BOLLETTINO DI GEOFISICA TEORICA ED APPLICATA VOL. 44, N. 1, PP. 59-67; MARCH 2003

Overview of the SACLANTCEN family of trawl-resistant ADCP: evolution from self-recording to real-time profiler configuration

S. FIORAVANTI, F. DE STROBEL, V. GRANDI, L. GUALDESI, R. TYCE and A. CARTA

SACLANT Undersea Research Centre, La Spezia, Italy

(Received, January 2, 2003; accepted March 5, 2003)

Abstract - Recently there has been an increased demand for shallow-water current measurements, as a result of both military and environmental interest in littoral water activity. This has accelerated the technological evolution of Acoustic Doppler Current Profilers (ADCP) and has broadened the market. Long term (several months) deployments of ADCPs in heavily fished coastal waters are now relatively common. This paper describes the work conducted at SACLANT Undersea Research Centre (SACLANTCEN) since the 90s, in the field of trawl-safe ADCP platforms. This includes both the enhanced Barny Sentinel model developed at SACLANTCEN in collaboration with the US Naval Research Laboratory, Stennis Space Centre, and its more recent evolution into a Shallow-water Environmental Profiler in Trawl-safe Real-time configuration (SEPTR). All these platforms have a design that allows recovery by releasing the ballast, even if the platform is overturned as a result of trawling. Several of these units have been successfully deployed for two periods of nearly one year in total, by NRL in the Korea Strait, an area of intense fishing activity. The SEPTR system is a further evolution of the Barny Sentinel ADCP bottom platform, in that it adds an automated water column profiler, additional sensors, and two-way communication at regular intervals. It is intended for 3-6 month deployments in areas where water column instruments are at risk from fishing trawlers, but with real-time data return and control via two-way satellite communication. SEPTR includes a micro-controller based bottom platform which houses an ADCP, wave/tide gauge, ambient noise sensor array, and water column profiler buoy system. The profiler performs autonomous vertical profiling of CTD within the water column at depths down to 100 m. Recovery of the entire system is accomplished through either radio or acoustic communication

---

Corresponding author: S. Fioravanti, SACLANT Undersea Research Centre, Viale San Bartolomeo, 400, 19138 La Spezia, Italy; phone: +39 0187527384, fax: +39 0187527344; e-mail: steve@saclant.nato.int

with the profiler in order to release a messenger buoy. Two-way communication of data, position and control allows profile results to be returned in near-real time, and operational commands together with profile schedules to be sent to multiple profiler instruments. Project status and future plans are presented.

1. The BARNY family

The BARNY family of Acoustic Doppler Current Profilers (ADCP) bottom mounted platforms is the result of work initiated in 1992 by SACLANTCEN. The goal of the project was the design of a recoverable bottom mounted platform to perform ADCP measurements offering trawler safe design, with weight and size appropriate to small vessels, and pop-up recovery capabilities with a cost compatible with the sensors.

Fig. 1 - BARNY system recovery pop-up.

The first realization was the BARNY system described in de Strobel and Gualdesi (1997). It was a trawler-safe platform with recovery pop-up but without the overturned capability. The BARNY went through intensive experimentation for 5 years at a number of locations: La Spezia and Formiche di Grosseto Islands, Strait of Istanbul, Sicily Channel, Greek-Ionian coast (Kiparissa Bay), Atlantic-Spanish coast (Cadiz Bay).

By using the lesson learned with the BARNY system, the platform has been intensively redesigned. The BARNY Sentinel platform, described in detail in Perkins et al. (2000), consists of a trawl-safe structure with an ADCP at the center of a fiberglass housing which contains the acoustic releases, surrounded by a heavy cement ballast ring. Fig. 2 shows a sequence of photographs as a BARNY Sentinel platform is deployed and put into operation.

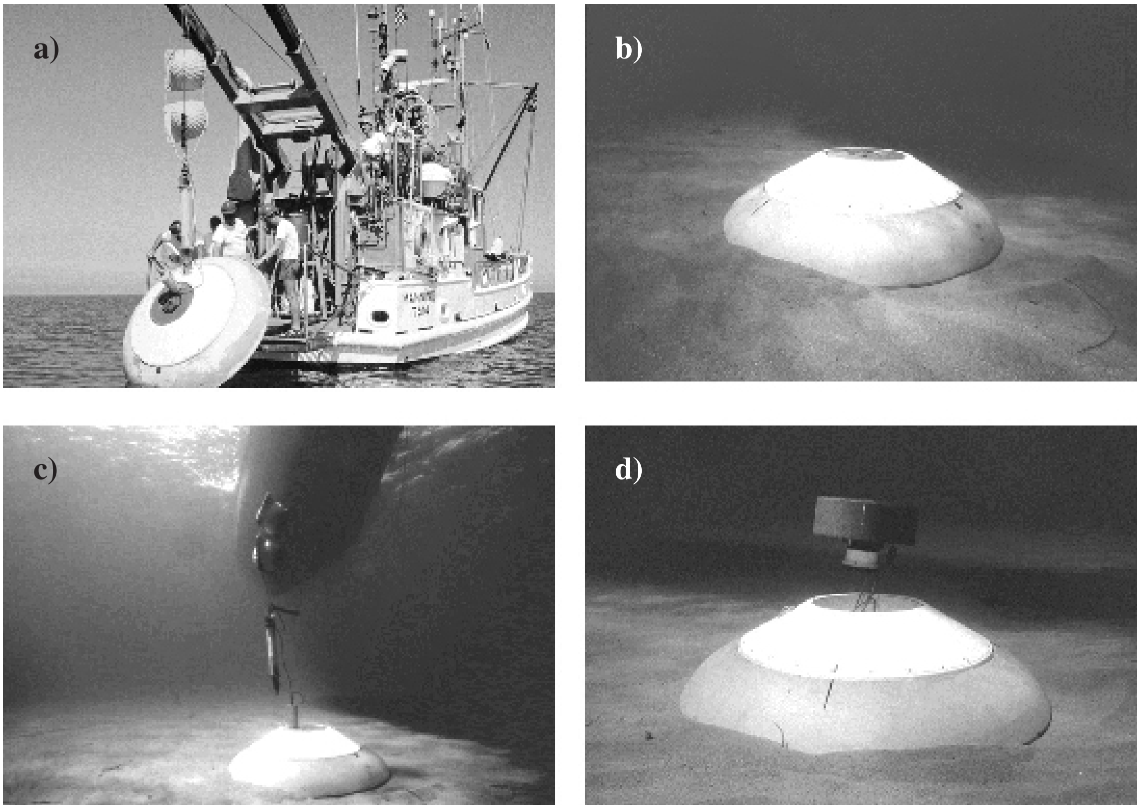

Fig. 2 - Barny Sentinel: (a) deployment; (b) position verification; (c) in operation; (d) standard recovery.

The unit is lowered by electromechanical cable. Through the cable, real-time information regarding instrument pitch, roll, and depth is passed from the sending unit (white cylinder near the ADCP transducers) to a PC-based display on the ship.

Once satisfactory placement on the bottom is confirmed the external release is activated and is retrieved together with the sending unit. An outer ring of reinforced cement provides impact resistance and ballast. The overall smooth profile minimizes the risk of being fouled by fishing gear. In Fig. 2d, the acoustic release that controls the pop-up float has been activated and the float, with the ADCP and recovery line, is rising to the surface.

A second backup acoustic release allows the platform to shed its ballast weight and float to the surface even if the platform is inverted as shown by the sequence of images in Fig. 3. If the pop-up recovery mode fails, firing the second internal release drops the ballast ring (Fig. 3a), as has been done a few seconds before the first photo. A trail of sediment marks the ascent. The loop of the line is incidental to the test procedure. In the second photo, the ballast ring has been dropped with the BARNY upside-down (Fig. 3b). The main housing rights itself after a few meters of ascent, as it has already begun to do in Fig. 3c.

This new system has some major advantages compared to the old one. Firstly, the pop-up buoy brings the ADCP to the surface, which is the most expensive part of the system. Secondly, there are two independent release mechanisms that greatly improve the reliability of the recovery operations, ensuring the platform can be recovered even when overturned.

Fig. 3 - BARNY Sentinel emergency recovery: (a) fire of second releaser; (b) platform inverted; (c) fire of second releaser with platform inverted.

During the last year the BARNY sentinel has been extensively used in several experiments and has proved its reliability even in harsh conditions or in areas with intensive fishing activities.

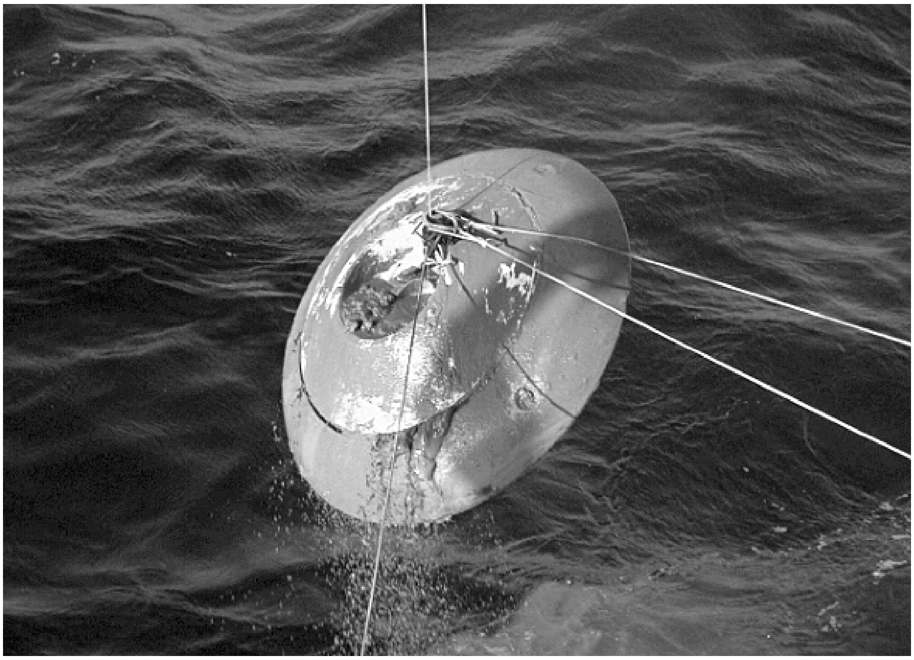

Fig. 4 - BARNY Sentinel, recovery after 6 months in the Yellow Sea (Korea) (picture by courtesy of H. Perkins, Stennis Space Center).

3. The real time evolution: SEPTR

Recent years have seen the development of a number of autonomous profilers to improve our ability to remotely observe the ocean as shown in several papers (Davis et al. 1991; Downing et al. 1992; McCoy 1994).

Since 1997 a design team consisting of engineers from the SACLANTCEN, from the University of Rhode Island Department of Ocean Engineering (URI), and from Italian industry has been working to develop new water column profilers to assist in ocean environmental observations. The first design was for a Shallow Water Expendable Environmental Profiler (SWEEP) for rapid environmental assessment as shown in Tyce et al. (1998, 1999).

In June 1999 a Project Plan was prepared for development of Shallow water Environmental Profiler in Trawl-safe Real-time configuration (SEPTR) at SACLANTCEN in support of ocean modeling and environmental assessment work with the capabilities summarized in Table 1 and the following operational requirements: deployment / recovery compatible with SACLANTCEN BARNY Sentinel system; trawl-safe bottom mooring; backup ballast release via acoustic command, with normal or inverted recovery.

Table 1 - SEPTR operational requirements: grayed values are features currently not yet implemented.

Function	Range		Resolution		Accuracy		Units
	Required	Desired	Required	Desired	Required	Desired	
Pressure	0- 10		0.01	0.003	0.02	0.01	Bars
Depth	1-100		0.1	0.03	0.2	0.1	m
Temperature	0- 40		0.02	0.0005	0.02	0.003	degrees C
Conductivity	0- 60		0.02	0.001	0.05	0.003	mS/cm
Current speed	0-100		10		10		cm/s
Current Direction	0-360		2		5		degrees
Noise Intensity	50-150		1		3		dB/uPa/Hz
Noise Direction		0-360		1		5	degrees
ADCP profiles		0-100 m		1 hr		5.14 cm/s	
Swell Magnitude	0- 20		0.1		0.5		m
Tide magnitude	0- 20		0.1		0.5		m
Vehicle Buoyancy	x		x		x		from CTD
Communication	Coastal	Global	2.4 up	15 up	4.8 dwn	15 dwn	kbaud
Light attenuation	0-100		1		1		%/m
Solar irradiance		1- 10^5		0.1%		0.2%	uW/scm/nm
Wave height		0- 20		0.1		0.5	m
Wave Direction		0-360		1		5	degrees

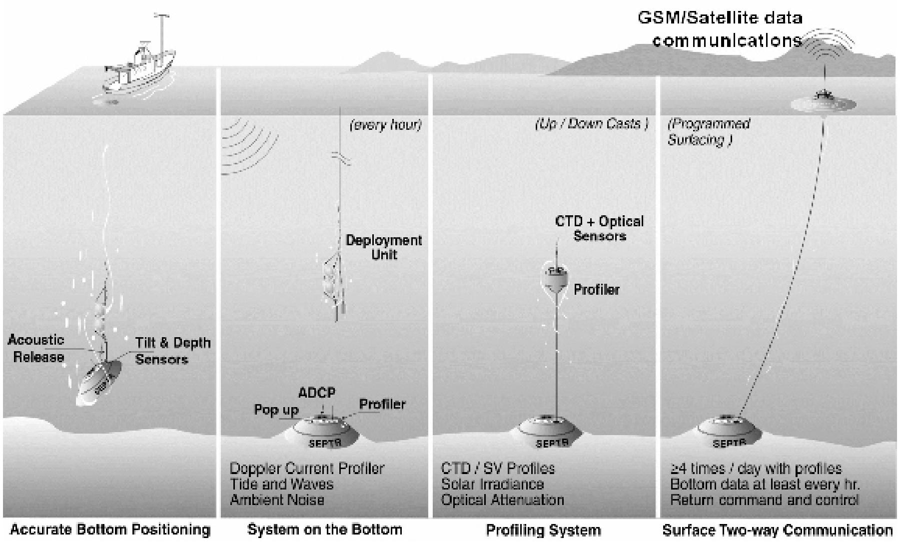

Fig. 5 - SEPTR operational scenario: deployment and operations.

The operational scenario for SEPTR is detailed in Fig. 5. The platform is lowered to the bottom by a surface ship, and released via acoustic command after monitoring depth and tilt of the platform. At least once an hour, measurements of Doppler current profiles, tides and waves, and ambient noise are made. Every 4-6 hours a profile of water column properties is made by the profiler buoy, which stops at the surface to communicate data ashore, and to collect any new instructions, via GSM cellular or satellite communication.

The SEPTR development reuses much of the technology developed for the BARNY Sentinel trawl-safe ADCP platform, and the SWEEP environmental profiler buoy.

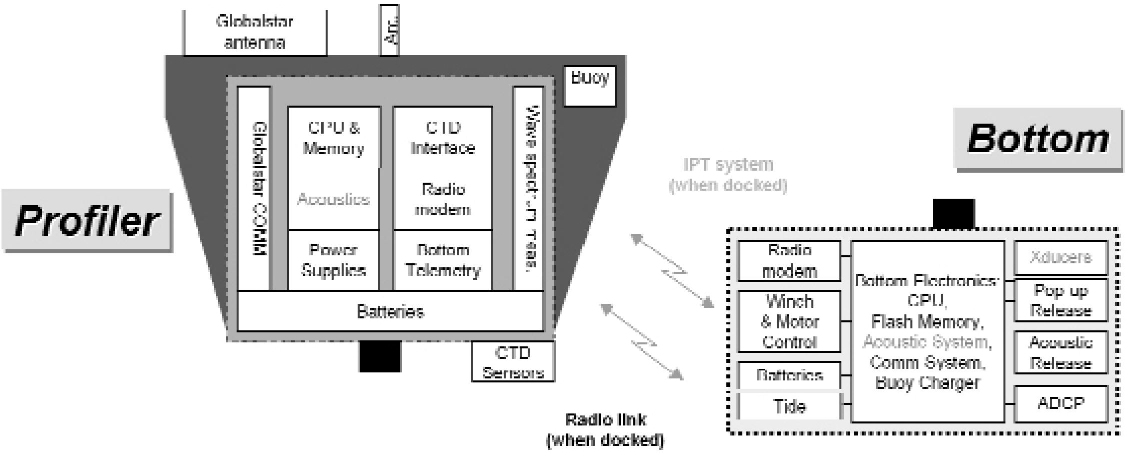

Fig. 6 - SEPTR block diagram: profiler and bottom subsystems.

For SEPTR, a smaller, independent pop-up float is used, housed together with the ADCP and profiler buoy in the same space reserved for the central BARNY Sentinel recovery buoy. This results in the rest of the BARNY Sentinel platform design requiring only a few changes for the SEPTR design. Fig. 6 shows a block diagram for the SEPTR platform.

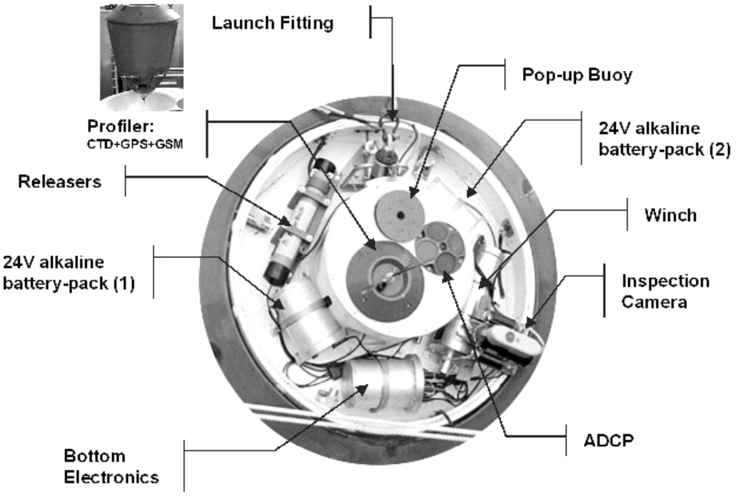

Fig. 7 - SEPTR components: an open view of the system showing the internal components.

The buoy electronics is housed in a 20-cm diameter cylinder (see Fig. 7), but makes use of most of the same 10-cm diameter electronics boards used by the SWEEP profiler by mounting them back to back on a mother board. Unlike the SWEEP profiler, which is completely self contained, the SEPTR has an added battery, winch, electronics and sensor subsystems housed in the bottom trawl-safe housing, which includes an electronics enclosure similar to that in the profiler buoy. The added capabilities of the SEPTR permit real-time reporting of ADCP and tide/wave gauge data together with all the SWEEP water column profiler data. Complete data are also stored on board the SEPTR platform.

3. Testing

The initial SEPTR design has been reviewed as a result of several experiments. Many weak points have been identified in the design during the first complete test performed in April 2000 e.g. e/m cable, magnetic limit switches interfering with ADCP compass, cable shock-absorber and accumulator, long-term sensors behaviour, rechargeable battery capacity, worldwide data communication. Among the listed problems, the e/m cable appeared to be the most serious obstacle to the completion of the SEPTR project. Many different off-the-shelf cables were tested without obtaining improved results. The possibility of a special cable was also considered. However, the dimensional constraints imposed on the cable by the SEPTR mechanics are such as to make the cable design very complex if not completely impossible.

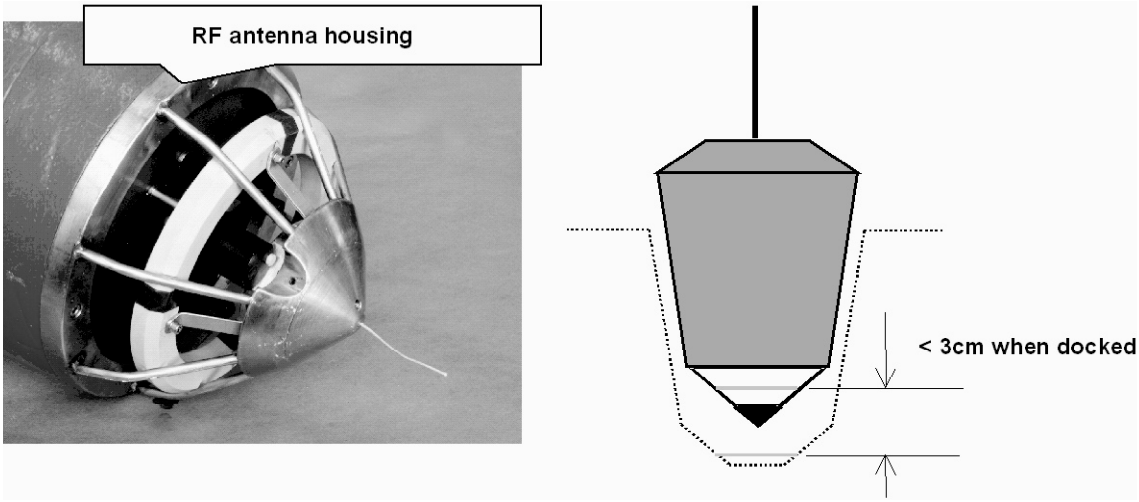

Fig. 8 - RF underwater data link. Communications are provided when the profiler is docked.

As a result, in the revised design the e/m cable has been substituted with a dyniema mechanical cable and communications between the two units implemented with a new RF underwater data link, described in detail in Grandi et al. (2002), which operates with the profiler in the docking position (see Fig. 8) as range is limited to a few centimeters.

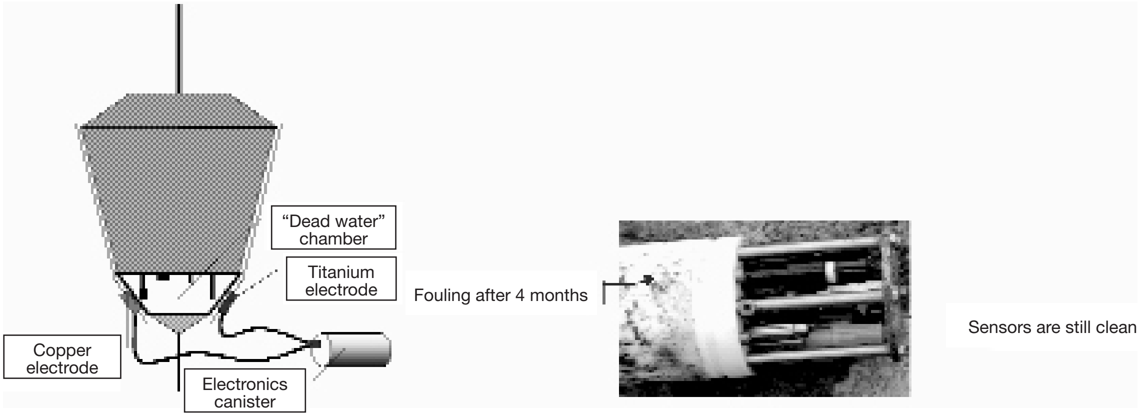

Fig. 9 - SEPTR antifouling system: drawings and test results after 4 month in the sea.

In addition to the new cable, the redesigned platform has the following major improvements. A worldwide satellite communications capability provided by a Globalstar modem (see Griffith et al., 1996), an antifouling system for CTD sensors (see Fig. 9) based on a device developed by Idronaut, improved battery capacity and recharging capabilities (NiMH), and finally underwater mechanical limit switches.

5. Conclusions and the way ahead

Field tests have proved the concept of a deployable/recoverable bottom-mounted platform that can provide real time ADCP/CTD data. Many important technological issues have been solved (world wide real time communications via Globalstar/GSM, batteries, biofouling, deployment and recovery, etc), but still some unresolved problems exist, especially regarding trawl safety. The profiler unit is still delicate and can be damaged by fishing activities especially when undocked; possible solutions could be the redesign of the external shell and to add intelligence to the unit to detect human activities.

During the next two years the SEPTR will be submitted to a critical design review to solve those problems. A project plan has been prepared that will lead to a final design and production at the beginning of 2005.

In the first stage the mechanics will be reviewed and redesigned to be more robust against fishing activities. The actual recovery mechanism will be replaced by a solution that will avoid the use of the concrete ballast ring by using two independent pop-up buoys. Both of them will be effective if the SEPTR is upside-down, as they will be able to bring a recovery line, even with the platform inverted to the surface. The new structure will allow more space for the electronics, batteries and sensors in the bottom unit, and will allow the redesigning of the profiler buoy in order to provide more protection against external devices (GSM/satellite antenna, optical sensors, etc.).

In addition, we are working on the possibility of adding new sensors (i.e., acoustical and optical ones) to provide new measurements. We are planning to mount hydrophones on the top of the bottom platform to measure ambient noise, and to house a simple optical sensor in the profiler, in order to measure the light attenuation coefficient in the water column.

During the second phase, the redesigned platform will undergo several tests to increase the reliability of this system that will be involved in several experiments both in the Mediterranean Sea and in the Gulf of Mexico.

References

Davis R.E., Webb D.C., Regier L.A. and Dufour J.; 1991: *The Autonomous Lagrangian Circulation Explorer (ALACE)*. J. Atmospheric and Oceanic Technology, **9**, 264-285.

de Strobel F. and Gualdesi L.; 1997: *'Barny': A trawler safe, bottom mounted, ADCP platform for Mediterranean, long term coastal water applications*. J. Marine Environmental Engineering, **4**, 175-187.

Downing J., De Roos B.G. and McCoy K.; 1992: *An autonomous expendable conductivity, temperature, depth profiler for ocean data collection*. In: Proc. of Oceans 1992 IEEE, **1**, pp. 672-677.

Grandi V., Carta A., Fioravanti S., Tyce R., de Strobel F. and Gualdesi L.; 2002: *A low-cost short-range underwater UHF radio data link for underwater oceanographic buoy.* In: Proc. of Oceanology International 2002, March 2002, Brighton, UK.

Griffith P.C., Potts D.C. and Morgan S.L.; 1996: *Low-Earth-Orbit satellite systems in ocean science*. In: Proc. of Oceans '96 MTS/IEEE, **1**, pp. 277-281.

McCoy K.; 1994: *The Autonomous Profiling Vehicle*. In: Proc. of Oceans 1994 IEEE, **1**, pp. 419-423.

Perkins H., de Strobel F., Gualdesi L.; 2000: *The barny sentinel trawl-resistant ADCP bottom mount: design, testing, and application*. IEEE Journal of Oceanic Engineering, **25**, pp. 430-436.

Tyce R., de Strobel F., Grandi V. and Gualdesi L.; 1998: *Shallow Water Expendable Environmental Profiler (SWEEP) design with control and data recovery via cellular phone and low earth orbit satellite networks*. In: Proc. of Oceanology International '98, 10-13 March, Brighton, UK.

Tyce R., de Strobel F., Grandi V. and Gualdesi L.; 1999: *Shallow-water expendable and trawler safe environmental profilers*. In: Proc. of Oceans '99 MTS/IEEE", 13-16 September, Seattle Washington, pp. 1229-1233.