Acoustic Command Release Series CR200

Mike Sawkins and Keith Tipping with Gwyn Griffiths (July 2017)

Mike Sawkins worked with Mac Harris and Greg Phillips on the CR200 command release system from 1972 to 1983 and spent many hours at sea with numerous scientists. The CR200 system is still ingrained in his memory and he thinks he could still could get a system up and ready for use, some 33 years after leaving Wormley! The phrase "it is difficult to overestimate the impact of ..." is often used these days, but it is certainly true in the case of the CR200 series releases that had such an impact across all areas of science at Wormley.

Background and early work at NIO in the 1960s

Self-recording oceanographic instruments capable of being left in the sea for weeks to months were being developed in the early 1960s, including, from 1964, the iconic **Aanderaa Recording Current Meter**. Where surface moorings were inappropriate or not feasible and sub-surface moorings were required there was a need for a means of remotely separating a buoyant mooring from its anchor. This need led to the concept of the acoustic release, a device for the deployment and subsequent recovery of moored instrumentation in which the recovery is triggered remotely by an acoustic command signal. A typical release consists of the hydrophone, the battery and electronics housing, and a hook which is opened by an electromechanical device to release the anchor.

Figure 1. A pair of NIO acoustic releases with magnetostrictive nickel scroll transducers being deployed on RRS Discovery cruise 38 in early 1971, courtesy Raymond Pollard.

Early work on acoustic releases at Wormley was undertaken by Malcolm (Mac) Harris and Dennis Gaunt. During 1963/64 Harris spent six months at the Christian Michelsen Institute, Bergen working on the acoustics and electronics and with Gaunt designed and built a "pop-up" buoy with its "listening circuits" and a motor-driven release mechanism for James Crease [1]. Early trials in the Denmark Strait at 400 metres were not successful, but by early March 1966 these devices were operating well at depths to 3000 metres in the NE Atlantic on RRS Discovery cruise 10 led by John Swallow. A deployment from RRS Discovery in 1971 is shown in Figure 1.

A key enabling technology was the earlier development at Wormley of the Precision Echo Sounder (PES) and particularly the modifications to its Muirhead Mufax facsimilie chart recorder with its electrosensitized wet-paper. The Mufax provided a sweep-by-sweep visual correlator that enabled the weak signals from acoustic beacons to be clearly seen as coherent lines distinct from incoherent noise.

In parallel with this work for the marine physicists Harris and Gaunt designed an acoustic control system for opening and closing nets for the biologists that "promises to revolutionise the operation of net closing systems"[2].

The CR200 series

As improved component technologies became available the IOS Acoustic Command Release CR200 series was designed, manufactured and supported at and from the Applied Physics Group at Wormley from the 1970s until well into the 1990s. In the early 1970s Mac Harris had been joined by Greg Phillips, Eric Darlington and Mike Sawkins. David Edge worked with Eric from 1980 and David White joined Greg in 1985 replacing Mike Sawkins.

The CR200 series was derived from the earlier NIO releases with new micropower operational amplifier analogue filters and CMOS digital electronics. Instead of the earlier low-efficiency megnetostrictive acoustic transducers the CR200 series of releases, net monitors and pingers used a specifically designed tonpilz or mushroom transducer comprising a stack of piezoceramic elements, a heavy tail mass and a lightweight, shaped cone forming the radiator. Cleverly, this transducer formed part of one endcap of the

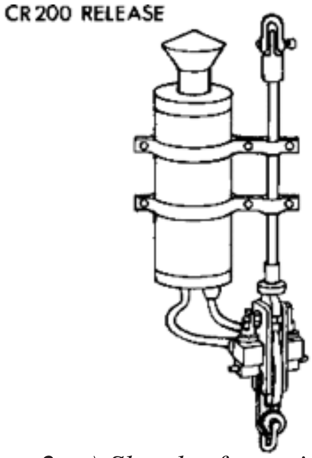
[1] NIO Annual Report 1963/64 and RRS Discovery Cruise 6

[2] NIO Annual Report 1965/66

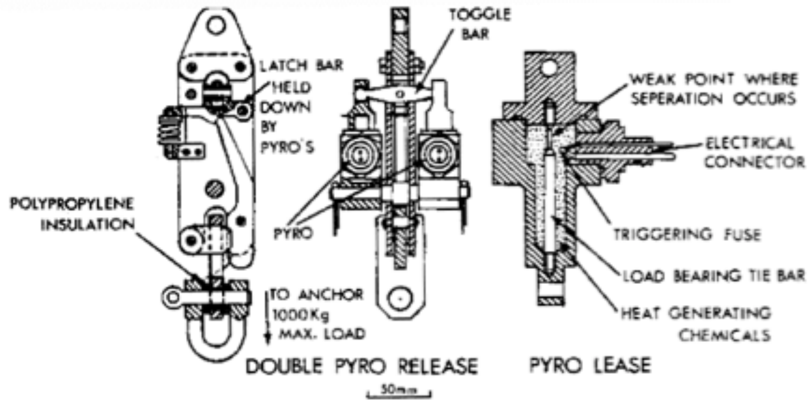
CR200 body making for a rugged unit, Fig. 2a. Another clever aspect was the design of the release mechanism itself by Gaunt and colleagues, where the use of levers enabled the mechanism to carry a load of several hundred kilograms (the anchor) held by two mechanically rather weak electrically fired pyrotechnic devices ("pyros"), Fig. 2b. Many tests and trials with the electronics and mechanical components were undertaken in the deep waters of Loch Etive and the Firth of Lorne, Scotland using the vessels from what was the Scottish Marine Biological Association, now the Scottish Association for Marine Science.

The interested reader will find a great deal of material on the background and full technical details in a series of three reports written by Greg Phillips: **Part 1** Operating Principles and Practice; **Part 2** The Shipborne System Mark III; **Part 3** Releases, Beacons and Transponders. The line drawings used here are taken from these reports.

The material for the pressure housing was dichromate sealed hard anodised aluminium, with, usually, stainless steel (316S16) mounting hardware. There were many iterations and discussions about the materials to be used because of the possible corrosion on long-term deployments in various locations and water masses, such as crevice corrosion in stainless steel in a low oxygen environment. Titanium was used later in the life of the CR200 system for the mounting hardware as this was better in the low oxygen waters encountered in some areas and lasted longer when crevice corrosion was encountered.



a)



b)

Figure 2. a) Sketch of a typical CR200 release, within a 6" diameter hard anodised aluminium housing with screw-on end caps, that clamps, with rubber buffers, to a stainless steel bar, with the mushroom transducer facing up, and two leads to the two pyros on the release mechanism, shown in detail in (b).
Courtesy National Oceanographic Library/NOC

The receivers in the CR200 releases required set-up at component level, a necessary compromise at that time in order to keep current consumption from the 5.4V mercury battery to about 350 microamps. The 10kHz carrier frequency was frequency modulated by a tone set by the deck unit. Each release had two channel filters, one at 320Hz common to all units, which turned beacon mode on and off, and the second was a unit-specific release frequency. These filters needed careful initial alignment, followed by tests in the environmental testing chamber when all on the Applied Physics corridor would know what was going on from the pinging sounds. At sea, they needed gentle coaxing to be kept in tune, followed by testing on a lowered wire at the intended mooring site (sometimes in tandem with a CTD cast) and if the acoustics and releases worked, they would fire a "puffer" to show that the release could have fired a pyro. After passing these at-sea tests the circuitry was generally stable and the release could be used with some confidence on the mooring, lasting over a year, the longest may have been over 2-3 years.

Shipborne equipment

There were three main parts to the shipborne equipment required to operate the CR200 series: a submerged acoustic transducer, a Deck Control Unit and a chart recorder or display.

A submerged acoustic transducer acted as a transmitter to send commands to the devices and as a receiver to listen for the the devices when they were in beacon mode. On the UK research ships the preferred transducer was a single element within the Precision Echo Sounder (PES) towfish. As the towfish was heavy, needing its own davit and winch, a lighter, smaller option when using other vessels was the "Dolphin" towfish, Figure 3a. In circumstances when the "Dolphin" could not be used a simple hand-held transducer was available, Figure 3b. In all cases, the transducer was the PES single element piezoelectric ceramic stack, Figure 3c.

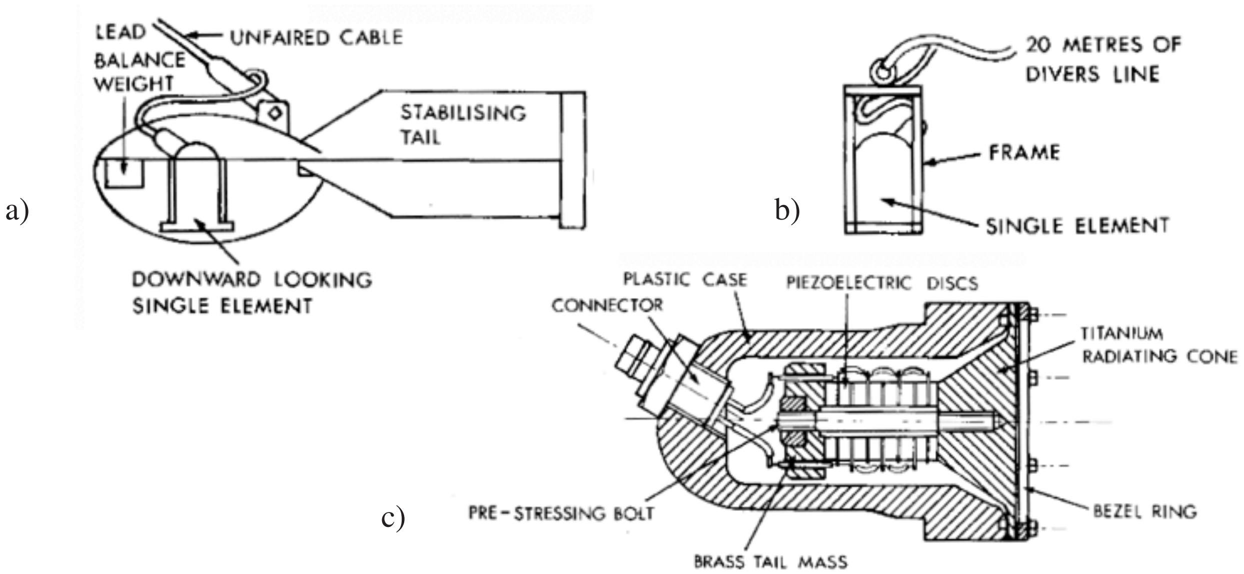


Figure 3. a) Sketch of the "Dolphin" towed body often used with the CR200 series on vessels when the much larger and heavier Precision Echo Sounder tow fish was not available. Here the transducer is pointing down, the transducer could be made to look backward for particular applications. b) In those circumstances where even towing a Dolphin was not possible a hand-held "Overside" version of the transducer was available. c) The construction of the single-element transducer as used in the PES towfish, the Dolphin and as an Overside. Courtesy National Oceanographic Library/NOC.

The Deck Control Unit (DCU), Figure 4, had three main components: a tuned amplifier to receive signals from the transducer to output to the display unit; a transmitter unit to generate and send frequency modulated (FM) signals to the releases and a synchronisation unit to set the sweep rate of the display to match that of the release's ping interval. A low-level transmitter output was provided for a test transducer that could be clipped to the release's transduce for in-air testing.

The display unit commonly used on UK research ships was the Mufax wet-paper chart recorder that formed part of the Precision Echo Sounder, Figure 5. Other chart recorders, including those from EPC and Raytheon, were used on other ships. In an era before the introduction of transponding releases, which enable the distance from the ship to be measured, and their use with receive transducer arrays to determine direction of arrival, there was both a science and an art in relocating the moored release. The limitations of the simple acoustic techniques then employed were compounded by infrequent position fixes of modest accuracy from Transit satellites (of the order of hours and typically within 100-400 metres).

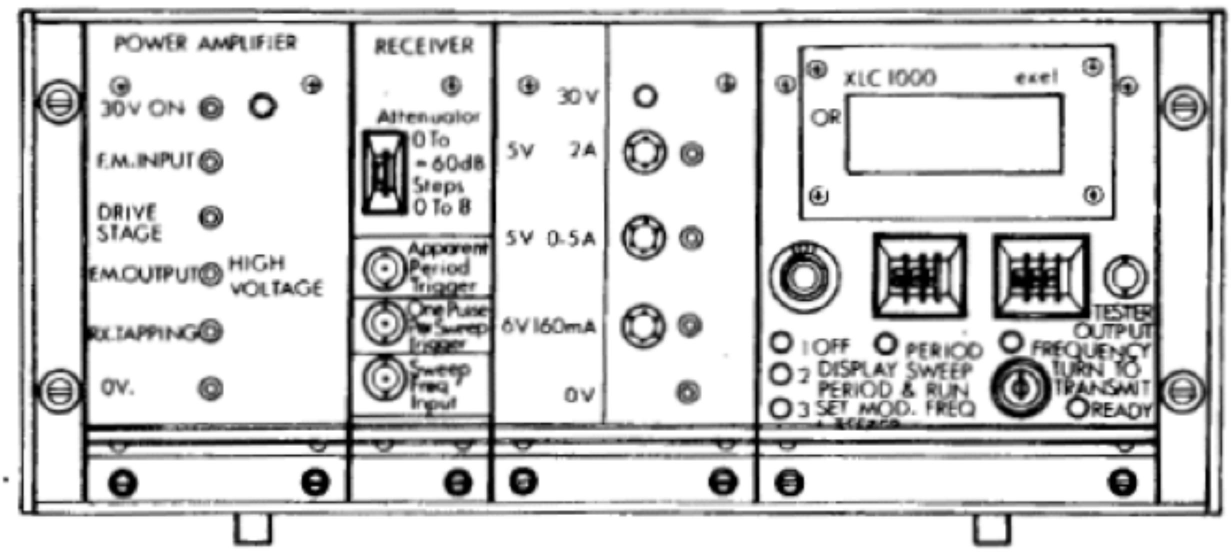


Figure 4. The MkIII Deck Control Unit that was introduced in the 1970s. The circuitry comprised four main modules, from the left: transmitter power amplifier; receiver with a thumbwheel to set the attenuation (gain); quadrulple voltage power supply; control unit and display, with thumbwheels to set the beacon and release FM command tones and the release's specific ping interval to synchronise with the display. Note that a key-operated switch was used to send the release command. Courtesy National Oceanographic Library/NOC.

Come the time to locate and trigger a release on a mooring or bottom lander a group on onlookers would invariably gather behind the operator. On reaching the location of the mooring (which could be story in itself) the ship would heave-to, minimising noise, and with the display sweep period set to that of the release a burst of 320Hz FM transmission would seek to activate the release's beacon mode. If successful, a trace would appear on the display, usually sloping to the left or right depending on the changing distance between the moored release and the ship (a ship at sea rarely being stationary relative to the earth). The operator would ask the officer-of-the-watch to steam on a set course while observing whether the range to the release decreased (to the left). If the range increased (to the right) a request to alter course would be given so as to decrease the range. With the range decreasing, there would be a moment when minimum range was achieved, the release would then be beam-on, either to port or to starboard. With the ship heading away from the release a course change to port or starboard would either increase or decrease the range, subsequent manoeuvres and a subsequent beam-on minimum range would lead to the release's position being fixed, Figure 6.
At position 'H' the ship would heave-to and a release command sent (a unit-specific tone at 20Hz intervals between 240 and 460 Hz). If heard by the release a second ping would start, showing as a parallel line to the beacon ping on the chart display. After the minimum of 64 seconds of sending the release command a relay would discharge a capacitor to fire the pyros. The relay also introduced a delay to the second ping and the operator would see the second trace jump position. All would smile when the distance of the release from the seabed, as measured by the difference between main and bottom echo, Figure 6, would increase.

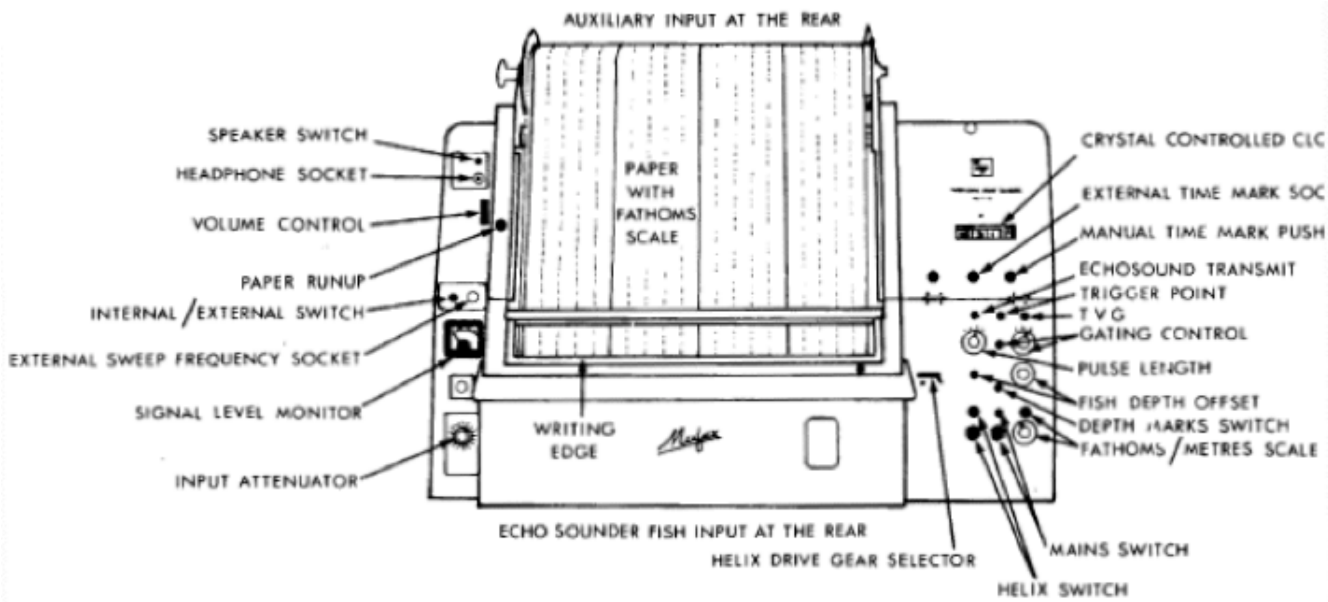


Figure 5. The original Muirhead Mufax wet-paper chart recorder is the wide centre unit, the panels to the left and right having been added to produce the Precision Echo Sounder with interconnections to the CR200 series Deck Control Unit. Courtesy National Oceanographic Library/NOC.

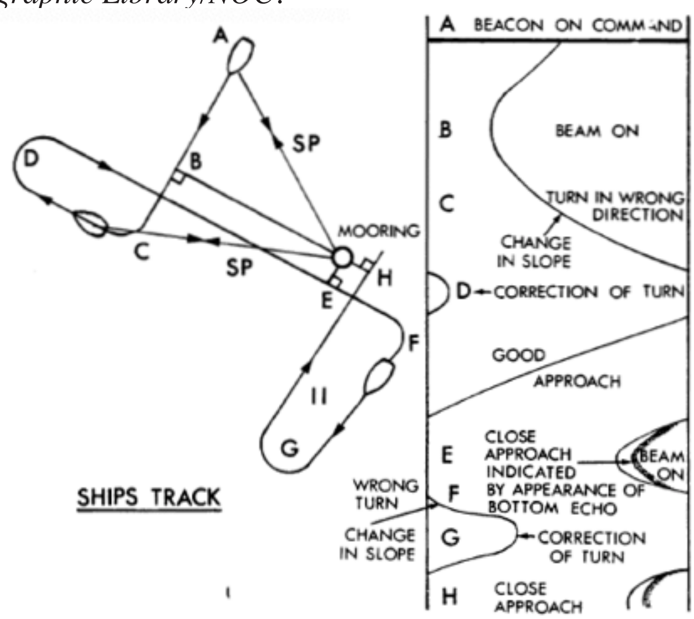


Figure 6. Left, map of the manoeuvers to locate a release and right, the corresponding traces on the chart recorder. Courtesy National Oceanographic Library/NOC.

Production of the CR200 series

Keith Tipping, who had much to do with the production of CR200 releases in the late 1970s and 80s, provides these recollections. The Drawing Office reference IOS 5230 covered the mechanical components. The pressure cases were tubes of 6.125” outside diameter with 4.25” bore of aluminium alloy **7075T6** originally from **High Duty Alloys Birmingham**. The minimum batch order was 1 ton and the raw tubes always took several months to arrive. Later, the tubes came from a European supplier, but still as one-ton batches.

The main problem in producing high reliability pressure cases was avoiding contamination during machining. Any contact from steel (from the lathe’s chuck’s jaws or even from sweat from human hands) almost immediately produced a rust-like corrosive colouring that sank into the material itself. Consequently, lathe chuck jaws were fitted with isolation pads and machine operators wore plastic gloves. All machined parts were dipped immediately into a dewatering fluid (Ensis) then stored individually in plastic bags prior to hard anodising.

The machining was originally carried out by Claytons of Poole, and later by Frazer-Nash Engineering and Elkins Engineering. Jim Young handled the original metal tendering process with Dennis Gaunt. When Keith Tipping moved from the Workshop to the Production Office he was taken on a visit to High Duty Alloys by Dennis Gaunt to meet their team and to see the forging plant in action (smoke & flames). After that he did the tendering.

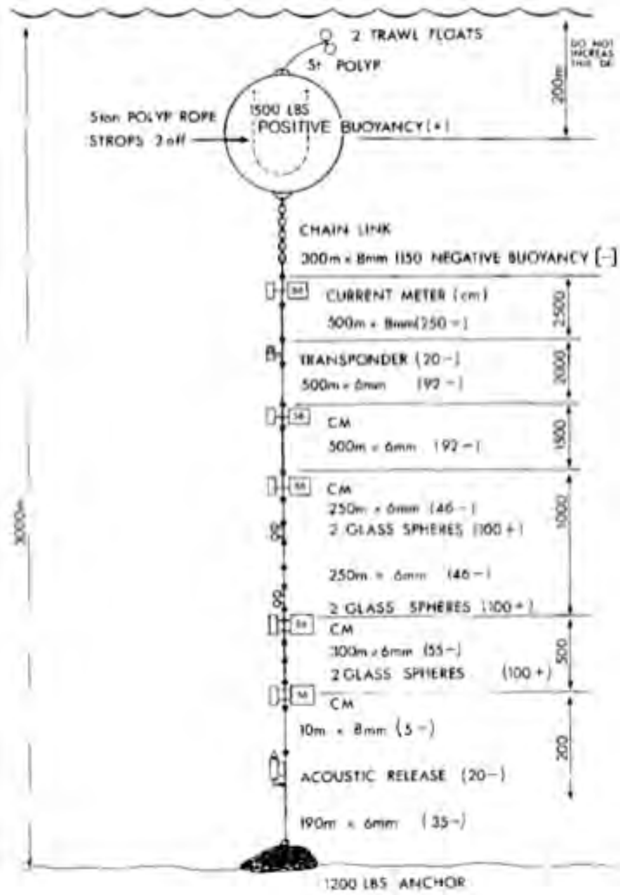


Figure 7. Example of a sub-surface current meter mooring of the 1980s using a CR200 series release. Courtesy National Oceanographic Library/NOC.

Obtaining an acceptable hard anodised finish proved problematical. Numerous companies tried; the original work was done by High Duty Alloys Birmingham until they closed, Poeton Industries had difficulties and the best being **Walton Plating**. The anodising process creates a skin, ideally adding 5-7 thousandths of an inch to the machined dimensions Machining allowances and tolerance adjustment had to be considered for threads in the tube end caps and mushroom transducers. The end caps had threads tapped for the underwater connectors. These threads were also cut over-sized to allow for anodising (as this was well before the era of CNC machining over-sized taps were purchased and issued to the various contractors as necessary). Some parts came back from anodising badly damaged, these required the anodising to be acid stripped, then re-machining and sending back to be anodised again. Keith Tipping recalls, “One day, without telling a particular anodising company near Heathrow that I was coming. I can remember walking into the factory and immediately seeing several ladies (in saris) unpacking and just tossing our newly machined precious end caps into their wire baskets prior to anodising! Quality control by the finisher did not exist.” However, George Bryan always inspected these components at Wormley before and after anodising.

Wooden boxes for the releases were made by in-house carpenters Mick Wakeford and Harold Plato. These boxes were lined with rubber foam to store finished items for transportation after manufacture, important to protect the “O” ring surfaces and the anodising. Internal chassis details presented no problems, and were originally made from **Tufnol** - a resin-bonded cloth-reinforced plastic.

Pressure tubes and mushroom transducers were made in batches of six, held in the Stores and draw out as required. Mac Harris or Greg Phillips generally informed the Production Office as to their future needs so that they could plan and order in advance.

The CR200 series releases in use

Marine Physics at Wormley was one of the main users of the CR200 series of releases for current meter moorings, Figure 7.

In various forms the releases were also used on instruments developed at Wormley, including:

- **Bathysnap** - a benthic lander with a time laps camera and current meter for long-term biological observations for Dr Richard Lampitt and colleagues, which shed new light on the seasonal arrival at the seabed of phytodetritus from the upper ocean.
- **Bencat**- a benthic lander that measured near-seabed profiles of current, temperature and conductivity for Drs Steve Thorpe and Alan Elliott.
- **Ocean Bottom Seismometers** of two main types, the PUBS instrument at Wormley for controlled-source seismology by Dr Bob Whitmarsh and the OBS for microearthquake studies by Dr Tim Francis' group at Blacknest.
- **Ocean Bottom Tide Gauges** that were initially developed at Wormley and from the mid-1970s at Bidston where their applications expanded from the study of astronomical tides to include low frequency variations in sub-surface pressure due to changes in ocean circulation.
- **PUPPI** - a free-fall pop-up pore pressure instrument with a 3-metre sensor lance that penetrated the sediment that was left behind when the release activated for Dr Schultheiss.

Further examples of the uses of CR200 series releases are shown in Figure 9. Many deployments and recoveries were from non-UK vessels, a notable example being the recovery in 1992 by the *FS Alliance* of seven moorings after 600 days at depths from 1000 to 2130 metres in the Iceland Basin.

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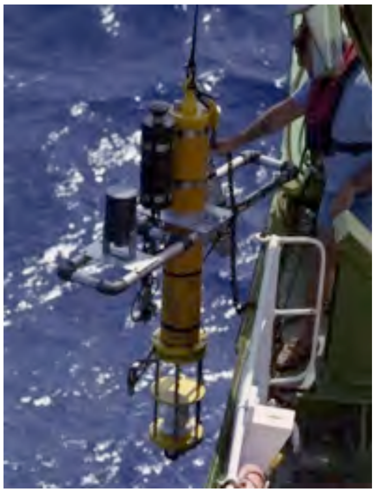
b)

c)



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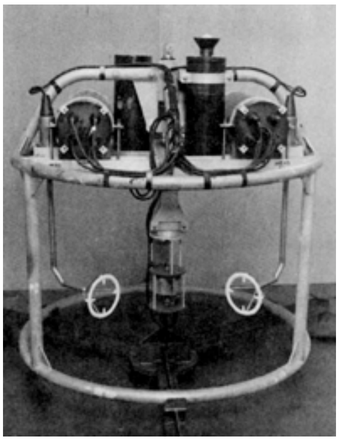

e)

f)

Figure 9. a) Greg Phillips deploying a release on RRS Discovery cruise 181, 1989. The visor and gloves are for protection in the unlikely case of the pyros firing on deck (NOL image 2047). b) Ian Waddington (black cap) recovering a CR200 release from the forward 'A' Frame of RRS Discovery cruise 130, 1982. c) Wire test of a release fitted to an EG&G Vector Averaging Current Meter for use with a benthic lander camera tripod on RRS Discovery cruise 117, 1981. The pyro release mechanism had been modified to release the tripod and allow the camera and VACM to be recovered. d) Bencat, with two electromagnetic current meters (white rings), a rotor current meter in the centre and a CR200 release at the top of the frame (IOS Annual Report 1982). Caption continued at foot of next page

Some causes of failure

To the authors' knowledge there is no published analysis of the failure modes of the CR200 releases. Without detracting from the clear successes of these acoustic releases, there were inevitable failures. Root causes were difficult to establish where the equipment was not recovered by other means, e.g. dragging (a challenging task, especially in the era before GPS navigation) or by washing up ashore.

Cases of no response at all from the acoustic release were the most problematical as to possible causes. Hypotheses would have included:

- A fault with the receiver electronics or premature depletion of the 5.4V mercury receiver battery.
- A fault with the beacon electronics or its 15V battery, such that the transmission from the ship may have been heard, but the ship did not receive a response.
- Flooding of the pressure tube, e.g. from a slow leak caused by an "O" ring seal contamination or failure, including due to corrosion of the anodised aluminium surface at the seal. (There were four "O" rings, two for the bulkhead connectors for the cables to the pyros and one for each end-cap). Collapse of the pressure tube would have been a very unlikely cause.
- The entire mooring was no longer in the location it was deployed. It was not unknown for moorings to "walk", especially if the anchor weight, for some reason, provided a low hold-down force against the buoyancy.
- The mooring was no longer upright, e.g. due to collapse of the buoyancy, and the acoustic release was lying on or within the sediment such that it could not hear signals from the ship.

Where there was an acoustic response from the release but the mooring did not separate and rise hypotheses would have included:

Figure 8. Pair of heavily fouled CR200 releases recovered by FS Alliance, 1992.

- Failure of the 9V pyro-firing batteries, the firing relay, the connectors or cables.
- Failure of the pyros.
- Failure, or partial failure, of the buoyancy, with insufficient left to lift the mooring.
- Failure of the mechanical release mechanism, e.g. jamming, including that due to fouling.

In 1992 Greg Phillips noted [3] : *"The moorings recovered by FS Alliance were particularly interesting in that several of the mechanical releases showed extensive growth of biological fouling (Figure 8). These moorings were fitted with two independent release systems. Despite this, at least one failed to release until 20 minutes after the device had been fired, when mooring action presumably had worked clear the fouling. This could well explain occasional previous failures to release moorings, despite apparent successful operation of the acoustic link"*

Using two releases was not the usual practice, but neither was it uncommon. The expectation from using two releases was a greater probability of retrieving the mooring, however this required the faults in the two units to be independent of each other and the risks introduced from the doubling-up mechanism to be much less than the risk of failure of a release. While there would have been notes and analyses made in the team's logbooks of instances where one release of a pair worked and the other did not the authors of this note are not aware of this information being available.

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[3] IOS Annual Report 1991-92 see **http://viewer.soton.ac.uk/nol/image/240818/34/**

Figure 9 caption continued

e) Bathysnap time lapse camera lander, here the CR200 release is mostly out of the picture behind the sphere at top right, the black dot at the top is the acoustic transducer (IOS Annual Report 1982). f) A pair of releases being deployed with a current meter mooring (one of five) in the Weddell Sea from the icebreaker USCGC Glacier, 1978. These had been purchased by Dr Ted Foster, Scripps Institution of Oceanography, USA for the **International Weddell Sea Expedition**. *Just two of these five moorings were* **recovered,** *two years later rather than the planned one year. d. and f. Courtesy National Oceanographic Library/NOC.*

CR200 series end its two decades of service

By 1992 it was becoming clear that some of the parts within the CR200 releases were going to become obsolete within the following five years; procuring and shipping pyros was becoming increasingly difficult. Furthermore, acoustic releases with greater functionality were becoming available from industry, meaning that an in-house development of a new generation of releases would not be appropriate. After a review, releases from the French company MORS (available through Oceano UK) were chosen as the NERC standard and the CR200 series would be phased out by 1997[3]. During the transition period experience was gained with the MORS electronics within CR200 pressure cases, with titanium hardware and firing pyros, Figure 10.

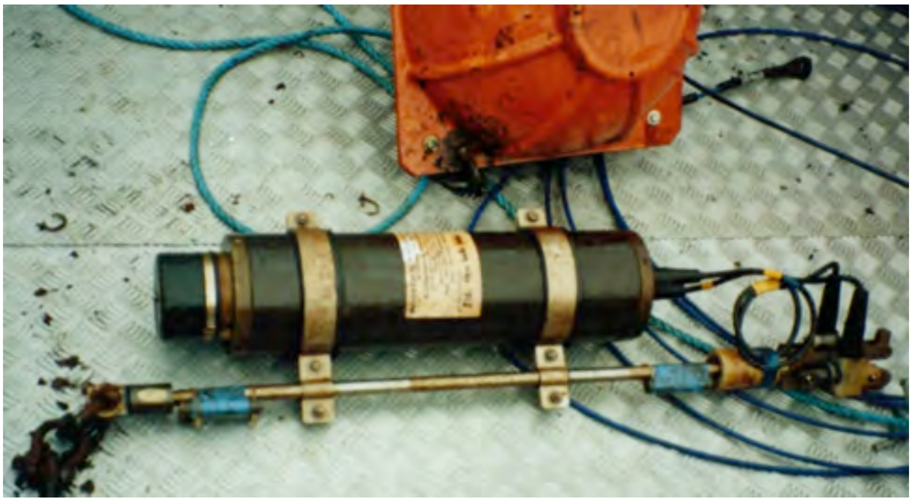

Figure 10. The end of the line for the CR200 - MORS (Oceano) release electronics packaged in CR200 hardware firing pyros with all-titanium CR200 hardware