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# Design of an automatic multiple launcher for expendable probes

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## Abstract

A main goal of a ships of opportunity program is the provision of near real time temperature profiles. The use of expandable probes allows the reduction of costs, in comparison to usual scientific cruises. A major cost effectiveness can be achieved by using an automated multiple launcher, that can be used with a minimum personnel effort. A multiple launcher, developed in the framework of the Mediterranean Forecasting System – Toward Environmental Prediction, allows to collect eight temperature profiles, with a sampling strategy that can be monitored automatically by means of a software. The data acquisition system is controlled internally in all functionalities, and data can be transmitted by GSM or satellite telephone systems.

## 1 Introduction

A Ships Of Opportunity Program (SOOP) was established in the Mediterranean in September 1999, on behalf of the EC funded project Mediterranean Forecasting System – Pilot Project (MFS-PP, Pinardi et al., 2003). Temperature-XBT profiles were collected along six transects crossing the Western and the Eastern basins from North to South and one transect crossing the whole sea from East to West. These transects were designed to specify, in each of the sub-basins (the Algero-Provençal, the Tyrrhenian, the south Adriatic, the Ionian and the Levantine), the variability of the main circulation features (Özsoy et al., 1991;1993; POEM Group, 1992; Hecht and Gertman, 2001, Fusco et al, 2003; Millot and Taupier-Letage, 2005; Zodiatis et al., 2005).

The initial aim of the study was the continuous and regular sampling of the Mediterranean upper thermal structure using XBT measurements. This included also the development of quality criteria for data collection and management, and the improvement of near real time data exchange capabilities. The technology was the same as that used in the international SOOP program (Smith et al., 2000): Sippican XBTs for data acquisition and ARGOS for data transmission. The temperature profiles were subsampled by the ARGOS software, and coded for transmission on the GTS (Global Telecommunications System) in the BATHY format (AODC, 1999; AODC 2001; Cook and Sy, 2001, Manzella et al., 2003).

During the years, the data collection strategy (including sampling design, technologies for data collection and transmission) was tested and implemented, as well as the near-real time (NRT) data management (including NRT QC, and data access). Data transmission was achieved using a normal GSM phone/modem for Internet connection. The edf – full resolution Sippican files were compressed and sent attached to an e-mail. This simple improvement was made possible by the GSM coverage available in the Mediterranean region. Transmitting the full resolution profiles required to change the quality control (QC) procedures. The software developed was based on Medar-Medatlas protocols (MedAtlas Group, 1994) and contained all the steps of the delayed mode quality control: gross range check, position control, elimination of spikes, re-sampling at 1-m interval, Gaussian smoothing, general malfunction control, comparison with climatology. Two visual checks were added at the beginning and at the end of the QC procedure, in order to detect the end of a given profile and look at the overall consistency of the profiles (Manzella et al., 2003).

The cost of the observations performed through ships of opportunity and XBT is relatively high (although less than the costs of research cruises), and is not sustainable by a research community. However, some technological implementations could make a SOOP more cost effective. This can be achieved by the selection of tracks, the development of multi-parametric observation systems and the development of automated data collection systems. The main requirements of the SOOP were defined in MFS-PP. An ideal sampling program is based on four goals:

- provide repetitive measurements along transects from coast to coast,
- the transects must cross significant dynamical features of the circulation,
- the sampling distance should resolve, as well as possible, the mesoscale,

- the technologies for data collection must be robust and simple, to be used on ships of opportunity, also by ship personnel.

Automated systems have been developed in Japan and USA. For example, the TSKA AL-12 multiple launcher can be loaded with 12 XBT probes that can be launched following some established criteria. The launcher has to be linked to a personal computer and Sippican data acquisition card. The TSKA is formed by revolving tubes, that are positioned in the launching position by an electric engine. It was used at the end of MFS-PP, with the launching system managed by a software allowing the selection of the probe type and the launch at defined sampling intervals. The conclusion was that the machine is robust to all weather conditions and reliable, but is hard to handle, heavy and needs continuous surveillance.

On the basis provided by this experience, two possible options were hypothesized for the development of a multiple launcher:

- a series of tubes revolving in circular
- a series of tubes along one or two lines

The second solution was selected, since it was minimising the number of elements in movements.

This paper presents some background information on technology used in SOOP and the development of a multiple launcher.

## 2 The Expendable Bathy-Thermographs (XBT)

An XBT probe has the shape of a small missile, contained in a cylindrical plastic canister. A precision NTC thermistor is enclosed in the zinc nose, while the copper wire assuring the connection to the measuring system is contained in two spools, one in the plastic body of the probe and the other one in the canister that also hosts on its back the electrical connections towards the data acquisition system

When the XBT is launched, it falls down into the sea and the wire in the probe starts dereeling. The wire dereels also from a spool within the probe canister, compensating the movement of the ship and allowing the probe to freefall from the sea surface. The system uses the water as a ground connection: when the electrode within the nose of the probe makes contact with the water, the circuit is closed and the value of voltage is telemetered to the shipboard data processing equipment. When the probe reaches the desired depth, or the wire breaks (on ship-side or on probe-side), the profile is completed and the system can be prepared for another launch. The nominal accuracy of the thermistor is ±0.1°C. The depth is estimated as a function of time using the formula developed by the manufacturer $Z(t)=At-Bt^2$.

## 3 Standard instrumental apparatus in MFS-TEP

The standard acquisition system consists of a hand launcher (LM-3A), a read-out MK21 (or MK12) card installed in a PC with ISA slot, and an interface box.

The LM-3A launcher provides portability, allows the selection of the launch position, and reduces the interference due to the electrical apparatus on the ship. The ISA card can be upgraded to USB with the addition of a particular kit. MK21 uses DSP technology for onboard processing and buffered I/O for operation with operating system such as Windows 98, Win2000, ME, and XP. Data collection is controlled by the MK21 and the buffered I/O stores the data until it can be read in by the operating system. MK21 has a flash memory for in-system programming to give users the flexibility to add newly developed probe capability and firmware upgrades. The computer performs system diagnostics and pre-launch tests, and indicates that the probe is ready for launch. It receives probe data during the probe descent, displays and stores them. Data are translated in ASCI text format. The MK21 Windows Software has auto GPS (NMEA 0813) input capability, selectable IGOSS and other fall rate coefficients, and post-processing options. The sampling rate is 10 Hz, which implies a vertical resolution of about 65 cm, an overall temperature accuracy of ±0.2°C, and a temperature resolution of ±0.01°C.

The launcher is connected to the MK21 card through a connection box, where the system ground is connected to the seawater ground from a lug on the outside of the box to some metal part of the hull of the ship. The seawater ground has to be electrically clean and as pure as possible. The connection should be protected from corrosion and vibration, and its resistance should measure less than 100 Ohm from the connection box to the seawater. The radio-transmission can produce hard interference with the data acquisition and may interrupt the XBT data, which will cause large spikes and noise on the recorded sequence of resistance values. Other troubles may occur when wind or occasional random movement induces a contact between the wire and the hull: in this case large spikes appear.

The XBT voltage readings were converted to temperatures through several steps. First, a Sippican XBT Controller transmitted hexadecimal voltage values (representing XBT thermistor measurements) to a shipboard PC. Second, the XBT program converted those hexadecimal voltage equivalents into resistance, and then into temperature (˚C), in the following manner:

1. Convert hexadecimal value into decimal value.
2. Convert decimal value to (V) voltage (i.e., V=10.0×decimal value/4096) (volts).
3. Convert (V) voltage into (R) resistance measured in ohms (i.e., R=18094–1490.1×V) (ohms).
4. Convert (R) resistance into (T) temperature measured in ˚C (i.e., $T=-273.15+\{1/[A+(B^*\ln R)+C^*(\ln R)^3)]\}$, where: $A=1.29502^*10^{-3}$, $B=2.34546^*10^{-4}$, and $C=9.9434^*10^{-8}$).

Steinhart and Hart (1968) first proposed such a logarithmic equation, which is an empirical expression that has been recognised to be the best mathematical expression for resistance-temperature relationship of NTC thermistors and probe and assemblies. The constants were determined empirically from laboratory tests of XBT thermistors (Georgi et al., 1980).

## 4 The new system

The new system is an integrated set of mechanical and electronic hardware and software programs giving the user the maximum of flexibility

### 4.1 The mechanical hardware

Heart of the system is a launch tube, built in AISI 316 steel, in which the probe is fitted with its envelope. An upper cap, holding the electrical connections of the probe, closes the launch tube; opening the lower door the probe is released and falls into seawater.

Two pneumatic cylinders control the door: a small one keeps it closed, a bigger one moves it. In the actual MFS-VOS design, the system assembles on a frame eight launch tubes with their pneumatic actuators; two watertight boxes host respectively the electro-pneumatic valves feeding the cylinders and the computerized control system (Fig. 1).

### 4.2 The control computer hardware and software

#### 4.2.1 The electronic hardware

All operations are coordinated by an industrial grade computer, based on IEEE 696 compliant boards, interfaced with GPS, data acquisition and communication devices. Both analog and digital interfaces are available to collect data coming from the most various devices (passive and active expendable probes, meteo sensors...).

Remote communications are performed using a GPRS modem with an embedded TCP-IP stack; a serial port is available to connect other communication devices (e.g. satellite modems), but also other communications systems could be used (e.g. satellite phones).

A balanced source circuit (Fig. 2) was designed to interface standard passive temperature probes with 12 or 16 bit Analog to Digital Converters.

Two equal currents are injected in both the wires coming from the probe and the potentials VA and VB are measured; the circuit is closed by the sea water; the switch SW1 (a relay contact) allows to test the continuity of the probe circuit before the launch.

To avoid any perturbation to the measurement, a multiple stage amplifier was used to adapt the signal coming from the probe to the need of the ADC; the circuit was built using high quality precision instrumentation amplifier ICs. The first stage uses unity gain configuration, having high input and low output impedance; the second stage is a differential amplifier with gain=2; the third stage is a low output impedance low-pass filter with gain=1 and ft=40 Hz. Ten times a second, the mean of 16 ($V_B$-$V_A$) measurements is calculated; the resistance of the thermistor is obtained using Ohm's law, or, better, using the regression coefficients obtained after calibration of the circuit against a set of standard high precision resistors. The measured temperature is finally obtained using the standard formula by Steinhart and Hart (1968)

### 4.2.2 The software

Two software sets were developed, able to manage 96 launch events.

Launch options are:

- northern than a defined latitude
- southern than a defined latitude
- eastern than a defined longitude
- western than a defined longitude
- far from a previous station
- at GPS time
- at PC time

Collected data are locally stored and can be transmitted as e-mails. A local control program was written in Microsoft Compiled Basic v. 7.1 with routines in Assembly Language, running in Datalight DOS environment. This program, executed on the launcher control computer is able to control all the launcher functions, i.e. real time and position acquisition, comparison against set points-times, launch, data acquisition and transmission, ancillary functions.

Every hour, a "sequence manager" starts a macro-command sequence, that can be different for each time and is remotely reprogrammable; new releases of the software and of the sequences are uploadable to the station without suspending its normal activity. The macro-commands enable to manage the data acquisition and transmission, the mission programming, the station hardware and the measuring instruments.

The entire system can be connected to a computer (local laptop or remote desktop), using a remote control program, written in Microsoft Visual Basic, running in Windows environment. This program enables to set up all the launcher functionalities, transfer files to and from the launcher, and, if needed, to take control of all the launcher operations, including the time-position acquisition and comparison.

## 5 Conclusions

The development of a multiple launcher improves the cost effectiveness of an operational observing system. Compared to the existing hand launcher system, the improvement is evident. The multiple launcher allows to automatically launch a certain number of XBTs without human intervention. With respect to the other multiple launcher tested before, the TSKA, the one developed in this project is lighter, and has a minor amount of electric or mechanic components, that makes the reliability of the entire system higher. Another advantage of this multiple launcher is the capability to be remotely managed, although this facility was not yet tested. The automatic multiple launcher was tested in laboratory and during a short cruise on ship of the Italian Hydrographic Institute. The first results obtained confirm the instrument reliability and open to further developments.

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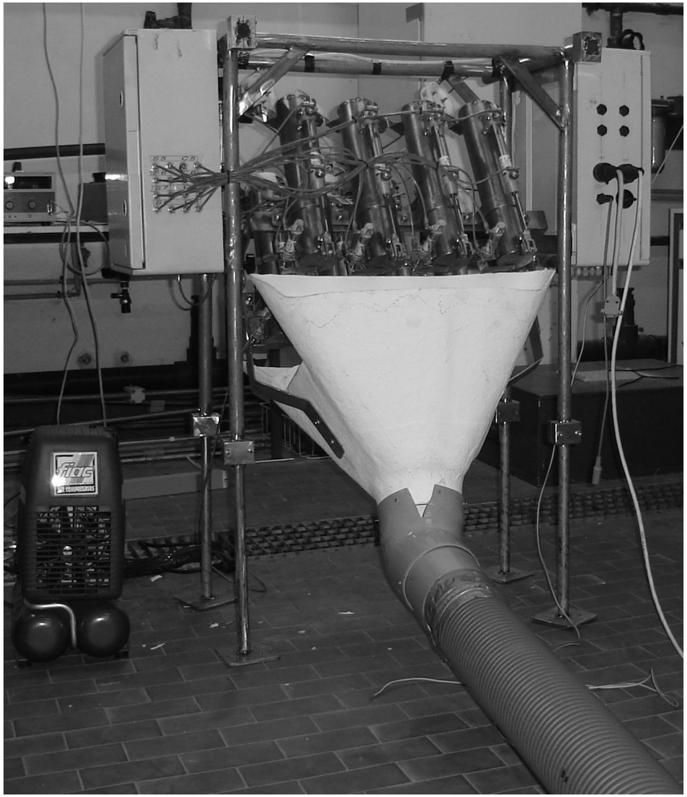

**Fig. 1.** The multiple launcher with the electro-valves box (left) and the electronics box (right), on the floor the air compressor (left) and the red pipe connected to the funnel to drive probes outboard.

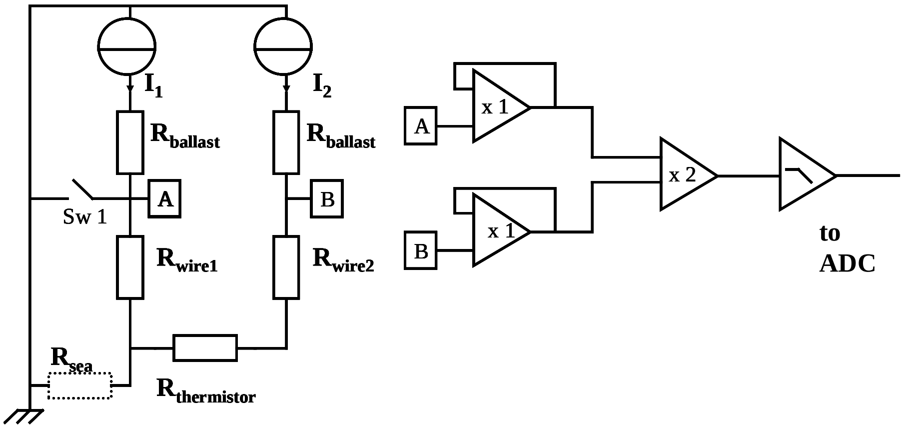

**Fig. 2.** The schematics of the probe interface board.