at IST-ISR, was used for automatic marine data acquisition. The vessel is a major redesign of the DELFIM Catamaran, developed within the scope of the European MAST-III Asimov project that set forth the goal of achieving coordinated operation of the INFANTE autonomous underwater vehicle and the DELFIM ASC and thereby ensuring fast data communications between the two vehicles.
The DELFIMx craft, depicted in Figure 1, is a small Catamaran 3.5 m long and 2.0 m wide, with a mass of 320 Kg. Propulsion is ensured by two propellers driven by electrical brushless motors.

Figure 1. The DelfimX Vehicle

The maximum rated speed of the vehicle with respect to the water is 7 knots. The vehicle is equipped with on-board resident systems for navigation, guidance and control, as well as mission control. Navigation is achieved by integrating motion sensor data obtained from an attitude reference unit and a DGPS (Differential Global Positioning System). Transmissions between the vehicle, its support vessel or the control centre installed on-shore are achieved via a serial radio link. The vehicle has a wing shaped, central structure that is lowered during operations at sea. At the bottom of this structure, a low drag body is installed that can carry acoustic transducers. For bathymetric operations and sea floor characterization, the wing is equipped with a mechanically scanned pencil beam sonar and a sidescan sonar, and a ladar for topographic surveys. The paper addresses the design of a laser range finder based coast line following controller to provide DELFIMx with the capability of safely performing automatic inspection of rubblemound breakwaters as is required by the MEDIRES project.

SEAFLOOR OBSERVATORIES, BENEFITS FOR THE MARINE AND EARTH SCIENCES. INTERNATIONAL AND EUROPEAN PERSPECTIVES TOWARDS NETWORKS

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1. Introduction
It is widely recognised that seafloor observatories offer Earth and Ocean scientists new opportunities to study multiple, interrelated processes over time scales ranging from seconds to decades. Scientific processes with various time scales should benefit from data collected by seafloor observatories, including episodic processes (such as volcanic eruptions, earthquakes, or biological, chemical and physical impacts of storm events); processes with periods from months to several years (like hydrothermal activity and biomass variability in vent communities); global and long-term processes (such as the role of the ocean in Climate). The establishment of an observatory network will be essential to investigate global processes, such as the dynamics of the oceanic lithosphere and thermohaline circulation.
This paper describes the State-of-the-Art of the seafloor multidisciplinary observatories, with particular emphasis to the European experience. The benefits of the multidisciplinary approach for the Marine and Earth Sciences are also discussed through some relevant examples.

Finally the perspectives at International and European level are depicted towards the establishment of "permanent" submarine networks particularly addressed to the study of seafloor and water-column processes.

2. Technical solutions for seafloor observatory architecture
The principal characteristic of a seafloor observatory is a two-way communication between platforms and instruments and shore. Seafloor observatories are characterised by the following basic elements: a) multiple payload; b) autonomy; c) capability to communicate; d) possibility to be remotely reconfigured; e) accurate positioning; f) data acquisition procedures compatible with those of shore observatories.

It is useful to introduce some definitions [1]:
Seafloor observatory is an unmanned platform, capable of operating in the long-term on the seafloor, supporting the operation of a number of instrumented packages related to various disciplines. Seafloor observatories can have as possible configurations: 1) autonomous, 2) acoustically linked, and 3) cabled:

1) autonomous, observatory in stand-alone configuration for power, using battery packs, and with limited capacity of connection, using, for instance, capsules or an acoustic link from the surface, which can transfer either status parameters or a very limited quantity of data;

2) acoustically linked, observatory able to communicate by acoustics to an infrastructure, such as a moored buoy or another observatory;

3) cabled, observatory having as infrastructure a submarine cable (retired cables, dedicated cables or shared cables devoted to other scientific activities, such as neutrino experiments).

Infrastructure is any system providing power and/or communications capacity to an observatory (e.g., a submarine cable, a moored buoy, another observatory); an infrastructure may also serve as support for other instrumented packages.

Instrumented package is a sensor or instrument devoted to a specific observation task; it may be hosted inside the observatory, be operated autonomously, be directly connected to an infrastructure or be

placed near an observatory and interfaced to it (thus having the observatory as its infrastructure).

An important issue is the best configuration of each sensor package. Each sensor has its own requirements for correct installation and data acquisition in terms of sampling rate [1-2]. This is particular crucial for the seismometer that must be isolated, as much as possible, from the influence of the hosting frame, accurately positioned and oriented with respect to the North, and, overall, well coupled with the seabed [3].
In Table I world-wide seafloor observatories validated at sea are listed.

Name	Type	Starting year	Country
Omaezaki	C	1978	Japan
Boso	C	1985	Japan
Hatsushima-I	C	1993	Japan
Ito	C	1994	Japan
Sanriku	C	1995	Japan
Hiratsuka	C	1995	Japan
LEO-15	C	1996	USA
GEO-TOC	C	1997	Japan
HUGO	C	1997	USA
Muroto	C	1997	Japan
MOISE	A	1997	USA
NeMO	AL	1997	USA
H2O	C	1998	USA
Mobile seafloor obs.	A	1998	Japan
Kushiro	C	1999	Japan
VENUS	C	1999	Japan
Hatsushima-II	C	2000	Japan
GEOSTAR	AL	2000	EU
MVCO	C	2000	USA
NEREID-1	A	2000	Japan
NEREID-2	A	2000	Japan
WP-2	A	2000	Japan
WP-1	A	2001	Japan
MOBB	A	2002	USA
ORION-GEOSTAR-3	AL	2003	EU
ASSEM	AL	2004	EU
GMM	C	2004	EU
NEMO - SN-1*	C	2005	Italy-EU

* SN-1 was used in autonomous configuration in 2002-2003

Table I. World-wide seafloor observatories validated at sea. A: autonomous, AL: acoustic link, C: cabled.

3. State-of-the-Art of seafloor observatories

The scientific benefits of establishing a seafloor observatory network and the importance of filling the existing gaps in the global land-based networks (particularly seismic and geomagnetic stations) have been recognised since many years. Many world-wide experiments and projects using observatories on the seafloor or into ODP boreholes, both in shallow and deep waters, have been launched (e.g., LEO-15, MVCO, HUGO, H2O, MOISE, MOBB, OSN, GeO-TOC, VENUS and OHP). The European experience on seafloor monitoring started in early 1990s with the OFM pioneer French experiment and the EC feasibility studies addressed to identifying the scientific requirements, to establishing the possible technological solutions for the development of seafloor observatories, and to defining needs and expectations for long-term investigations at abyssal depths [1]. These efforts were followed by many EC-funded projects, aimed at realising and validating seafloor platforms also in deep sea (GEOSTAR, GEOSTAR-2, ASSEM, ORION-GEOSTAR-3) [1-2]. See Table I for the complete list.

4. Benefits for Marine and Earth Sciences

A scientifically powerful component of the observatory concept is the long time-series collection of multiple variables. These multidisciplinary data sets will enable the enhancement of more traditional methods, giving strong benefits to many disciplines, like geophysics, physical oceanography and biology. A unique time reference of all the data sets allows an easy comparison to study possible interrelationship among different processes [2]. Long-term data allow also studying the temporal variability of the processes. Independent parameters have also the strong merit to better validate the scientific meaning of data coming from single sensor, the multidisciplinarity as a key to interpret the monodisciplinarity [4]. Another key issue of the seafloor observatories is to study the Benthic Boundary Layer that constitutes the interface between geosphere, biosphere and hydrosphere [5].

The use of seafloor observatories has also shown the possibility to collect new data, like the seismological ones, also in areas with a good coverage of land-based seismic stations [6]. Thinking to future seafloor networks integrated with the terrestrial stations, this opens a completely different picture of the seismicity distribution that will surely contribute to new geodynamic settings. On the other side, the innovative scientific contribution of an integrated use of seafloor and land recordings to geodynamic models is already well demonstrated [7].

Other intriguing scientific themes, like mutual relations between degassing, salt tectonics and seismicity, can be explored with the systematic use of long-term seafloor observatories [8].

5. Perspectives towards networks

Many committees and programmes have been launched to promote the activities towards "permanent" seafloor networks to be integrated with the terrestrial ones [1].

For instance at International level, the ION committee, affiliated to IUGG, was formed to foster synergies among different disciplines, and to promote international co-operation in the development of critical elements of the seafloor observing systems. In the USA, the NSF established the ORION programme to operate and manage existing and future ocean observing sites, like OOI infrastructure. OOI is an integrated observatory with three elements: 1) a regional cabled network consisting of interconnected sites on the seafloor; 2) relocatable deep-sea buoys that could also be deployed in harsh environments, such as the Southern Ocean; 3) new construction or enhancements to existing facilities leading to an expanded network of coastal observatories. NEPTUNE, the regional cabled component of OOI, is a project to establish a lithospheric-plate scale multidisciplinary observatory network on the Juan de Fuca Plate, located a few hundred kilometres off the US-Canadian west coast [9]. NEPTUNE will include two test sites in Canada (VENUS) and in USA (MARS).

In Japan, the DONET project has been recently funded by the Ministry of Education, Culture, Sports, Science and Technology and mainly performed by JAMSTEC. This project focuses to monitor on seafloor earthquakes, tsunamis and crustal movements related to the activity of plate boundary, improving the observation capability of the Nankai trough [10].

In Europe, the seafloor networks was sponsored by EC initially with the ESONET-CA that promoted activities to develop the multidisciplinary "seafloor segment" of the ESA-EC GMES Programme. These activities were particularly aimed at researches in geo-hazards, global change and biodiversity. In this context one of the most important outcomes was the definition of "key-sites" at which cabled multidisciplinary observatories should be deployed [11]. At several sites several scientific activities have been running for a long time in preparation for cabled

observatories. Among these sites, the one in Eastern Sicily is already operative in real-time, having, at the end of January 2005, connected the NEMO-SN-1 observatory to an electro-optical cable and acquiring data at the shore station (see Fig. 1) [12]. After two years, many activities are running to implement this infrastructure [13].

At present, EC has funded a new on-going project, ESONET-NoE, a network promoting the European underwater ocean observatory system with a major aim at integrating the interested scientific and technological community. The scientific objectives are wide, including: a) Physical Oceanography and Global Change; b) Earth Sciences, geo-hazards and seafloor interface; c) Marine ecosystem; and d) Non-

Figure 1. NEMO-SN-1 real-time seafloor observatory, operative node of ESONET. SN-1 multidisciplinary observatory on the seafloor, image taken from the ROV before the operation of real-time connection [12].

At the end of 2006, the EC published the ESFRI Report that has defined 35 large-scale research infrastructures important for Europe. Among these, one is related to the seafloor network, EMSO (European Multidisciplinary Seafloor Observatory) [15]. Consequently, the EC has launched a call in the frame of FP7 for the preparatory phase of each infrastructure. One of the major aims for the preparatory phase of the EMSO infrastructure is to establish the governance entity serving scientists and stakeholders in and outside Europe for long-term deep-sea observations and investigations.

The sites in which it is foreseen to develop the nodes of the future network are shown in Fig. 2.

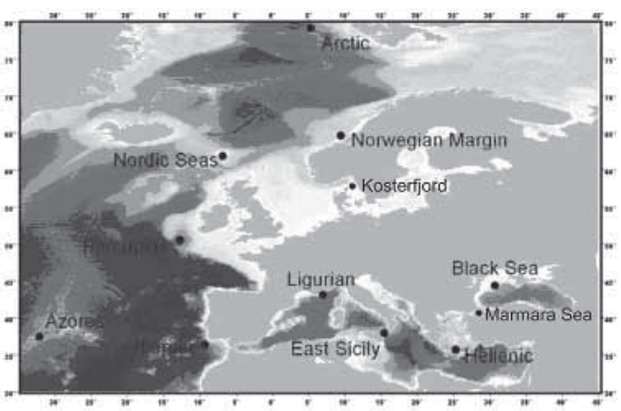

Figure 2. Map of the future nodes of the EMSO infrastructure.

The geographical distribution of all the future cabled seafloor networks at global scale is depicted in Fig. 3.

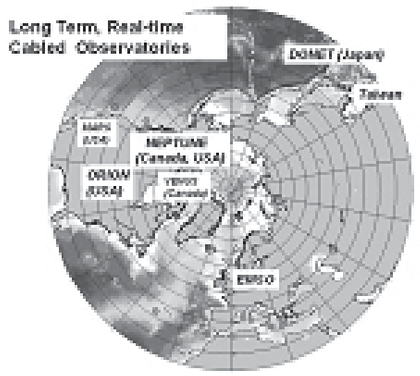

Figure 3. Distribution of the future global cabled seafloor networks.

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