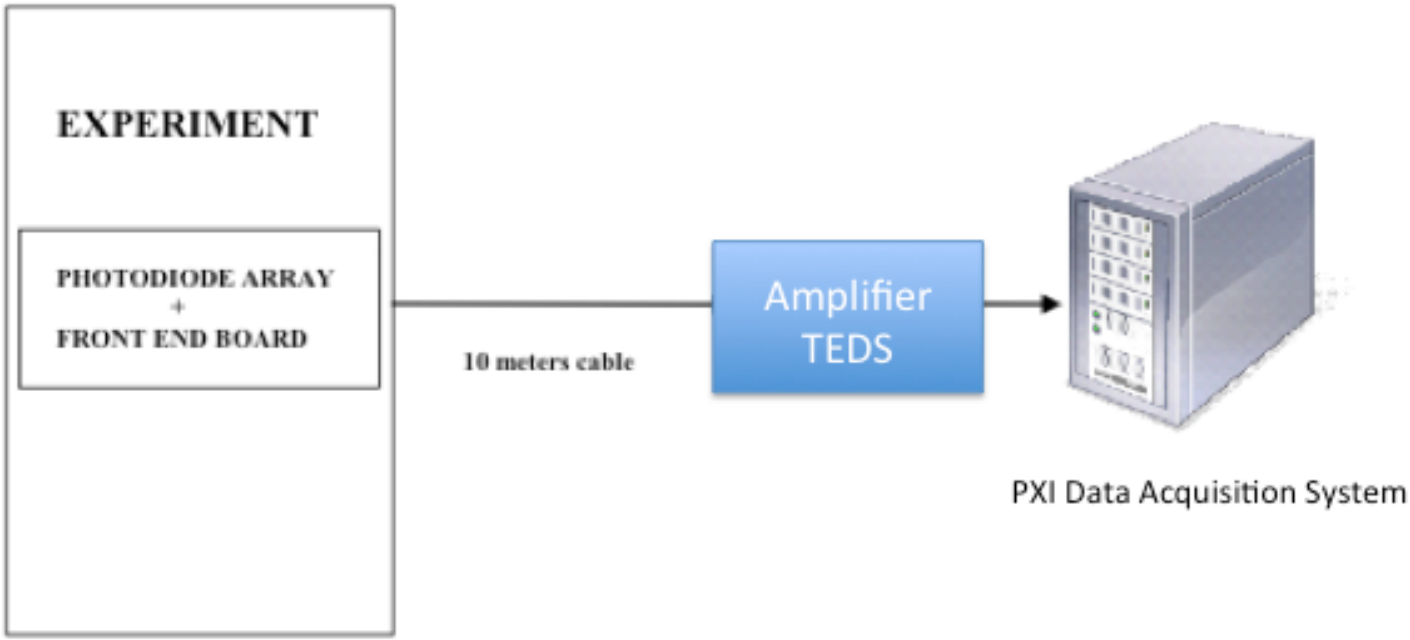
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament d'Enginyeria Electrònica

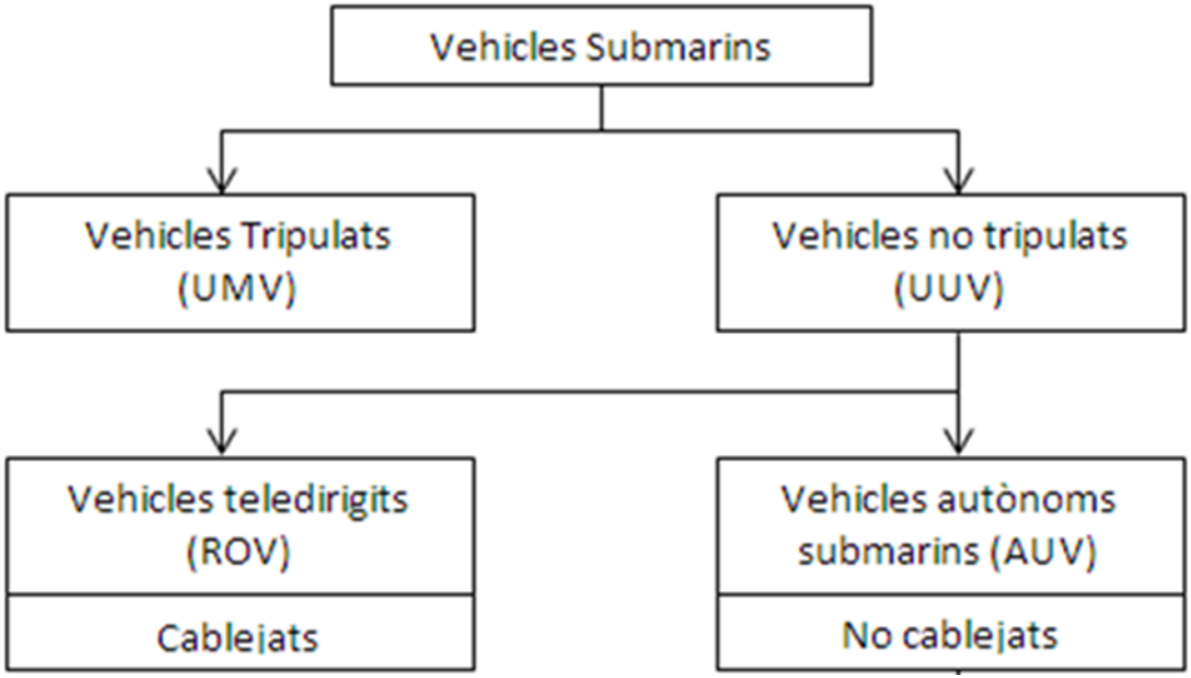
Sistemas de adquisición de datos inteligentes en entornos de fusión.
Proyecto Plan nacional coordinado: INTELECT (CIEMAT, UPM, UNED, UPC)

Aplicació a Bolómetros en reactor de fusión
IEEE Std. 1451



Introduction Unmanned underwater vehicles

Today, market demands have created remotely operated for all kinds of underwater work in offshore industry, scientific research and supporting divers and submarine



ROV. Remote Operated Vehicle

It is an unmanned underwater robot and connected to a ship on the surface via a long cable. Energy and commands are sent using a remote control via cable to the ROV.

AUV. Autonomous underwater vehicles

- An autonomous underwater vehicle is a robot which travels underwater without requiring input from an operator
- These vehicle can follow a predetermined route with certain degrees of flexibility and intelligence to change under certain circumstances.

Classification by propulsion:

AUV: using an engine with a propeller

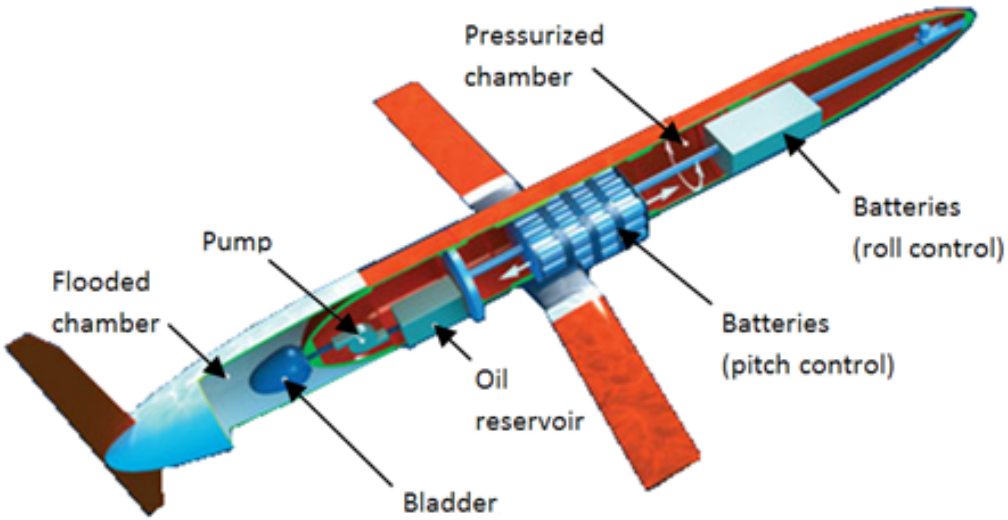
Remus:
Remus 100; Remus 600,
Remus 6000

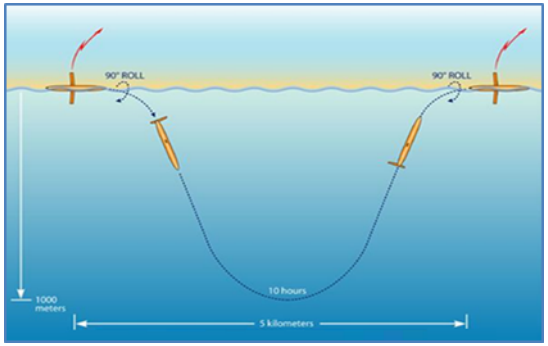
Guanay II
upper-water-column

AUV. Autonomous underwater vehicles

Gliders:. is a underwater vehicle that uses small changes in its buoyancy in conjunction with wings to convert vertical motion to horizontal, and thereby propel itself forward with very low power consumption.

Spray Glider de Bluefin Robotics,

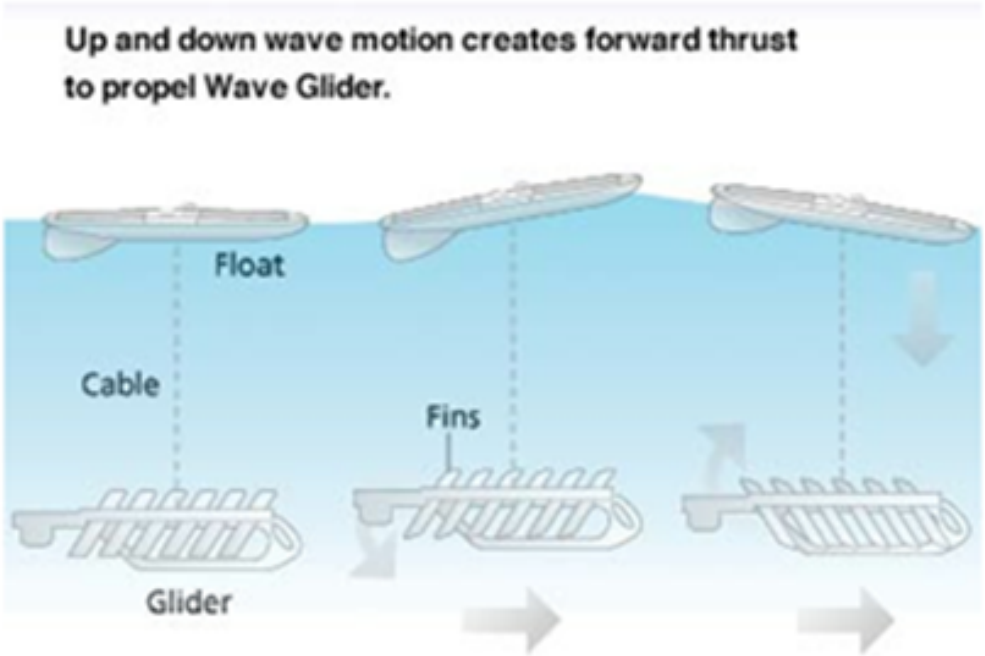


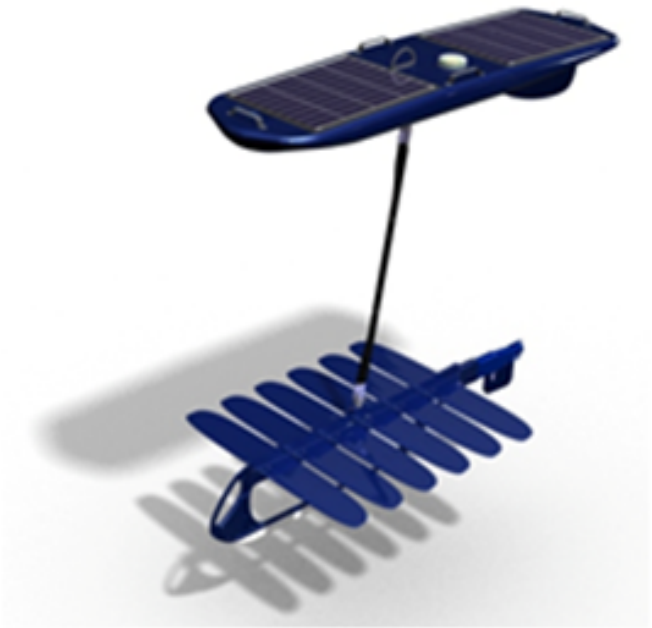


Depth: 1500 m
Range:4800km
Velocity : 35cm/sec

AUV. Autonomous underwater vehicles

Wave Gliders: autonomous marine robots to use the ocean's endless supply of wave energy for propulsion



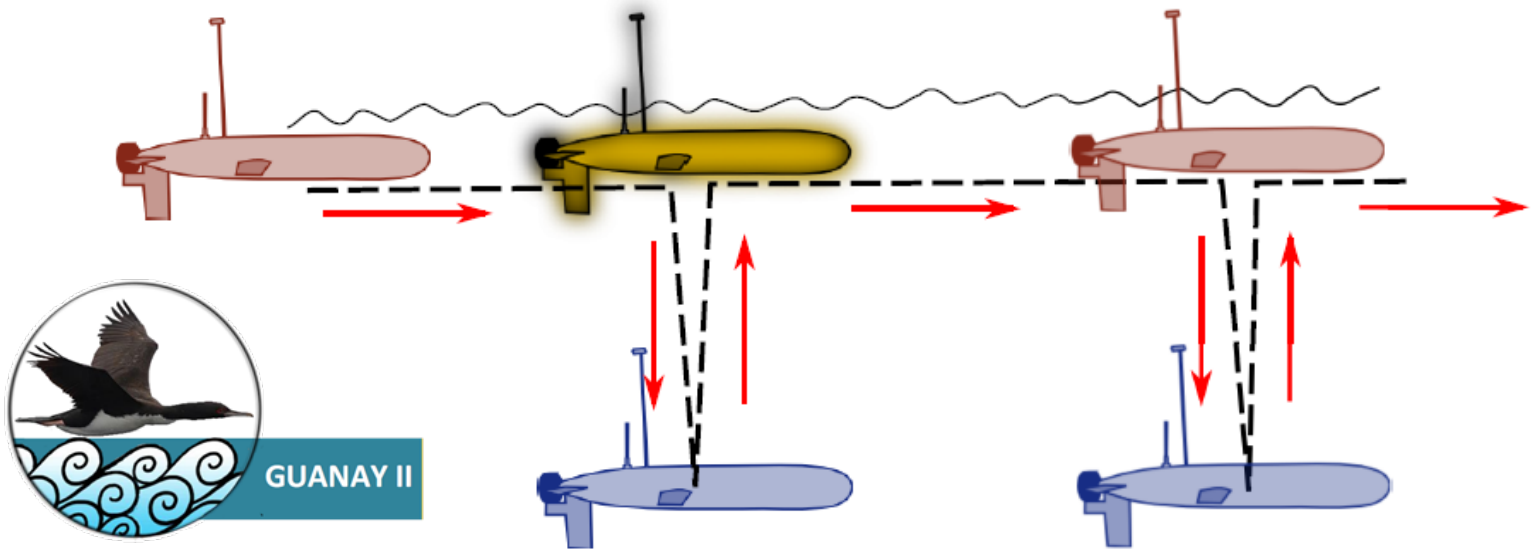


AUV. Guanay II

- It is an autonomous underwater vehicle that navigates over the sea surface and, at certain fixed points, dives vertically to obtain a profile of a water column.

. The study of environmental variables such as temperature, salinity (upper-water-column)

- Avoid creating perturbations in the environment.



AUV. Guanay II

- The vehicle is 2300 mm in length by 320 mm in diameter, and weighs 90 kg.

- The designed vehicle has a double-hull structure.

- The external fiberglass hull, which is not watertight, has been designed in accordance with Myring profiles to provide good hydrodynamic performance.

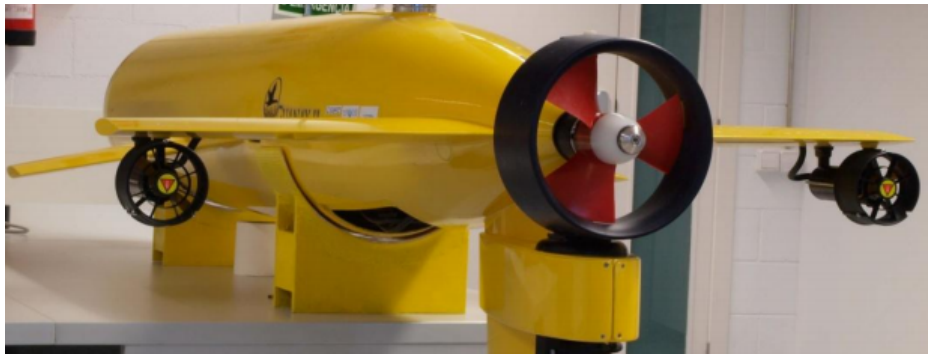
Propulsion and direction engine

SM7 Thruster (Seaeye)

- Without brushes
- 24 VDC
- Power: 300W
- Max. Force: 110N

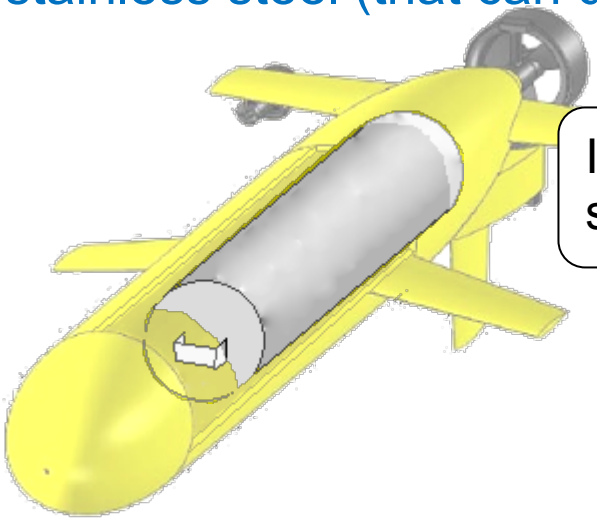
BTD150 Thruster (Seabotix)

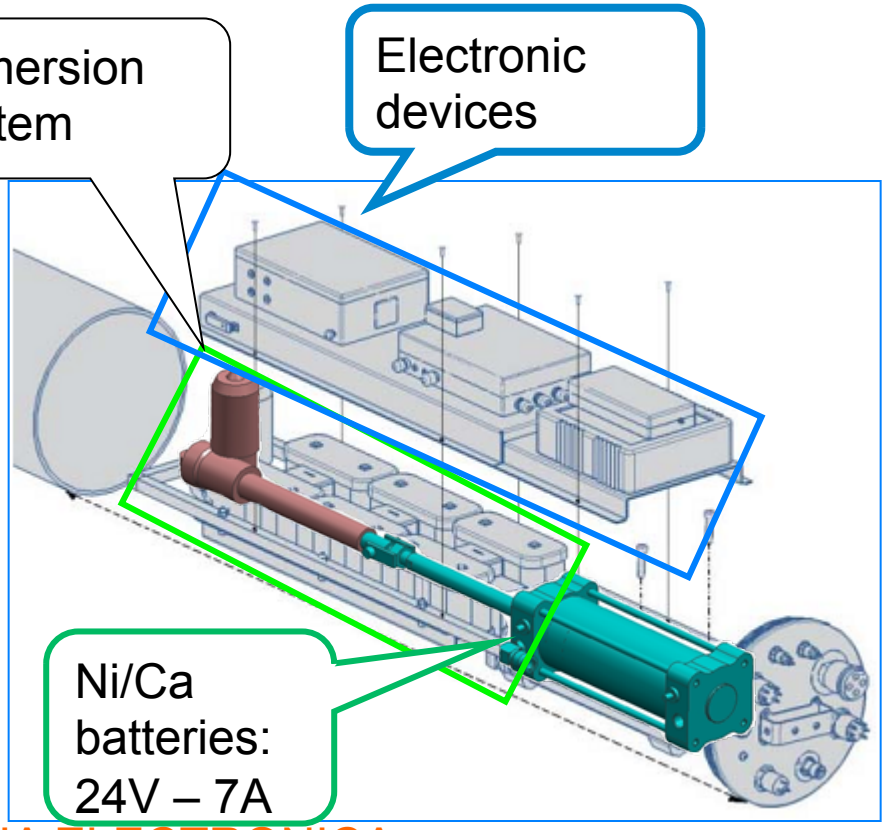
- 12 VDC
- Power: 80 W
- Max. Force: 24N



Watertight module.

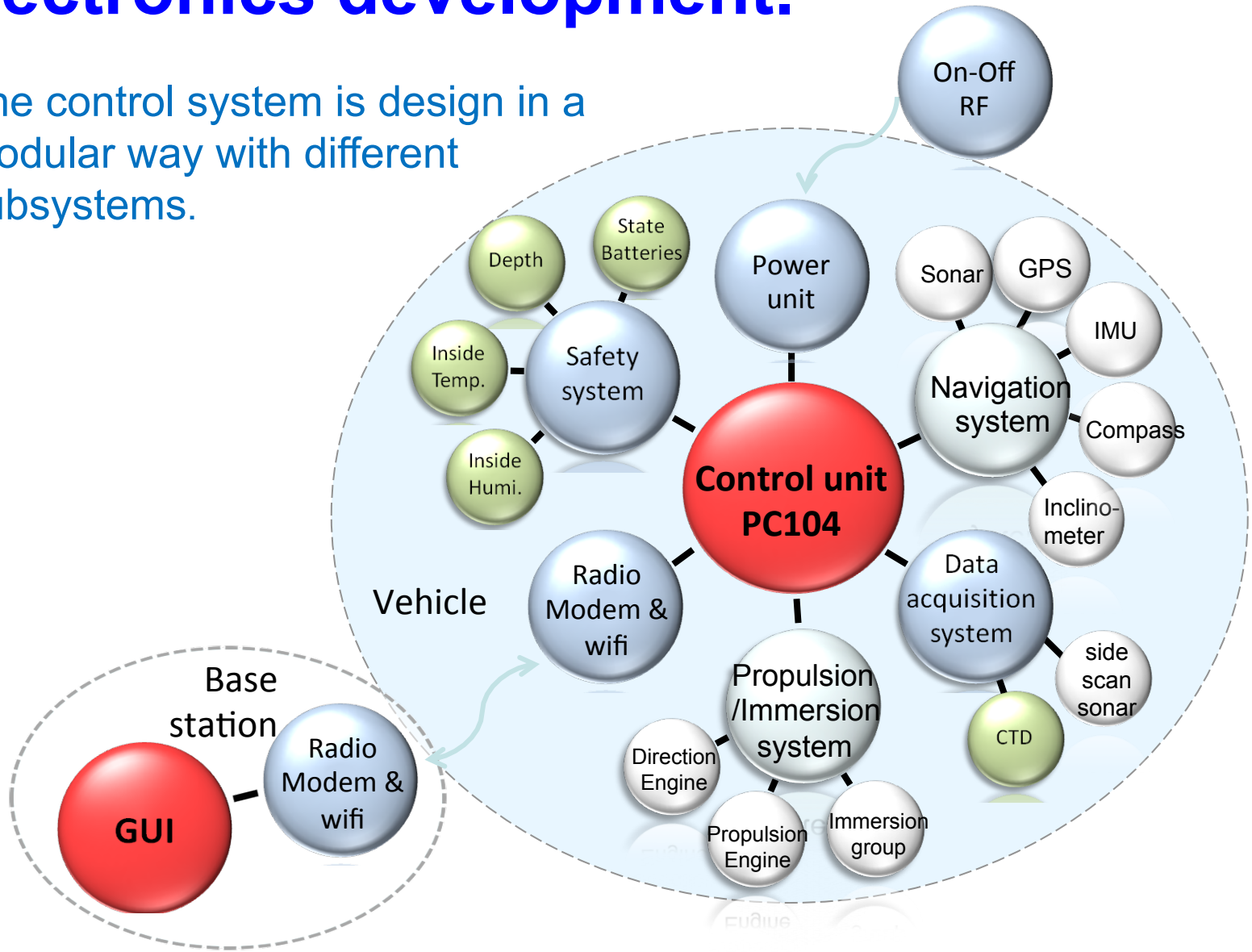
- The watertight aluminum-6063 cylinder is located inside the outer structurel
- Immersion/emersion system is composed of a pneumatic cylinder of stainless steel (that can displace up to 1500 cm3 of water),





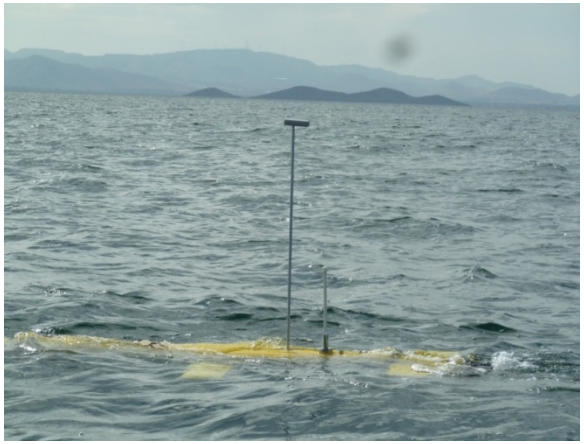
Electronics development.

The control system is design in a modular way with different subsystems.



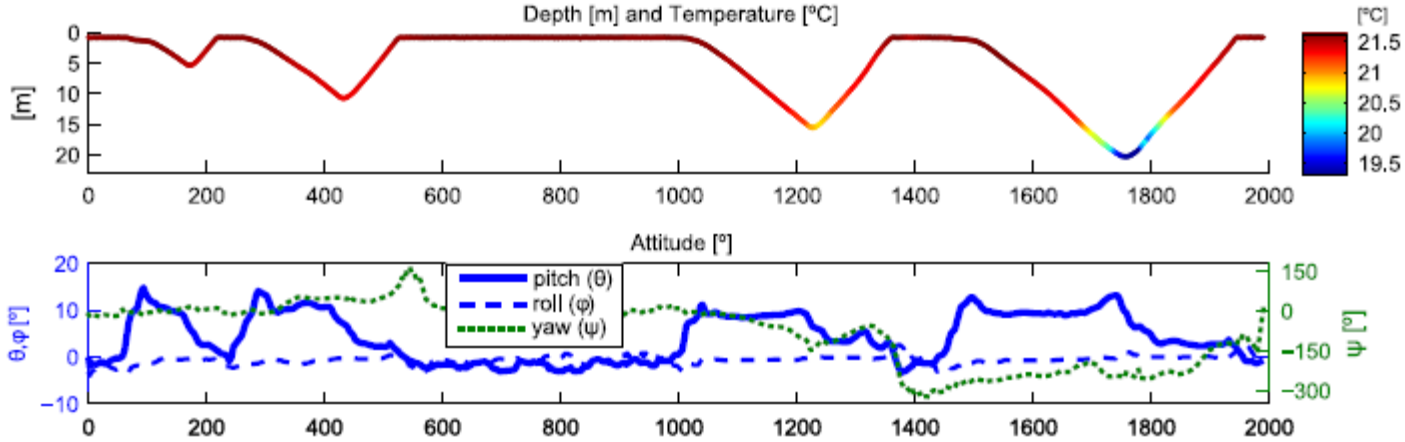
Experimental results

- Tests of the vehicle have been performed in pool, water canal and the sea.

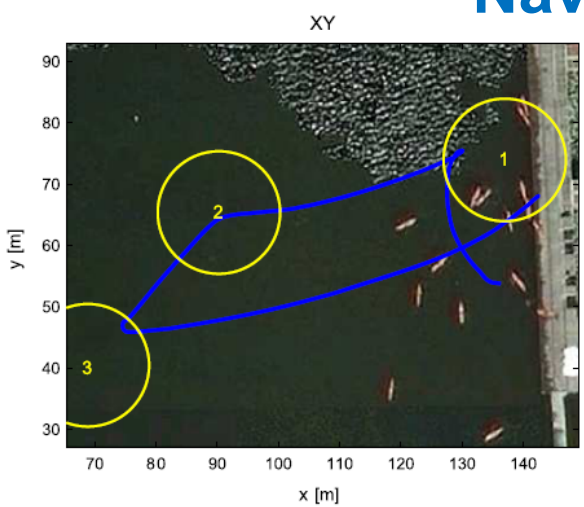


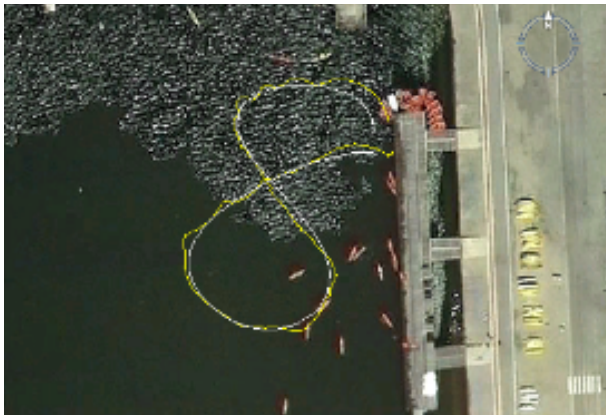
Experimental results

Depth test

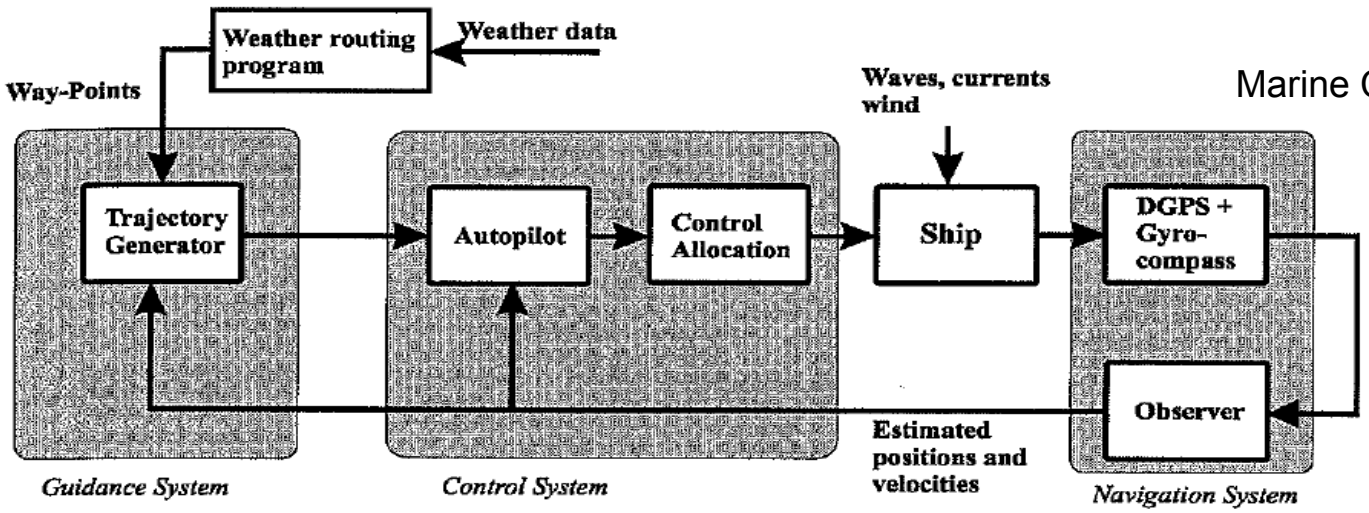


Navigation test





Mathematical modeling of the vehicle



Marine Control Systems
T. I. Fossen

$$m\dot{u} - mvr = X_{\dot{u}}\dot{u} - Y_v vr - Y_r r^2 + X_{u|u|}u|u| + X_{prop}$$

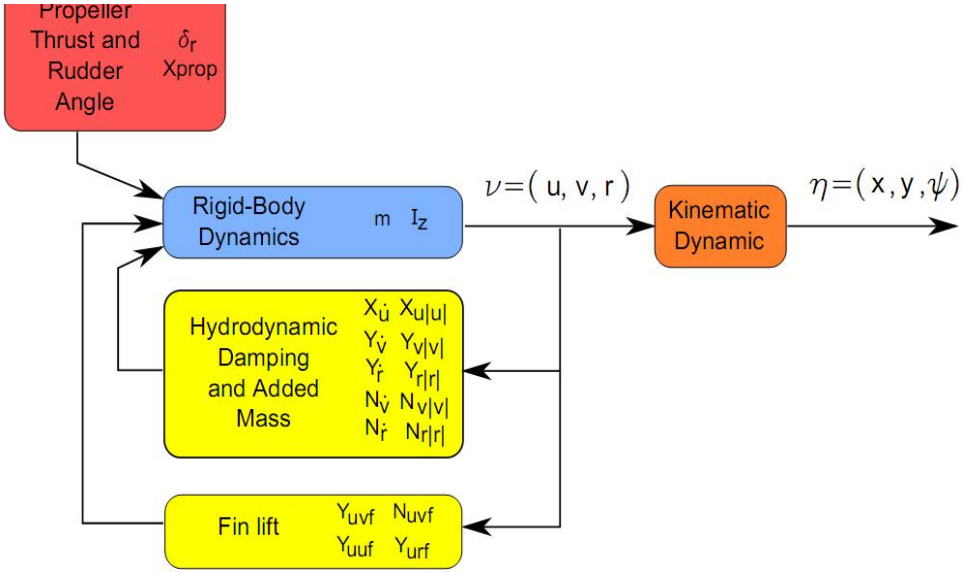
$$m\dot{v} + mur = Y_{\dot{v}}\dot{v} + Y_{\dot{r}}\dot{r} + X_{\dot{u}}ur + Y_{v|v|}v|v| +$$

$$Y_{r|r|}r|r| + Y_{uvf}uv + Y_{urf}ur + Y_{uuf}u^2\delta_r$$

$$I_z\dot{r} = N_{\dot{v}}\dot{v} + N_{\dot{r}}\dot{r} + Y_{\dot{r}}ur - (X_{\dot{u}} - Y_{\dot{v}})uv +$$

$$+N_{v|v|}v|v| + N_{r|r|}r|r| + N_{uvf}uv +$$

$$+N_{urf}ur + N_{uuf}u^2\delta_r$$



Proyectos, formación, tesis industriales

-AKO, Alstom, Applus, Ecotecnia, Generalitat de Catalunya, Consell regulador del Cava, CSIC, Diputació de BCN, SIMON, FireVision, Gervall, General Cable, GNE, Gallina Blanca, Iberco, Idiada, KUKA, Itene, Insituto Astrofísico de Canarias,Legrand, Pysmian…

THANKS FOR LISTENING