ASSEM : A New Concept of Observatory Applied to Long Term Seabed Monitoring of Geohazards

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***Abstract* - Recent marine and geophysical research has demonstrated that long-term time series of critical parameters are needed to understand the various ocean systems. ASSEM is the first application of a new concept of sea bed observatories dedicated to long term monitoring of a small area (a few km^2), lying on a network of interconnected measurement nodes. It is a project that enhances marine technologies allowing real time monitoring of the sea bed. The main component of each node is the COmmunication and STOrage Front end, COSTOF. providing a set of enhanced sensors (pore pressure, methane, geodesy, tilt, CTD, turbidity, currents,…) with the means to communicate with the external world through an underwater acoustic or cabled network, and to locally store the produced data. Alarms can also be generated by processing these data. The architecture is organized around an internal CAN/CANopen bus, hosting sensors, communication and memory devices on a common transmission backbone. The software resources enabling a monitoring node to act as a network node (routing algorithms throughout the network, network configuration management, data transmission protocol and other network layers) are implemented in every COSTOF. Alarms can be generated for example if a critical parameter, or a group of parameters, exceeds a programmed threshold for a given time.**

The evaluation of this new concept will be made through two experiments addressing two sea bed problems: slope instability risks and seismic risks. . The first one will take place at a site in Norway offering a risk slope instability. The experiment should include hook-up of integrated pore pressure sensors, installed in bore-holes, and set-up of standard sensor interface and communication system for data transfer to the surface. The second experiment will take place in the Gulf of Corinth. The shelf, slope and margin of the basin off the coast of a faulted area is selected for the deployment of the ASSEM array of sensors. It is the most active extensional basin in Europe, with high rates of margin uplift

This concept could be applied to other domains such as long-term studies in biology or emergency monitoring.

I. INTRODUCTION

With offshore exploitation developments, continental margins are the focus of increasing human activities which are moving towards deeper waters. They are witnessing high technological advances for deep-water development. Some of these margins are also a place where drastic phenomena like slope failures occur, hence questioning the safety of people and installations. Moreover, some areas, surrounded by densely populated belts and associated infrastructures are located in seismic zones where the seafloor may also be unstable.

In both cases, there is a strong need to better understand the phenomena leading to instabilities. This understanding can be widely enabled by measuring a set of geotechnical, geodetic or chemical parameters related to the sediment and seafloor. A site must be monitored in several locations along failure lines, near a fluid expulsion zone or on a line of change of slope or a possible presence of gas hydrates. In addition, long term slow variations of the measured parameters must be detected, leading to the necessity to have access to both spatial and temporal variability.

Understanding our ocean and the complex physical, biological, chemical and geological masses at work within it, conducts to the same requirements.

II. GENERAL CONTEXT

Long term seafloor observatories are already deployed, but even if they are interdisciplinary, they are mainly dedicated to seismic objectives. These measurements require high bit rate data links. The most efficient but expensive solution is to deploy cabled seismic seafloor observatories: a total of nine cabled seafloor observatories exist in Japan. Three real time ones are operated by JAMSTEC on the sea floor, off-Hatsushima (8 km cable length, off- Muroto (120 km cable length and off – Kushiro – Tokachi (240 km cable)[1]. To reduce the cost of a cabled system, it is sometimes possible to re-engineer retired coaxial undersea telephone cables. The US navy has repowered SD cables to SOSUS arrays. The Hawaii-2 Observatory (H2O), sited south of the Moonless Mountains, between Marray and Molokai fracture zone, uses the Hawaii-2 Cable (HAW-2) in its part from Oahu to the observatory [2], [3]. The VENUS project re-commissioned the second Trans-Pacific Ocean cable between Okinawa and Guam. The goal of VENUS is to construct a multi-purpose earth observation system. Technology for coaxial electric and fibre optic cables that permits them to be connected and disconnected underwater was developed. A technique for connecting transfer units at the seafloor, using submersible or ROV was also developed.

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In order to achieve low-cost long term seafloor monitoring, JAMSTEC developed and tested at sea the Mobile Seafloor Observatory [4]. The observatory consists of a multi-sensor Mother Station surrounded of four Satellite Stations at separations between 20 to 50 kilometres. Data can be retrieved by recovering the stations. Part of the sensor data in the Mother Station can be monitored through satellites by releasing pop-up buoys. The same approach is encountered in the GEOSTAR European project [5]. A low to medium capacity two-way acoustic link between the station and a surface buoy, coupled with a satellite communication system (INMARSAT) is used to control and collect a set of reduced data every day.

All these systems are too large and too expensive for long term monitoring of most geohazard areas. The European ASSEM project is a new concept of sea bed observatory dedicated to this kind of monitoring problems [6].

III. TECHNICAL DESCRIPTION

A. *General design*

To achieve these objectives of long term monitoring at lower costs, ASSEM brings several innovations and new methodologies:

- enhanced sensors for long term monitoring.
- A controlled deployment of sensors and stations by ROV or submersible;
- A modular design, with standard connecting and easy installation interfaces allowing to adapt the system to the site of interest, add new sensors and replace components for maintenance;
- a two-way communication link between sensors and shore, built on either an acoustic network or wired links;
- a local storage of all the raw data in each node with local analysis resources able to generate alarms;

B. *Electronic design*

An array is composed of several nodes. Each node includes an electronic unit, named COSTOF (COmmunication and STOrage Front-end), providing a set of

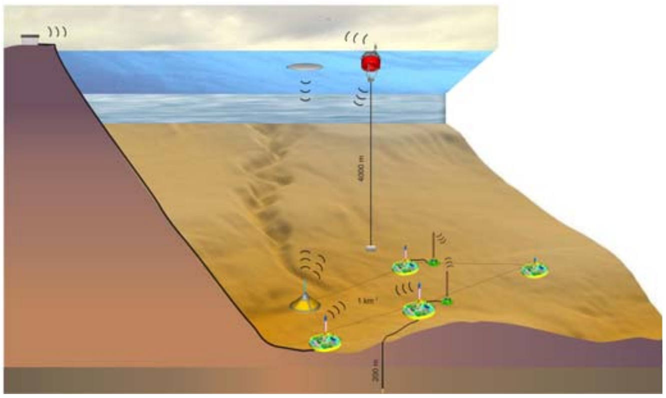

Fig. 1. Example of an ASSEM observatory.

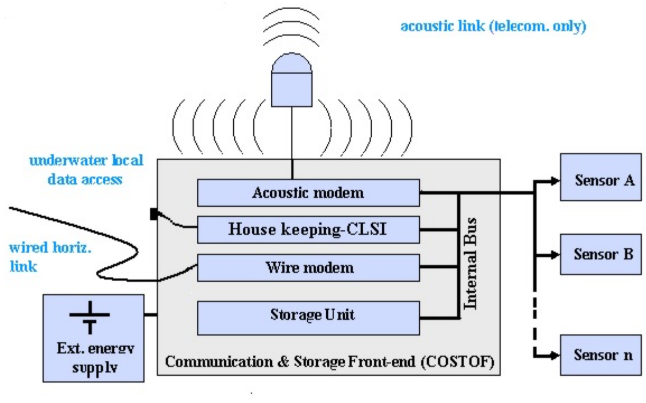

Fig. 2. Monitoring node modular architecture

sensors (pore pressure, methane, geodesy, tilt, CTD, turbidity, currents,…) with capabilities to communicate with the external world through an underwater network, and to locally store the collected data.

The architecture is organised around an internal CAN/CAN open bus hosting both sensors, communication and data storage resources on a common transmission backbone. All the modules connected to the bus include the same "kernel" card and a specific extension card building a "bridge". Each "kernel" card includes a Atmega129L processor, a 512Kbytes flash memory, a real time clock and 2 RS232 links.

The software resources enabling a monitoring node to act as a network node (routing algorithms throughout the network, network configuration management, data transmission protocol and other network layers) are implemented in every COSTOF unit. Alarms can be generated for example if a critical parameter, or a group of parameters, comes above a preset threshold for a given time length. This distributed architecture allows to configure a Monitoring Node very easily and to add new functions without modifying the existing ones.

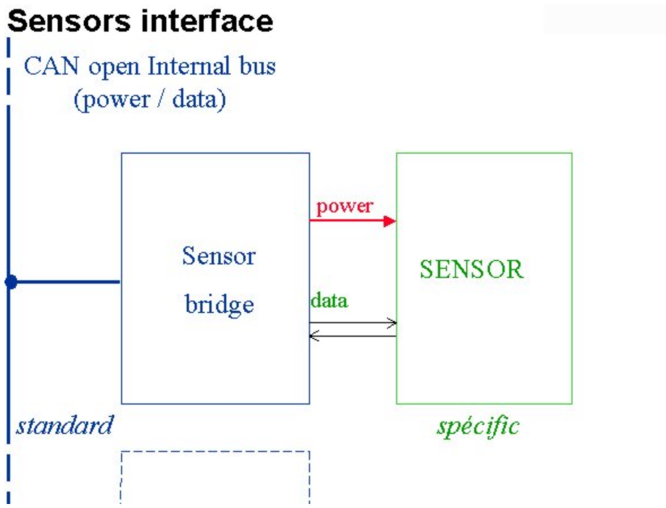

Fig.3 . CAN open bus structure

C. *Mechanical design*

The same modularity concept is applied to the mechanical design. The usual deployment and maintenance procedures of the node imply the use of a submersible or a ROV, but free fall launching is possible.

The design includes some innovations:

- A low cost underwater connection system is used to replace in-situ power packs, to install or to replace sensors and to establish cabled links between nodes, if needed;
- A contact-less serial interface (CLSI) allows to test the node before launching and during maintenance operations;
- An acoustic array, is mounted at the top of a flexible mast to have protection against trawlers.
- In addition, a bell-shape protection can be implemented for anti-trawling purposes

Lithium cells are used as power source. Two voltage, 12V and 24V are available with a capacity up to 12kWh. Power packs are replaceable by ROV or submersible.

D. *Sensors*

A lot of sensors can be installed on a ASSEM node. The configuration is chosen depending of the scientific objectives. Usually, temperature sensors will be implemented on each node.

Pore pressure is an important parameter for the modifications of the soil before and during geohazard event. It will be possible to measure it at several levels, in bore holes down to 200m and in tubes of CPT probes inserted in the sediment down to 30m.

The natural occurrence and emission of gas on the sea floor (methane seeps) are increasingly recognised as an important marine process for its environmental and geohazard implications. A methane sensor from CAPSUM is being adapted for long term deployment and deeper operation (3500 m instead of 2000 m).Power consumption is divided by a factor of 2 to 3.

In tectonically active areas, ground deformation sensors are claimed but geodesy is still in its infancy in deep water. Different sensors are developed and will be tested : a long range taut wire distancemeter (NGI) for measurement of distances up to 100/200m with accuracy of a few millimeters, an acoustic distancemeter (IPGP) and a tiltmeter. A benchmark, based on a suction anchor has been designed for long term deployment. It will be installed by the submersible THETIS of NCMR. At least, one node from a network is equipped with a CTD probe and another one (or the same) with a currentmeter. Turbidity sensor, current profiler, static and dynamic water pressure will be also available.

An suction anchor is essentially an overturned "bucket" penetrated into the seabed. Partial penetration is achieved by self-weight. Full installation is complete by pumping water from the interior of the anchor. Typical differential pressures required for full penetration are on the order of 10 to 100kPa. Benchmarks of three diameter, 400 mm, 600 mm and 800 mm were studied, with skirt depth of 1.00 m, 1.50 m and 2.00m.

E. *Acoustic network*

ASSEM uses an acoustic network based on the MATS 200/R acoustic modem from ORCA instrumentation. This digital modem based on micro-controller and DSP cards, is capable of data transmission under adverse channel conditions.

Original network protocols, with autonomous handshaking and adaptive bit rate, adaptive modulation and adaptive routing were implemented. Patented modems perform noise analysis and impulse response measurement of the channel. Such a network offers much more reliable and much higher data rates links than are now available.

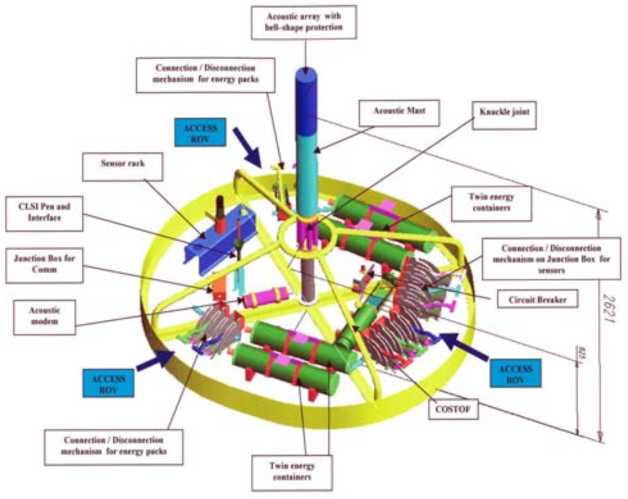

Fig. 4. An Assem node: diameter is abour 2 meters for a weight of 600kg. The acoustic array culminates at 2,621 m/.

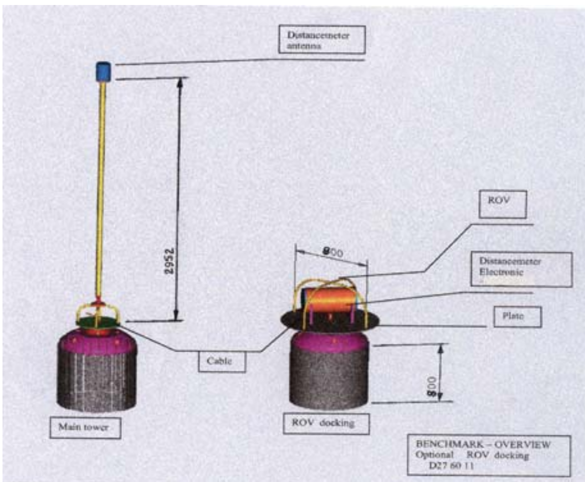

Fig. 5. Benchmark

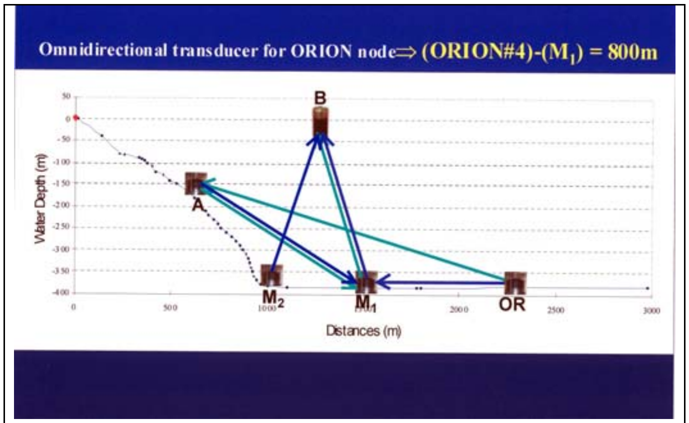

Fig.6 :Acoustic configuration for Trizonia experiment

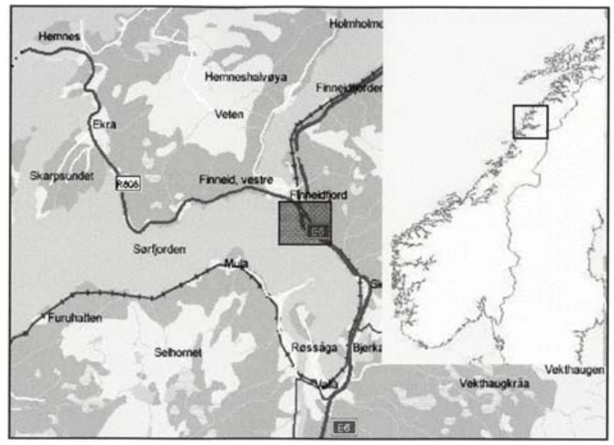

Fig 8. Finneidfjord Norway

Directional transducers were developed to decrease power consumption. They are used also to reduce multipaths effects. Fig.7 shows directivity diagrams.

IV. PILOT EXPERIMENTS

Two complementary pilot experiments are planned. The first one will take place at a site with a risk of slope instability, in *Finneidfjord.* The experiment will include a new design of pore pressure sensors installed in bore-holes and installation of standard sensor interface and communication system for data transfer to the surface. The experiment should at least include one year monitoring with remote data recovery. The main objective is to verify installation and operation of the ASSEM system in such conditions. In addition, the importance of long-term seabed pore pressure data for slope stability assessment will be demonstrated by obtaining a validated data set of measurements on site.

The second experiment will take place in the Gulf of Corinth. The shelf (with its pockmarks) , the slope and the margin of the basin off the coast of a faulted area are selected for the deployment of the ASSEM array of sensors. It is the most active extensional basin in Europe, with more than 1 cm/year of deformation across the Gulf and high rates of margin uplift.

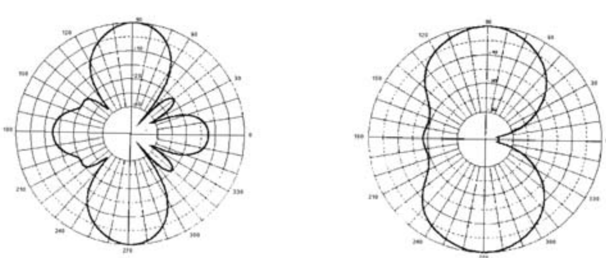
Fig.7. Directional transducer: narrow and wide beam
Electric connection allow to choose the pattern

Together with physical oceanographic measurements, both horizontal and vertical deformation devices will be installed. Horizontal deformation estimates will be based on acoustic traveltime measurements and vertical deformation estimates will be based on pressure measurements. The array will be deployed in the south of Trizonia island and will also host a satellite of the EU-ORION system, which includes a seismometer, demonstrating the compatibility between the two systems.

Data collected in real time or after recovery of storage devices, will be available to end users over the internet. Results from the EU project EMEW for the data handling of warning systems will be applied, especially for the Corinth experiment.

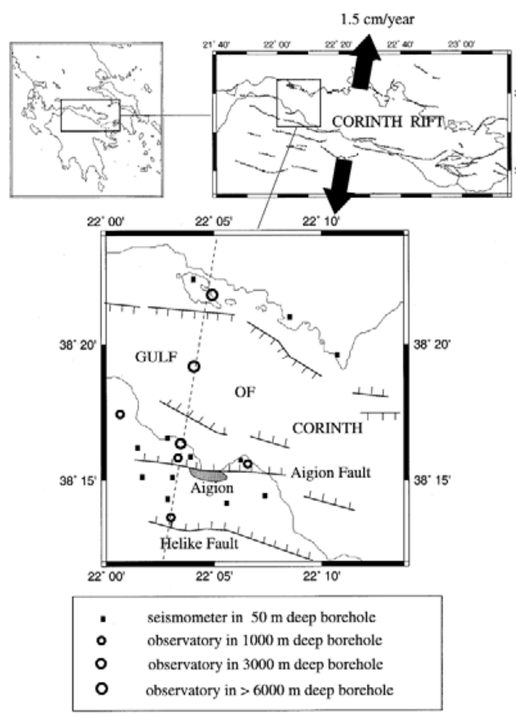

Fig.9. The Gulf of Corinth

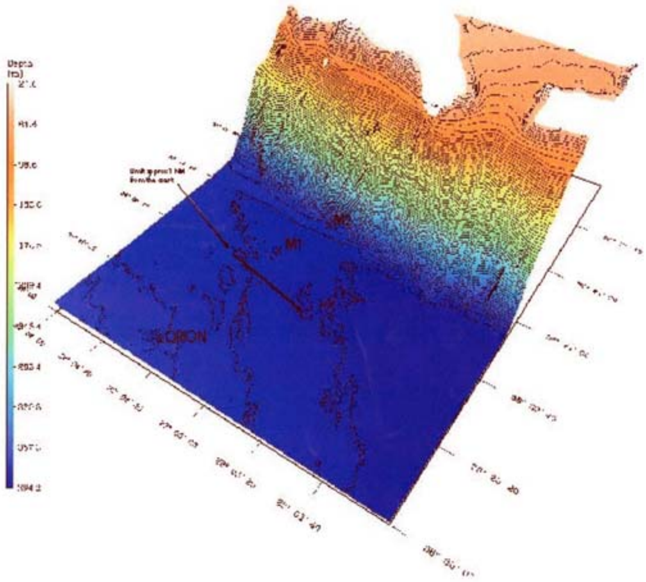

Fig.10. Bathymetry of Trizonia area

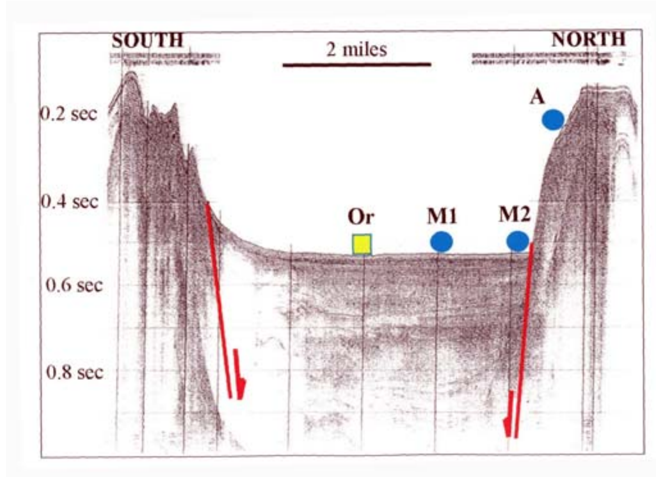

Fig. 11. Air Gun profile showing the tectonic structure of the Gulf of Corinth to the south of Trizonia island. The approximate location of the ASSEM monitoring nodes is also indicated on the profile.
A: on the upper slope – Geodetic sensor (tilt-, pressure-, distance-meter), temperature, CTD
M1: in the basin - Geodetic sensor (tilt-, pressure-, distance-meter), temperature, CTD, short-period seismometer
M2: at the trace of the marginal fault – temperature, turbidity, gas-sensor
Or: ORION-node, in the basin

V. CONCLUSIONS

ASSEM presents a new concept of real time sea floor observatories dedicated to deliver warning information and collect data with low sampling rate. It can be operated alone or linked to other observatory system, such as GEOSTAR/ORION. This concept could be applied to other long term studies in a wide variety of applications such as biological ones or in emergency to environment monitoring of dangerous wrecked ship .

Ackknowledments

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