Chapter 20

SN-1 – The first Italian seafloor observatory for seismic monitoring

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Abstract

The Istituto Nazionale di Geofisica and Vulcanologia (INGV) is co-ordinator of an experiment funded in the framework of the 2000-2003 programme of the Gruppo Nazionale di Difesa dai Terremoti. The experiment aims to develop and operate a deep-sea observatory, namely Submarine Network, mainly to address seismic monitoring. The design and realization of SN-1 has been derived from previous European projects also co-ordinated by INGV and funded by the European Commission: GEOSTAR and GEOSTAR 2. These projects realized, tested and operate a European prototype of a benthic multidisciplinary observatory, namely GEOSTAR. The prototype successfully performed a 7-month deep-sea mission in 2000-2001 in the Southern Tyrrhenian Sea, at around 2000 m w.d. SN-1 was deployed in October 2002, at a depth of 2105 m, around 22 km off-shore of the Eastern Sicily coast. The operating status and the data acquisition are presently checked monthly through acoustic communication from the sea surface during surveys on the deployment site. The connection to an existing underwater cable for power supply and real-time communication is foreseen in the near future, leading to the integration of the observatory in the existing monitoring networks. This paper presents the state of the art of SN-1 and the future developments.

Keywords: seafloor observatories, seismology, sea technology.

1 Introduction

Investigations of the Earth’s structure and dynamics take significant advantage of the improvement of the distribution of scientific multidisciplinary
observatories, inadequate in the oceans. Significant efforts in settling long-term monitoring systems on the sea bottom have been undertaken worldwide since the early nineties (e.g., Kasahara et al., [9]; Montagner and Lancelot, [15]). Long-term and real-time experiments are generally multidisciplinary and innovative in implementing new technology for power supply and real-time data transmission. In 1993, a seafloor observatory was deployed off Hatsushima Island by the Japan Marine Science and Technology Centre (JAMSTEC) in order to study the relation among biological, seismic, and volcanic activity along the plate boundaries (Momma et al., [14]). The Hawaii Undersea Geo-Observatory Project (HUGO) was one of the first attempts to integrate the technology of marine electro-optical cables with existing sensor technologies to create a permanent multidisciplinary laboratory on the ocean floor at the summit of Loihi submarine active volcano (Dunnebier, [5]). HUGO had the potential to support experiments from a wide range of disciplines, including submarine vulcanology, biology and geochemistry. This experiment has been considered a pilot project for the more ambitious task of establishing ocean instrumented centres, by means of existing telephone cables. In mid 1998 the Hawaii-2 Observatory (H2O), consisting of a cable termination, a junction box in 5000 m depth of water placed halfway between California and Hawaii, and seismological sensors, was installed taking advantage of redundant commercial submarine telephone cable (Butler et al., [3]). Re-use of submarine cables is also utilized in the VENUS project and the GeO-TOC program mainly devoted to geophysical measurements (Kasahara and Momma, [9]; Kasahara et al., [11, 12]). Most of the above mentioned experiments need the support of Remote Operating Vehicles (ROVs), not only for deployment and connection of devices and sensor packages to cable terminations, but also for the correct installation and operation of the sensors.

In the framework of the Marine Science and Technology (MAST) Programme of the European Commission (EC), feasibility studies have been undertaken since the early nineties to establish the basic technologies needed for a prototype of a deep-sea multidisciplinary observatory that would have overcome the traditional free-lander modules. In particular, DESIBEL (DEep-Sea Intervention on future BEnthic Laboratory) and ABEL (AByssal BEnthic Laboratory) feasibility studies (Thiel et al., [17]; Berta et al., [2]; Rigaud et al., [16]). Between 1995 and 2001 the EC funded the GEOSTAR and GEOSTAR-2 projects for the design and development of an autonomous deep-sea observatory prototype (hereafter referred to as GEOSTAR) for multidisciplinary, long-term monitoring (up to one year). The observatory was conceived both to comprise a wide range of sensors and a platform for external experiments, thus representing the first prototype of a central node of future submarine monitoring networks. For brevity, we omit a detailed description of GEOSTAR and address the interested readers to Beranzoli et al. [1], Clauss and Hoog [4], Favali et al. [6], Gasparoni et al. [7], Iafolla and Nozzoli [8], Marvaldi et al. [13].

SN-1 observatory, developed in the framework of the 2000-2003 programme of the Gruppo Nazionale di Difesa dai Terremoti (GNDT), represents the consolidation of the GEOSTAR experience, being based on the same approach for deployment/recovery procedure and on the technological solutions adopted.
for sensor installation, sensor and devices control and communications. SN-1 was deployed early October, 25 km off-shore from the eastern coast of Sicily at a depth of 2105 m and is presently operating in autonomous mode. The deployment site is close to the Ibleo-Maltese seismogenic structure, considered responsible for most of the disastrous earthquakes of the area.

In the next future SN-1 will be connected to an existing underwater cable deployed in the same area by the Italian National Nuclear Physics Institute (INFN) for an experiment of neutrino detection (NEMO). In this way SN-1 will become the first European cabled seafloor observatory being powered from land and providing data in real-time. This paper deals with the description of the main features of SN-1 and of the deployment and control operations.

2 SN-1 system description

SN-1 sea floor observatory is able to operate down to 4000 m w.d. in autonomous mode for 6-8 months. Being SN-1 derived from GEOSTAR, the technical solutions adopted in previous projects have been straightforwardly transferred to SN-1 design. Like GEOSTAR, SN-1 is based on a two-module scheme: the bottom observatory and MODUS (Mobile Docker for Underwater Science), a vehicle already developed in the GEOSTAR projects. Dimensions, weight and main characteristics of the whole system are given in Table 1. A scheme of the deployment/recovery procedure is shown in Fig. 1.

Table 1: SN-1 technical features.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>(2.9 × 2.9×2.9) m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight in air</td>
<td>~ 1500 kg</td>
</tr>
<tr>
<td>Weight in water</td>
<td>~ 800 kg</td>
</tr>
<tr>
<td>Lithium batteries</td>
<td>~ 2000 Ah (≥ 200 days)</td>
</tr>
<tr>
<td>Power consumption</td>
<td>~ 5.5 W</td>
</tr>
</tbody>
</table>

The bottom observatory is presently equipped with sensors primarily addressed to seismic monitoring but the design takes into account the chance to extend the set of sensor packages in the future. The list of sensors presently mounted on the observatory is given in Table 2. One of the peculiarities of both GEOSTAR and SN-1 is the unique time reference for the different sensors. This provides time-series immediately comparable in the time domain. A water current meter and a CTD have been selected as auxiliary sensors to characterize eventual environment sources of disturbance at the observatory site. Status sensors have also been installed to control operating parameters (e.g., battery level), malfunctioning and events that can put at risk the integrity of the observatory (e.g., water intrusion). The sensors are managed by a central unit, namely the Data Acquisition and Control System (DACS), also mounted on the sea-floor observatory frame, which acquires the measurements, tags them with a unique time reference and transfers onto hard disks. The bottom observatory is
also equipped with a standard acoustic communication system which is used to periodically check the status of the observatory: by means of a surface unit managed by an operator it is possible to retrieve some significant parameters related to the functioning. This additional device has been adopted, as already mentioned, to make possible the connection to the existing underwater electro-optical cable deployed in late summer 2001 by INFN. A special junction box, presently under construction, will also be deployed for a proper interfacing (see Fig. 1).

Figure 1: Scheme of deployment/recovery of SN-1. During the descent the observatory is latched onto MODUS, which is managed from the surface by an operator on board a vessel. After the observatory touches down, MODUS releases the observatory and is recovered on board. During the mission, SN-1 can be acoustically requested to send to the surface information on the status of the sensor packages and of other devices (e.g., batteries, hard disks). During the recovery phase MODUS localizes the observatory to a range of a few hundred metres, by means of sonar which approaches the observatory and latches onto it prior to starting the ascent. The picture also shows the existing INFN underwater cable and the junction box, presently under construction, which will allow the connection of the observatory to land for the power supply and the real-time data transmission.

MODUS is the dedicated tool used to deploy and recover the observatory. This tool is a simplified Remote Operating Vehicle and is equipped with thrusters, a type of propeller-engines able to move heavy loads horizontally and vertically. The vehicle is driven by an operator on board a vessel through an
electro-optical cable and together with the cable constitutes the primary means of communication between the observatory and the surface operator who can control the status of the different sensors and devices. Video-images acquired by means of cameras installed on MODUS’s frame also help to deploy the observatory on a smooth sea bottom.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sampling rate</th>
</tr>
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<tbody>
<tr>
<td>Three-component broad-band seismometer</td>
<td>100 Hz</td>
</tr>
<tr>
<td>Gravity meter</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Hydrophone</td>
<td>80 Hz</td>
</tr>
<tr>
<td>Three-component single point current-meter</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Conductivity, Temperature and Depth (pressure) sensor (CTD)</td>
<td>1.6×10⁻³ Hz</td>
</tr>
</tbody>
</table>

### 3 Deployment operations of SN-1

The deployment area is, as mentioned above, within the Ibleo-Maltese escarpment area, the most important seismogenic structure of the western Ionian Sea. The location site (37° 26,53312′ N, 15° 23,58716′ E, 2105 m w.d., 25 km offshore from the city of Catania) has been selected after a bathymetric survey implemented with side scan and CIRP. The results of the operation were made available in the framework of another GNDT project co-ordinated by Istituto per la Geologia Marina of the Italian CNR.

The logistics for the deployment operation requires the fulfilment of the following constraints:

- a navigation system (e.g., NavPro) to reach the deployment site and maintain the position during the operations;
- a dGPS to define the co-ordinate of the deployment site;
- a winch-cable system for MODUS management;
- suitable deck to locate the complete SN-1 system, the winch-cable system and the auxiliary materials;
- a mechanical system (e.g., a crane) able to move SN-1 outboard;
- 80 kW/h power supply generator for winch and MODUS;
- radio-receivers for personnel on board to co-ordinate the work of captain, winch driver and MODUS operators.

Specific inspections of vessels to verify the fulfilment of the previous requirements have led to the selection of a moto-pontoon, namely “Mazzarò”, of
the Gestione Pontoni s.r.l. In Fig. 2 the first deployment manoeuvres executed to immerse SN-1 in water are shown. Once the SN-1 system is in water MODUS takes the full load of it and lowering toward the sea floor begins. The status of SN-1 till the landing can then be controlled by means of the vessel sonar echo signal and MODUS telemetry providing altimeter measurements, status parameters and video images. When settled on the sea bed, MODUS turns on all the sensor packages and devices, and after a check of the regular functioning, starts the acquisition of the geophysical and environmental measurements. After the check of the regularity of the acquisition process, MODUS releases SN-1 and is recovered on board. The operation made by means of the MODUS telemetry system can also be performed through the acoustic communication system, which represents a useful back-up arrangement.

Figure 2: First operations for SN-1 deployment: SN-1 is uplifted by the crane of the moto-pontoon and put outboard (a, b, c). Then the crane is lowered in a horizontal position and the observatory is immersed (d).

4 Periodical checks of SN-1 functionality

Unlike GEOSTAR, SN-1 does not take advantage of a surface buoy for status parameter retrieval and data communications. However, SN-1 offers the chance to periodically check the status of the observatory from a vessel: the surface
operator sends commands to the ocean bottom observatory by means of an
telemetry system making use of a surface acoustic device connected to a
dedicated portable PC (Fig. 3). The observatory replies by sending back the
values of status and sensor parameters. These values appear to the operator on
the screen of the PC as in Fig. 3. Some of the more significant parameters related
to the correct operation of the observatory are the internal temperatures of the
vessels hosting the electronics, the available bytes of the hard disks, the
subidence and tilt of the frame. Commands to change the mission configuration
parameters (e.g., the mission duration), the configuration parameter of the
sensors (e.g., sampling rate) are possible. Switching on/off sensors or
definitely stopping the mission is also allowed through the acoustics.
Periodical checks have been performed in December 2002, and January and
March 2003. During the checks the status and scientific sensor parameters were
retrieved and displayed on the portable PC screen; an example is given in Fig. 4.
In particular, this check has revealed abrupt increment of the hard disk used
space especially with seismometer and hydrophone data in coincidence with
seismic events occurring locally.

![Figure 3: Acoustic system: a) acoustic surface transducer; b) operator at the
surface acoustic unit and portable PC for parameter retrieval.](image)

5 Conclusions

SN-1 has been deployed in October 2002 at 2105 m w.d. 25 km offshore from
the Eastern coast of Sicily for a long-term mission of 5-6 months. The
deployment operations have been successfully performed by means of a vessel of
standard type. The periodic checks have not revealed any functioning anomaly.
The increase of the used memory of the hard disk has been evidenced in the
period of occurrence of regional and local earthquakes. After the first long-term
mission the observatory will be connected to an underwater cable of INFN by
means of a junction box presently in development. In this way the observatory
will be powered from on land and will provide real-time data. This connection
will make SN-1 the first European seafloor real-time observatory.
Figure 4: The status parameters displayed on the PC: the parameter value refers to the 5 December 2002 (8:00 a.m.) check.

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References


