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The Automated Recovery Timer (ART): An Alternative to Traditional 'Burnwire'- Based Subsea Instrument Recovery Devices

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Abstract

Traditional methods of data collection in the ocean often fall into one of two research categories, active and passive. Active, often diver-based, subsea research's greatest limiting factor is often time. When data collection needs surpass maximum allowable time by direct diver-based studies, passive techniques can provide an alternative to data collection. Passive data collection usually entails the deployment of instrumentation (i.e. data loggers, sensory systems, cameras, traps, etc.) from a boat and subsequent recovery via line and float or acoustic recovery systems. Common electronic recovery systems are largely cost-prohibitive and limited in their ability to deploy instruments in a variety of orientations. This study describes the development of a new, cost effective alternative to traditional systems that differs largely in that equipment remains negatively buoyant throughout the deployment period rather than tethering positively buoyant instrumentation to the sea floor and then dropping weight. This method reduces the likelihood of instrument damage and loss due to unpredictable ocean currents. The Automated Recovery Timer (ART) is the first subsea package recovery device to utilize a drive gas cartridge for resurfacing and was produced at a fraction of the cost of currently available systems.

Keywords: Subsea Recovery Systems; Underwater Monitoring

Introduction

One of the primary obstacles for scientists performing research in open water is that the oceans are unpredictable. Thus,marine research is often shifted into controlled (laboratory) settings. However, for research requiring real world exposure, remotely operated vehicles (ROVs) and/or SCUBA technology allow limited and often costly and/or dangerous periods in the marine environment. The proven method of "trap and grab" allows for very limited surveys of specific and/or targeted research objects; for example targeting a taxon of choice, or limited surveys at a location/depth of choice. Despite these stark limitations, the simplicity of this sampling method makes it the tool of choice for many underwater scientists. The method involves deployment of research equipment to a targeted depth/location using a line, and is either tethered to the surface vessel, or to a buoy for longer exposure periods. However, surface currents, predation by marine life movements of other marine vessels, as well as other human activities can easily compromise sampling devices, resulting in either loss of location or loss of equipment.

To overcome this obstacle, timed-release sampling devices are available for marine research. However, current available sampling devices are often prohibitively large, relatively expensive and limited in application [Table 1]. The majority of traditional subsea instrument recovery devices operate via electrolysis and acoustics. The sampling device is dropped from a surface vessel with a weight affixed to the bottom and a float attached to the top. After the deployment period, a unique acoustic 'code' (often encrypted) is sent via a command box at the surface. This signal activates a high voltage device, which starts electrolysis of a 'burnwire' and in 3-15 minutes, depending on manufacturer specifications, a lever drops the weight and the device surfaces (Figure 1). This process of electrolysis requires saltwater for activation, limiting applicability only to marine environments with exception to the ARC-1XD [1-6].Traditional acoustic systems are best suited for devices that are suspended off the seafloor (sensory systems, environmental loggers, etc.), placing instrumentation at significant risk from ocean currents.

A less common method/tool for equipment recovery involves the use of positive drive-off mechanical systems (ex. Sonardyne's Lightweight Release Transponder (LRT), where a small motor is activated upon request releasing anchor weight via an unscrewing mechanism [5]. The complexity of this mechanical system makes

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Table 1: Comparison of the ART to a variety of current subsea instrument recovery devices*.

	Sub Sea Sonics www.subseasonics.com		Sonardyne www.sonardyne.com	Desert Star Systems LLC www.desertstar.com		This study
	AR-50 Acoustic Release System	**TR-45 Timed Release**	**Lightweight Release Transponder (LRT)**	**ARC -1XD**	**PERC-1**	**ART (Automated Recovery Timer)**
Releasing device cost ($USD each)	870 (excludes battery pack)	165	3,898	1,995	500 (single use only)	100
Topside command box ($USD)	1,900	595	9,210	2,995	3,000	25
Release link cost (replaced after each use)	8-10	8	12	NA	NA	2.50 (16g C02 cartridge)
Max. deployment time	1 year (approximately)	6 months (approximately)	18-51 months (Alkaline or Lithium Batteries)	4 -17 months (Alkaline or Lithium Batteries)	4 years	40 days (rechargeable)
Dimensions (cm)	29.2 L x 5D	38.1L x 3D	49L x 6.3D	55 X 5.7D	14.0L: X 2.5D	10.0L x 8.0W x 3.5H
Depth Rating (msw)	183	183	500	300	2000	110**
Environments	SW	SW	SW	SW + FW	SW + FW	SW + FW
Time to activation once initiated	3-20 mins. ***	10-20 mins ***	0.5 min	instantaneous	instantaneous	instantaneous
Communication with user on release device	LED to indicate operational	None	None	None	None	LED to indicate battery voltage

*This table is not a comprehensive list of all recovery systems available. Systems detailed are those with similar utility to that of the ART. Many additional recovery systems exist, but are outside the scope of this project in terms of cost and application.
**Maximum tested depth = 110m; may be able to deploy deeper but untested.
*** Time for electrolysis to complete and activation to occur varies depending on ambient water temperature.

it more suitable for larger-scale commercial applications. The aim of this project was to design and manufacture an automated recovery timer (ART) that would be cheap, portable (=relatively small size), and generally non-intrusive, to facilitate efficient instrument placement and retrieval in aquatic environments. It was decided that the most economical design would include an electronic drive-gas solenoid.

Methods

In the case of the automated recovery timer (ART) in this study, the production aim was in the magnitude of tens of units to be made by hand. Costs of raw material were kept low, although further reductions in material costs are possible. The initial design, as well as code writing, was undertaken with the aim of functionality, leaving room for further improvement, as well as cost reduction. The entire cost of each unit was approximately 100USD. Of the total unit cost, the waterproof Fischer®connector alone accounted for 72% of total material cost.

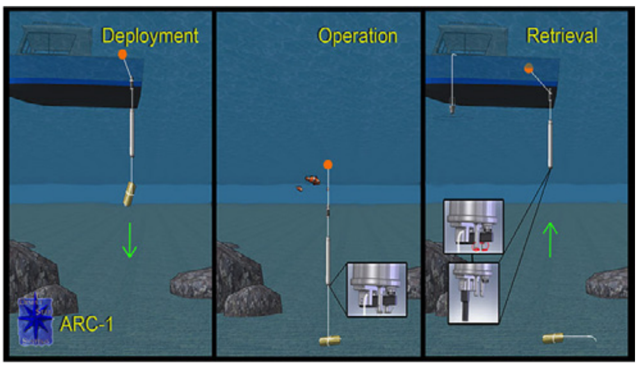

Figure 1: Deployment, operation, and retrieval of Acoustic Release Subsea instruments. (Desert Star Systems LLC 2009).

Materials

- Eagle CAD (offers free home-use version)
- Microchip IDE
- Microchip microprocessor. The authors considered two of the most popular, Microchip and Atmel. Cost and performance with respect to power consumption were comparable and did not provide a clear incentive. Microchip was hence chosen solely based on previous experience.
- PicKIT3 programmer
- Terminal program (putty, minicom, etc.)
- Snap-tite 12V DC Wattimizer solenoidvalve (Solenoid Solutions Inc).
- 3.7v Lithium battery
- 7 Pin Fischer® Female water proof connector

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Functionality

The Automated Recovery Timer (ART) is an electronic timer, which upon going from a preset countdown time to "time remaining =zero", sends an electronic signal to a 12V one-way gas solenoid valve. This signal activates a magnetic pin within the solenoid chamber allowing gas from a 16g disposable C02 cartridge to fill to a closed-system diver's personal lift bag. A closed-system lift bag was chosen to prevent loss of gas while at the surface awaiting retrieval. The lift bag is fitted with an over pressure valve to facilitate venting of gas during ascent.

This system allows for easy, semi-automated recovery of subsea instrumentation. The desired deployment (saturation) period is user changeable, depending on the user's needs, with a maximum tested duration of 40 days. For ease of transport and applicability in a wide variety of research projects, the entire system was designed to have a small size comparable to a cigarette carton(10L x 8W3.5Hcm).In order to program activation time, the ART is connected to a computer and communication-box (comms box) via a standard USB cable with no requirement of proprietary software. Any terminal software (Putty, Minicom, etc.) will suffice. Once connected, the ART offers on-screen instructions on how to change the settings such as activation timer, solenoid valve test fire upon activation, and solenoid valve activation period. Once connected to the USB comms box, the ART's internal rechargeable 3.7V lithium-ion battery is charged at a rate of 100mA (standard allowed maximum for USB) [1]. A 1000mAh battery will require approximately 10 hours to be fully charged via a standard computer USB port. For use in the field, a charging unit has been developed to facilitate charging five ART units simultaneously from a standard wall plug (Figure 2).

Benchmarks

- 1000 mAh battery
- Timer power consumption approx. 1.0 mA (Figure 3).
- LED status indicator power consumption approx 5 mA when turned on, 0.02 mA average (Figure 4).
- Approximately 25 mAh per day ->40 day operation untilempty battery (Figure 3).
- Solenoid power consumption 100 mA for 10 seconds (during activation period) = 0.28mAh (Figure 4).

The unit is designed to be waterproof to a maximum tested operational depth of 100m. To achieve this the electronics assembly is enclosed in an acrylic case and filled with waterproof transparent electronic potting compound. 'Bricking' the electronics via potting compound was chosen to avoid common failure points of waterproof electronic enclosures (o-rings, humidity etc.).

Deployment

In the field, the ART is turned on by briefly placing a magnet on top of the unit "(Figure 5). The ART will confirm timer activation by test-firing the solenoid valve (if configured that way), and blinking a battery status LED once every minute. Solenoid valve

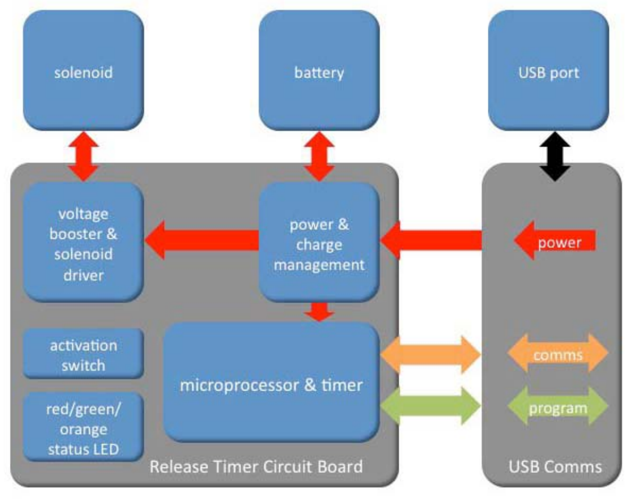

Figure 2: Functional schematic of new Automated Recovery Timer (ART).

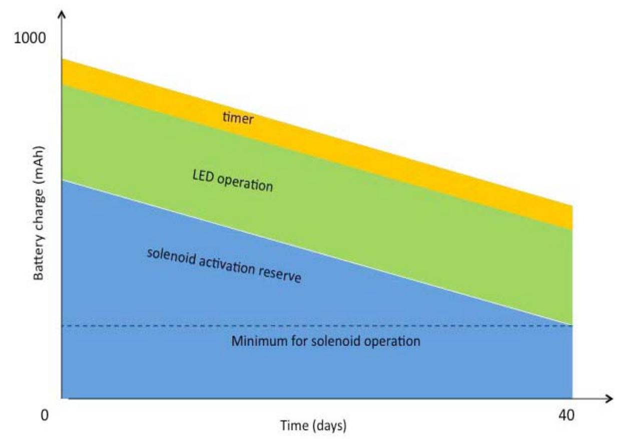

Figure 3: Battery consumption rate (mAh) for the Automated Recovery Timer (ART).

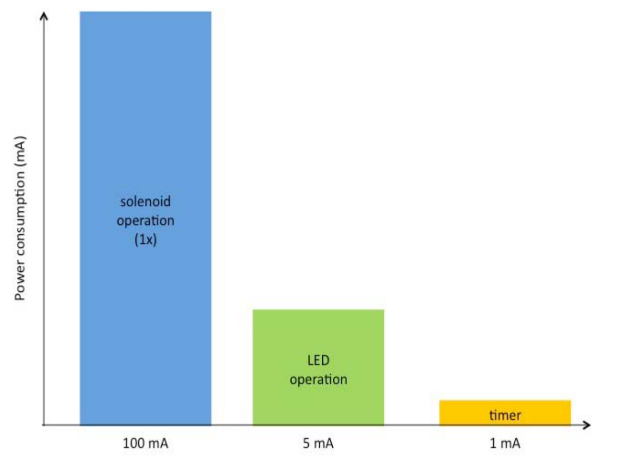

Figure 4: Breakdown of component power consumption for active ART unit.

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Figure 5: Assembled ART unit ready for attachment of C02 cartridge and deployment.

activation is performed upon expiration of the timer period. The ART features an emergency battery reserve in the event the rechargeable battery becomes depleted prior to the expiration of the timer (this feature can be programmed on/off). Deployment of the ART is performed in two phases. The programming phase includes charging the battery via mating the five unit-charging adapter to a standard wall plug. The programming assembly (Figure 5) is attached to the unit via a female Fischer© plug on one end and the other end to a computer via a USB. Cable. Utilizing the GUI, the timer duration (hh:mm:ss) can be programmed as well as if in test-function mode and emergency activation mode is desired.

Post programming, basic communication between the user and each unit can be achieved via brief placement of a magnet near the proximity/reed switch on the top of the unit. The tri-color LED will flash a color corresponding to the unit's current battery status: 1.greenfor≥3.8 v; 2. orange3.5-3.8 v; or 3.red for ≤3.5 v. Once initially turned on, the unit's LED automatically blinks once per minute indicating battery status. At any time, in the event of misplacement or inclement weather, the user can turn the unit off by holding a magnet to the reed switch and waiting for 10 repeated blinks of the LED to occur, after which the unit is turned off.

Discussion

The Automated Recovery Timer (ART) is a cost-effective subsea instrument recovery device with features rivaling existing recovery devices. The ART is unique compared to most burnwire-based devices in that it is capable of deployment in both freshwater and marine environments (Table 1). Common problems associated with biofouling and acoustic systems are eliminated through the alleviation of environmental exposure of mechanical components [1]. The ART is not without its limitations. The drive gas cartridges (16 g threaded C02 canisters) are not available for sale in remote locations and airline transport is limited to 4 units per person per flight [7]. "Bricking" of the electronics system for waterproofing also creates risk as the permanent bond prevents repair of electronics (Figure 5). It would prove beneficial in future development to utilize a smaller solenoid coil as it would lead to a substantial decrease in overall unit size, maximizing portability. Additionally, given that plans change frequently when performing fieldwork, it would prove highly beneficial to develop a portable field programmer allowing alteration of the timer settings via laptop.

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