National Oceanography Centre

Cruise Report No. 03

RRS *Discovery* Cruise 360

19 JAN-02 FEB 2011

Trials of the Autosub LR AUV, HyBIS, PELAGRA, Ellsworth Camera and MYRTLE-X Lander systems

Principal Scientist
S D McPhail

2011

National Oceanography Centre, Southampton
University of Southampton Waterfront Campus
European Way
Southampton
Hants SO14 3ZH
UK

Tel: +44 (0)23 8059 6370
Email: sdm@noc.soton.ac.uk

DOCUMENT DATA SHEET

AUTHOR	*PUBLICATION DATE*
MCPHAIL, S D et al	2011

TITLE

RRS *Discovery* Cruise 360, 19 Jan-02 Feb 2011. Trials of the Autosub LR AUV, HyBIS, PELAGRA, Ellsworth Camera and MYRTEL-X Lander systems.

REFERENCE

Southampton, UK: National Oceanography Centre, Southampton, 39pp.
(National Oceanography Centre Cruise Report, No. 03)

ABSTRACT

There were five main objectives for the trials cruise: The first tests of the Autosub Long Range AUV, testing of the HyBIS video guided grab system, testing of the MYRTLE-X Lander systems, testing of a deep camera system for the Lake Ellsworth probe and test deployments of the PELAGRA neutrally buoyant sediment capture drifters.

The working area was about 300 miles south west of the Canary Islands, in international waters, over benthic plains of 4000 m depth, with some tests of the video systems over a isolated sea mount rising to 1200 m depth. Most of the objectives of the cruise where met, with successful diving and control of the Autosub LR, tests of the HyBIS and Ellsworth camera systems, and 3 deployments and recoveries of two PELAGRA floats. Several wire tests of MYRTLE-X systems were carried out, predominantly successful, but concerns over the release system prevented a deployment of the lander.

KEYWORDS

Cruise D360, Autosub Long Range, HyBIS, AUV, MYRTLE -X, Lander, Acoustic Telemetry

ISSUING ORGANISATION **National Oceanography Centre, Southampton**
University of Southampton Waterfront Campus
European Way
Southampton SO14 3ZH UK
Tel: +44(0)23 80596116 Email: nol@noc.soton.ac.uk

CONTENTS

1. Ship's Personnel .... - 6 -
2. Scientific Personnel .... - 6 -
3. Itinerary .... - 7 -
4. Diary of Events .... - 7 -
5. Autosub Long Range Operations. .... - 9 -
6. HyBIS operations: Cruise D360 .... - 21 -
7. Ellsworth HD camera trials .... - 24 -
8. Pelagra Operations .... - 26 -
9. MYRTLE-X system tests .... - 35 -
10. Acknowledgements .... - 39 -

1. Ship's Personnel

Leask	John	Master
Gwinnell	James	Chief Officer
Laidlow	Vanessa	Second Officer
Hemphill	Thomas	Third Officer
Coultas	Mark	Chief Engineer
Murray	Michael	2nd Engineer
Harnett	John	3rd Engineer
Graham	Christopher	3rd Engineer
Smith-Jaynes	Karl	ETO
Bullimore	Graham	PCO
Lewis	Thomas	CPOD
Smyth	John	ERPO
Squibb	Mark	CPOS
Spencer	Robert	POD
Moore	Mark	SG1A
Alford	Philip	SG1A
Watkinson	Andrew	SG1A
Preston	Mark	Head Chef
Whalen	Amy	Chef
Osborn	Jeffrey	STWD

2. Scientific Personnel

McPhail (PI)	Stephen	National Oceanography Centre. Southampton
Boorman	Benjamin	National Oceanography Centre. Southampton
Da Fonseca Brito	Mario	National Oceanography Centre. Southampton
Fowler	Lee	National Oceanography Centre. Southampton
Furlong	Maaten	National Oceanography Centre. Southampton
Huehnerbach	Veit	National Oceanography Centre. Southampton
Jacobs	Colin	National Oceanography Centre. Southampton
Murton	Bramley	National Oceanography Centre. Southampton
Pebody	Miles	National Oceanography Centre. Southampton
Perrett	James	National Oceanography Centre. Southampton
Phillips	Alexander	University of Southampton
Saw	Kevin	National Oceanography Centre. Southampton
Steenson	Leo	University of Southampton
Stevenson	Peter	National Oceanography Centre. Southampton
Ward	Samuel	National Oceanography Centre. Southampton
Yaniv	Yair	National Oceanography Centre. Southampton
Mack	Steve	National Oceanography Centre. Liverpool
Shannon	Geoffrey	National Oceanography Centre. Liverpool

3. Itinerary

Departed Santa Cruz, Tenerife, 19th January 2011

Arrived Santa Cruz, Tenerife, 2nd February 2011

4. Diary of Events

Start Date	Time (GMT)	Activity
16/01/2011	12:00	Mobilisation
19/01/2011	08:54	Passage to Autosub Launch Site
20/01/2011	17:48	Rigging CTD
20/01/2011	18:10	CTD#1
20/01/2011	19:19	Rigging Pelagra buoys
20/01/2011	22:35	Deploying and Recovering Pelagra Buoys
21/01/2011	00:24	Standing By whilst AUV tests continue.
21/01/2011	13:05	Transducer test using CTD wire
21/01/2011	14:00	Rigging and Testing of Equipment for Ellsworth Camera
21/01/2011	20:06	Ellsworth Camera Ops using Deep Tow
21/01/2011	21:18	Ellsworth Camera fault finding
22/01/2011	03:10	Ellsworth Camera Ops using Deep Tow
22/01/2011	07:36	Winch Problems encountered during last 100m of recovery
22/01/2011	08:10	Conducting Various test on AUV Prior to launch
22/01/2011	09:20	AUV operations
22/01/2011	11:48	Rigging of Myrtle Lander equipment
22/01/2011	13:58	Testing of Myrtle Lander equipment using CTD wire
22/01/2011	17:38	Transit to Pelagra buoys
22/01/2011	19:00	Recovering Pelagra buoys
22/01/2011	19:48	Transit to Tropic Seamount
22/01/2011	22:51	HyBIS operations
23/01/2011	06:44	Autosub preps
23/01/2011	12:59	Autosub ops
23/01/2011	16:13	Rigging of Myrtle Lander equipment
23/01/2011	20:28	Testing of Myrtle Lander equipment using CTD wire
23/01/2011	22:46	Rigging Pelagra Buoys
24/01/2011	00:05	Deploying Pelagra buoys
24/01/2011	00:34	Fault finding on HyBIS, repositioning ship to Tropic Seamount and Preparing Autosub
24/01/2011	11:30	Autosub Operations
24/01/2011	13:22	Waiting on Weather for launching Autosub and effecting repair to AC in winch Suite
25/01/2011	16:25	HyBIS operations
25/01/2011	21:23	Reposition v/l and rigging Ellsworth Camera
26/01/2011	02:40	Waiting for Lander to surface
26/01/2011	05:04	Preparing Autosub
26/01/2011	08:53	AUV ops
26/01/2011	11:27	Preparing Autosub
26/01/2011	15:00	Autosub ops. Autosub recovered due to damage to it
26/01/2011	15:57	Awaiting Pelagra buoys to surface and reposition to buoy site

26/01/2011	19:18	Recovering 2 x Pelagra buoys
26/01/2011	20:48	Rigging Elsworth Camera
26/01/2011	22:00	Elsworth Camera ops
27/01/2011	02:15	Reposition vessel to North of Seamount. Rigging Lander communications kit to CTD wire
27/01/2011	12:36	Lander communications testing
27/01/2011	19:18	Rigging Pelagra buoys
27/01/2011	20:08	Deploying Pelagra buoys
27/01/2011	20:40	Reposition Vessel to approx 4000m of water
27/01/2011	21:41	Elsworth Camera ops
28/01/2011	03:32	Preparing Autosub. Operations eventually cancelled due to WX and technical issues with Autosub
28/01/2011	18:32	Deployment of deep tow wire for test purposes
28/01/2011	21:11	Awaiting Autosub launch
29/01/2011	16:48	Autosub ops
29/01/2011	17:48	Transit to Pelagra buoys
29/01/2011	22:48	Recovering 2 x Pelagra buoys
29/01/2011	23:32	Lander communications testing
30/01/2011	00:42	Awaiting AUV launch
30/01/2011	10:15	AUV Ops
30/01/2011	14:14	Rigging AUV
30/01/2011	15:34	AUV Ops
30/01/2011	21:12	Rigging Deep tow test WT
30/01/2011	21:30	Conducts tests on deep tow winch
31/01/2011	00:48	Relocate to Position closer to Tenerife but in International waters
31/01/2011	04:50	Awaiting weather to Moderate. No improvement End Science set onto Tenerife
31/01/2011	13:00	Passage to Tenerife
02/02/2011	10:29	Demobilising

5. Autosub Long Range Operations.

Steve McPhail, Peter Stevenson, Miles Pebody, James Perrett, Maaten Furlong.

Alex Phillips, Maaten Furlong, Miles Pebody, Steve McPhail, Peter Stevenson, James Perrett, Mario Brito, Leo Steenson. Autosub LR , with top panel removed revealing the two main pressure spheres (forward – battery, aft – control system, ADCP).

Summary of Autosub LR deployments on RRS Discovery 360

The cruise was a success and important milestone for the Autosub Long Range AUV programme . The AUV dived, controlled its heading and depth accurately at a range of speeds tested from 0.33 to 0.62 ms^{-1}. The effective control of heading and depth (to fraction of a degree rms) was an important achievement not only for practical purposes (simplifying further testing), but also that it proved that a novel control technique for the AUV (controlling without any explicit feedback of the actuators position), worked effectively. The control was able to cope with significant control plane backlash. There were no problems with the magnetic couplings for propulsion or actuation. The AUV also floated sensibly on the surface, with good antennae exposure. The ADCP worked well, as did the attitude and heading sensor. The production of mission scripts using the dynamic linked library approach proved workable and flexible. The abort system repeatedly and correctly reacted to the events of I2C interface stopped, ADCP data stopped, ground fault.

The hydrodynamic design of the AUV was shown to be successful, with the in house designed, single-bladed propeller proving effective at powering the AUV, and the wings and control planes producing a stable vehicle capable of operating at very slow speeds. The cruise has thus demonstrated the effectiveness of the hydrodynamic design, a crucial element in allowing Autosub LR to achieve its very long range. Considering that the AUV had never before moved in water, this all was a very satisfactory result.

The mechanical systems also proved to be easy to work on, robust and reliable. The actuators and propulsion motors could be quickly removed allowing modifications to the onboard software, while the installation of the antennae and lights in the top fin proved effective from both a hydrodynamic and functional perspective. The control planes also proved very hardy with a number of impacts with the ship on producing only minor damage which could be simply rectified.

Launch procedures, with one contact with the ship early on, improved throughout the cruise, with the 'head off on current heading' mode working effectively to drive the AUV from the ship. Recovery was practical, but only in sea states of 4 (possibly low 5) or less on this vessel.

There were, however, many problems identified. Several of these were known of before the cruise, and had not, despite our best efforts, been completely mitigated pre cruise. Others were faults or vulnerabilities identified which will naturally disappear when the system is fully implemented as originally conceived. A lack of robustness in the system electronics was revealed, as a consequence of damage during the launch and recoveries. The hardware was surprisingly robust, although some strengthening of the final actuation drive may be needed for long deployments where very rough seas can be expected. However, it should be appreciated that this vehicle is designed for energy efficient, long duration missions, and once launched would not be expected to experience the degree of stresses experienced during the cruise, with at times two launches and recoveries in a day.

So, in the main , these problems were inconveniences (often major inconveniences) during the trials cruise, and are not of great concern for the development programme, they being either fixable, irrelevant in the final version, or are a type predictable due to lack of testing time pre cruise (due to our effort spent trying to debug problems rather than system test) , and the frequency of these problems should decrease during the development programme. However, in the light of our experiences, the issue of system vulnerability to a single flooding event of an actuator or motor will be considered further.

Drag and Propulsive Efficiencies.

The propulsion system on Autosub Long Range comprises an in-house designed single bladed propeller attached to a custom designed magnetic coupling. This is driven by a brush-less DC motor which in turn is controlled by an in-house designed control board. All of this was contained in an in-house designed pressure housing. As the system was custom designed for this AUV, there was some uncertainty about how it would perform on the vehicle, particularly with respect to the propeller.

Observations of the early missions show that the propulsion system performed well; this was a real success given the novelty in the design. Unfortunately, the installed propulsion motor was irreparably damaged by impacting the ship during the launch on 26/1/2011. Prior to that useful drag figures had not been obtained, as the vehicle pitch and heading control had not been successfully tuned.

Again, unfortunately the spare propulsion motor was found to be faulty just before the cruise mobilisation, and the only replacement that could be delivered in time was of a different specification to the original. This series of events somewhat limits the applicability of the results which we did obtain.

There were only two sets of results which give useful drag figures. Mission 9 and Mission 10 (the last mission).

With only a very basic analysis at this time no attempt has been made to separate out the coefficient of drag from the propulsive efficiencies (propeller, motor and gearbox). Rather it has so far only been possible to estimate the ratio $K = Cd_v/\epsilon$, where Cd_v is the drag coefficient (based on Volume$^{2/3}$, as is our norm) and ϵ is the total propulsive efficiency. Hence K is a unitless coefficient, a scaled up version of Cd.

For comparative purposes, the K value for Autosub6000 is of the order of 0.12, which is also approximately the target performance which we are aiming for with Autosub Long Range.

From :

$$Ptot.\epsilon = \frac{1}{2}\rho.Cd_v.\mathrm{V}^{\frac{2}{3}}.\mathrm{U}^3$$

Where ***Ptot*** is the total input electrical power (measured), ***V*** is the AUV volume, ***U*** the speed though the water (measured by the ADCP).

Hence it is easy to calculate K= Cd_v/Є.

For Mission 9 , the AUV ran at 0.62 ms^{-1}, and had a total input power of 17.2 Watts. This yields a K value of ***0.12***. Buoyancy was 19 N.

For Mission 10, the AUV ran at 0.33 ms^{-1} and had a total input power of 6.65 Watts. K is ***0.35***. Buoyancy was 12 N.

Hence the AUV is performing at near specification for the higher speed, and factor of almost 3 x worse than specification at the lower speed. These results give some encouragement, plus a pointer to the need to gather more data and investigate further. The poor results at lower speed may be simply due to the (replacement) motor mismatch, and running at lower than the designed minimum speed, hence, for the moment, are not a cause of great concern.

Further analysis and testing of the propulsion system should allow some resolution of the drag and propulsive efficiency figures, even given the sparse dataset. Knowing the propeller characteristics , with the measured RPM, vehicle speed and motor torque, should provide an estimate of the AUV's drag (the greatest uncertainty being in the inflow conditions which have been calculated using computational fluid dynamics).

It is quite unfortunate that poor weather prevented the final planned tests , involving multiple speeds, and varying buoyancy (by varying the depth), plus a buoyancy driven steep ascent. This would have provided a great deal of information, thereby allowing the drag and efficiencies to be more effectively resolved. However, given the novelty in the propulsion system design, the results that have been obtained show that the system is working effectively and the design choices made produced a credible system.

Control Performance

Due to the very low speeds that the AUV would be operating in, the AUV would be operating in very low Reynolds number flows. Thus, considerable care needed to be taken in the hydrodynamic analysis as significant uncertainties exist in these regimes. It was therefore pleasing to see that the hydrodynamic design made the AUV stable in straight and level flight; this is a major requirement for the AUV's long range ambitions. The control planes also worked well at the low Reynolds numbers experienced without showing the hydrodynamic dead band seen on some aerofoil sections seen in these flow conditions. The mechanical limits to the control plane travel, imposed by the control architecture, proved to be correctly set allowing the AUV to quickly manoeuvre without showing signs of stalling. The wings also proved very effective at allowing the AUV to operate at a very low 0.33 ms^{-1} without producing significant pitch in the AUVs. These results, although only early observations, give significant confidence that the basic hydrodynamic design of the AUV is well suited to achieving the very long range laid out in the specification.

The Autosub LR has an unusual control approach : the actuators have no feedback mechanism (beyond internally) counting how far they have moved (by hall effect transition counting), the control loop makes no attempt to measure the actuator position, and the control demand to the actuators is a "move by angle", rather than "move to angle". The reason for all this, is in a word, *simplicity*, or more precisely hardware simplicity. The absence of a position sensing device removes one more sensor (for each actuator) which could potentially fail.

Initial control gains were set rather high. This was done for AUV safety reasons. Due an initially rather large deadband in the actuator control , there was concern that the actuator might not react at all to small repeated demands, and the AUV potentially dive out of control. Later in the cruise, the deadband was reduced significantly from 2 degrees to about 0.5 degrees, significantly reducing this problem.

These settings, did, as expected, cause unstable control (approximately +/- 10 degrees oscillation in pitch , with a period of 25 seconds). However the degree of instability , and ineffectiveness of reducing control gain to improve stability, did not, at first, tally with simulation results. Eventually it was realised that the settings for actuator were artificially, and unnecessarily, introducing a process delay in the control loop of more than three seconds. This would be significantly destabilising. Adjustment of the relevant parameter in the simulations, plus extra information introduced into the simulations from the early test results (such as the effective turn rate at full plane demand), produced simulation results which matched reality more closely, allowing us to more effectively select the control parameters. The problem with the actuators were also easily solved, such that no unnecessary process delay was added, the only delay being due to the limited slew rate of the actuators. A further problem was identified in the actuators – the effective operating voltage was lower than specification due to an incorrectly calculated pulse width modulation setting. Once corrected , this also increased the system phase margin by increasing the plane slew rate.

Simulation results showed that there would still be a residual limit cycle behaviour in yaw and pitch, as a consequence of the actuator dead bands. Although the values of this cycling would probably not be of any great consequence (+/ - a degree or two in pitch), it was felt that it would mask out the finer details of the linear control performance, making it difficult to resolve changes due to different control parameters, and so for the purposes of the tests, it would be useful to be able to mitigate this problem. The solution was to “dither” the control planes. For each of the 1 second control cycles , alternately +/- 0.5 degrees was added to the control plane move demand. Simulations, eventually confirmed by the mission data, showed this to be effective in removing the dead band non linearity.

A series of tests were carried out during mission 9, with a set of 12 different control setting 3 each of the integral coefficient and 4 of the proportional coefficient.

The control stability for the tuned parameters were very satisfactory, there is a 5 minute section of mission 9, where the high pass pitch standard deviation is less than 0.5 degrees, and the high pass filtered depth standard deviation is less than 60 mm (the data was passed through a simple 100 seconds time constant high pass filter prior to evaluation of the standard deviations, as the lengths of the runs at different depth demands was not sufficient for the depth achieved to be fully stabilised – see figures 2 and 3).

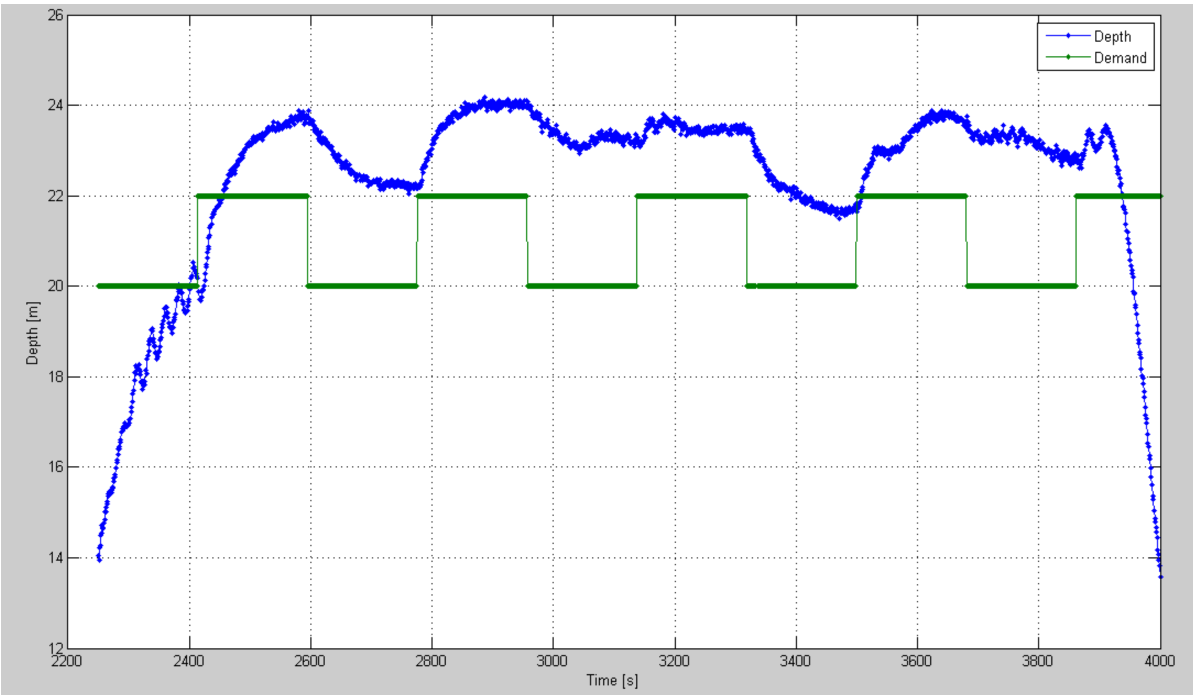


Figure 2. Depth Demand (green), and achieved depth for mission 9. Due to fault, the AUV lost control at 3900 seconds, and the mission was aborted.

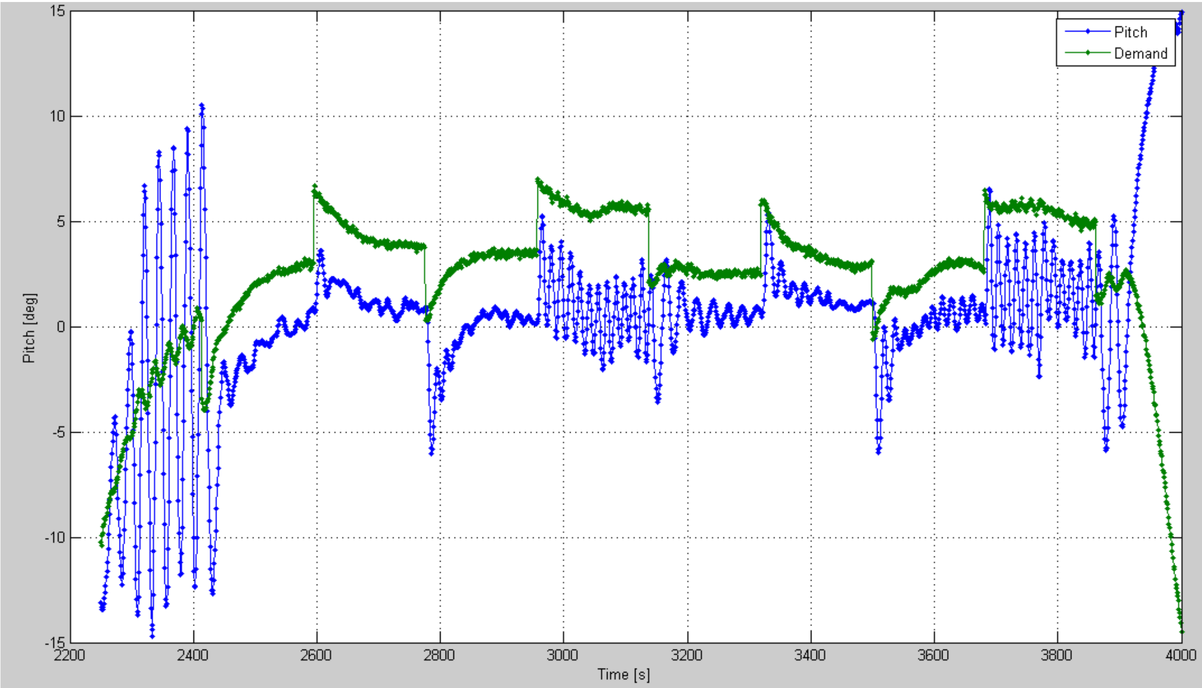


Figure 3. The Pitch demand (green), and pitch achieved for the set of control coefficients. The best control was achieved for the first three sets of control parameter at the start of the run. Best results are for I = 0.05, P = 0.6, where P and I are the control coefficients (2nd demand, 2600 to 2750 seconds). The start of the test begins at 2400 seconds.

For mission 9, run at 0.62 ms^{-1} the most effective control settings were: I =0.05, P =0.6.

For mission 10 run at 0.33 ms-1, the control stability was more easily achieved over a wider range of control gains. The most effective control parameters were : I = 0.05, P=0.9. Pitch standard deviation was 0.1 degrees, depth standard deviation of 52 mm. Further analysis and modelling should make it possible to correctly set the AUV control in depth, pitch and yaw over the full range of operating speeds.

The control in pitch and yaw are identical and of the form:

PlaneMoveDemand = I * pitch_error + P * Pitch_error_rate.

The integration effect of the planes (as they are given a move angle demand , rather than the more usual 'move to angle' demand), changes the effect of the two terms by adding an integration. In the controller code , - the plane integration effect converts the controller Proportional term (first term) to Integral , and the Differential term (2nd term) to Proportional.

The pitch controller loop runs within a depth control loop, the gain of which was deliberately set low for these initial tuning trials so that the depth control outer loop would be unlikely to affect the control stability. The outer depth control loop has the form PitchDemand = Pz * depth_error. For all the tests, Pz was set to 0.03 radian / metre, a relatively low value, which can also be interpreted as a look ahead value of 33 m.

Attitude and heading were measured with the PNI TCM 5LT sensor at a 1 Hz update rate. There were no obvious problems with this sensor, even though it was used with only with the factory calibration. The 3 axis measured field and 3 axis accelerometer output for this device was also measured, enabling us with further post processing to evaluate the compass errors.

Launch and Recovery

ALR sizes and weights:-

Dry eight – approx 560kg
Wet weight approx 1200 kg

Length approx 3.5m
Diameter – 0.8m
Wing span – 2.08m

Discussions took place before the cruise when it was agreed to use the Rexroth driven 'Rotzler' winch on the ships' CTD gantry frame. However, inspection of the winch during mobilisation showed there was not sufficient gap to winch through the Boss Hook connecting the ALR recovery line and the winch line. The plan was changed to utilise a 1.6Ton LeBus GP deck and a diverter block fixed to the deck.

Figure 4. Deck arrangement, Diverter block (by feet of Steve McPhail on right) and 1.6T orange winch in the background

Recovery lines stored in the ALR:-

12m x 12mm diameter Dyneema line (85kN breaking load) is attached to 3m to Nylon springer line attached to the ALR lifting eye.
6m loop x 5mm diameter polyamide grappling line
18m x 5mm diameter polyamide handling line attached to Dyneema line and nose of ALR.

Launch was similar to Autosub6000 and Autosub3 except it only has one lifting point.

The ALR was lifted over the side by means of the winch and CTD gantry, the lift line passed over the gantry roll enabling the ALR to be positioned as far away from the ship as possible. A light handling line attached to the tail with a small ty-wrap was used to orientate the vehicle nose away from the ship.
The ALR was lowered into the water; the lift line was released via a small Sea Catch. Soon after, the handling line was snatched off and a short 90 second mission started to drive the ALR toward open water.

Figure 5 Autosub L R lowered into the water for its first deployment in the Atlantic Ocean. Note the sea catcher release system, and the line on the tail, used to control the AUVs heading during launch (this is snapped off with a sharp tug).

Recovery is similar to Autosub6000 and Autosub3

The recovery lines stowed in the ALR were grappled using the Resqu Max line launcher to pull out the lines. Frequently, the hand thrown grapples proved more successful than the air launched one. Once the ALR's lines were been pulled on to the deck, the main lift line was made fast to a cleat and the end attached to the winch line via a Boss snap hook. The handling line was untied from the lift line to steady the ALR and keep the more vulnerable tail section away from the ships side.

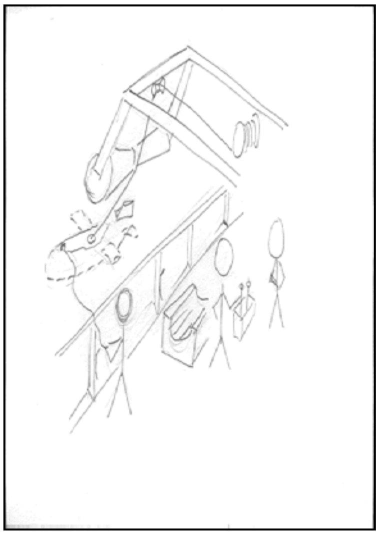


Fig 6. Schematic of the recovery once the ALR recovery lines have been attached to the winch line. Note the winch line passed over the FAR side of the roll to keep the ALR at some distance from the ship, not the near side as drawn.

The winch operator then hauled the lift line in. The ALR was lifted up close to the roller and the roller brought inboard, lifted over the bulwark and lowered on to its cradle

The recovery worked well and there were no real problems that needed addressing during the cruise although the operation of the 'roll' on the CTD gantry proved to be too fast and jerky for smooth control.   The same roll is designed to be extendable which would have helped reduce the fee board from roll to sea surface. This would have help reduce the pendulum swing during recovery.

Ship hit Incident of 26/1/2011

On 26/1/2011, the AUV came into contact with the ship following launch.

The problem with deployment of Autosub LR in the mid ship's position is the risk that the AUV could be sucked under the ship's starboard quarter, hence we arranged that the AUV runs under its own power away from the ship for 30 seconds following release from the ship. The implementation of this was that on command, the AUV runs at full power for 30 seconds, with fixed centralised rudder.

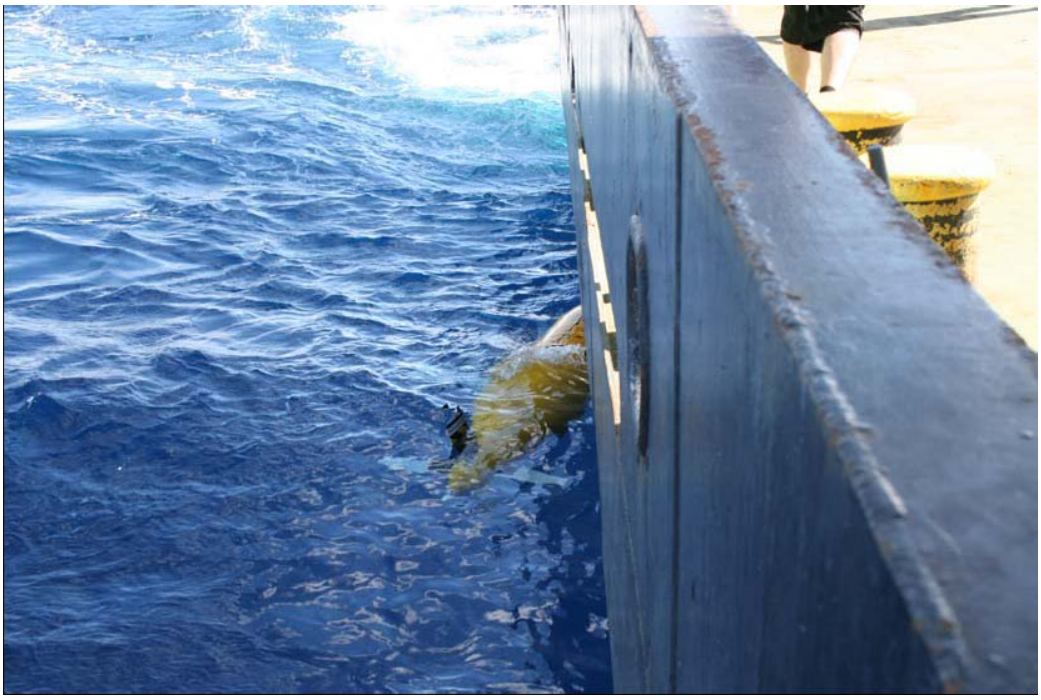


Figure 7. Autosub LR disappearing under Discovery's starboard quarter. The command to stop the ships propeller was issued

The AUV was launched as usual from the starboard side, but difficulties with release of the sea catch (it taking several attempts over several seconds) , meant that the AUV was not orientated ideally (at right angles to the ship , or slightly forward pointing), when it entered the water. In addition the tail handling line was released before the sea catch, hence we lost control of the AUV orientation at that point.

On release from the sea catch the AUV was already at a non ideal heading (about 110 degree relative to ship bow) . However the PSO decided that it was better to try and drive the AUV away, and gave the command for the AUV motor to start. With the AUV still containing a lot of air, the propeller was half clear of the water, and it seems likely that it was the paddle wheel effect of the counter clockwise rotating propeller which further yawed the AUV to point further towards the rear of the ship. For the remainder of the 30 seconds, the AUV continued to veer around aft-wards, and eventually towards the ship. In retrospect, it might have helped to stop the AUV propeller , after about 15 seconds , when the unfavourable trajectory of the AUV was noticed.

With the AUV drifting towards the starboard quarter, the ships side attempted to swing the ships head to starboard with starboard rudder and moderate propeller RPM. Unfortunately , with the AUV now close to the ship, this only had the effect of sucking the AUV under the counter and towards the propeller. At this point the request was made by the PSO to stop the ship's main propeller. This (fortunately) was executed almost immediately, preventing much more serious damage to the AUV.

The AUV surfaced on the starboard side. Initially the severity of the damage was not noticed. Following recovery, however, it was noticed that the propeller motor end cap assembly had been hit partially off, and the only thing preventing the propeller assembly being lost was the magnetic coupler attraction. Flooding of the motor assembly destroyed that system, and consequential to that, voltage from the main power bus were able to short circuit onto the I2C bus, causing irreparable damage also to the sternplane and rudder controllers.

We had enough spares to effect repairs, and the vehicle was operational 2 days later.

The general recommendations resulting from the incident were that:

Ensure the vehicle is pointing toward not aft of 90 relative to the ships bow.

Implement in future a more effective quick release system

Don't release the tail handling line until after the lifting line is released.

Being prepared to stop the ALR mission if it looks like the vehicle is turning toward the ship.

Being prepared to stop all ship manoeuvring if it looks like a collision might happen.

Implement that the AUV controls its heading away from the ship (rather than just keep constant rudder angle). (This was implemented successfully for later missions).

The Video evidence was extremely useful in determining the chain of events. We should endeavour to film L & R as much as possible in the future.

Further launches were without mishap.

Major Problems and Faults identified

The list below is a list of the major problems found. Not that several of these problems had already been identified, and that some are not fully relevant given planned developments.

Fault	Description	Remedy
SYSTEM PROBLEMS		
I2C Lock	The I2C interface on the PXA270 becomes locked during I2C transactions , at a frequency (minutes to hours, which is clearly unacceptable. It seems that noise on the line , or ground noise (the actuators and the motor share a common power and I2C signal return), make the problem more likely to occur. It may also be the case that the PIC I2C interfaces can also become stuck. This appears to be either a fundamental specification problem with the I2C interface specification or a problem with its implementation. It is clearly not acceptable behaviour for the system under any circumstances. The problem was recognised before the trials.	There is no remedy at present. Although it appears to be recognised that there is a hardware problem with the PXA270, it is not possible to reset the PXA270 interface using our present drivers. The control PICS can be reset, curing any such hang up with them, and the capability to do this was added during the cruise. Factors which reduce the likelihood of this occurrence, such as the ground noise, line capacitance etc, could be tackled but there will still remain the unacceptable vulnerability – until we can reset the PXA270 I2C interface.
Dynamic linked libraries out of sync	A failure during a mission was due to a change having been made in one dll (mission support scripts) , and other dll's which accessed data from that dll , not also being recompiled.	Change Management, Version Control, files under one project, needed for all builds of the system.

More than one instance of control program running	One abort was caused by the operator running two instances of the ALR control programme	The system and procedures at present is recognised to be temporary , and needing better control. Such will be implemented. A more integrated operations and runtime environment is needed.
VNC crash. Cannot be recovered without a system reboot.	The virtual desktop which we were using for control of the AUV operation (VNC) will crash periodically. This requires a reboot to restart. VNC instability is also suspected to worsen the I2C lockout problem (some interrupt conflict or service rate problem?)	Virtual desktop is a temporary approach to control of the AUV programmes. In future this will be replaced with a simpler command line driven system, which can be operated over Iridium. Hence not worth spending much time fixing the VNC problem.
Checksum weak for I2C transactions	The checksum (16 bit addition of all the data words) is too weak at detecting message errors. This is not of great consequence for command data, as the data are repeated every 1 second, and sensibility checks are made. However , for the configuration data the consequence of a undetected fault could be catastrophic and is suspected of causing an abort.	Short term remedy was to implement a “lock variable”. Configuration cannot be set if the lock is active. The chance of the specific unlock code occurring by chance was considered acceptably low for the trials. Longer term solution is probably a stronger CRC code on all data.
The Abort system is vulnerable	The abort system as presently implemented is recognised to be vulnerable to main process crash. The system worked without fault during the trials, but the vulnerability is recognised.	The abort system as presently implemented was a short term solution. The original design calls for a separate system running on a PIC. This allows it to operate independently of the main system, and able to check for the main system health via watchdog messages.
System Vulnerability to single point flood	A flood in the propulsion motor caused irreparable damage to the three motor controllers, and an I2C daughter control board in the main pressure sphere. Within a single mission a flood is irrecoverable, hence what happens to the rest of the system is somewhat irrelevant. But for the purposes of testing and trials however , it is inconvenient to lose so much hardware with one hit.	Increased buffering and protection will be considered for the system rework. Such protection had been kept minimal in order to save power.

MECHANICAL PROBLEMS

Shear Pin Failure on drives.	Shear pins for final drive of actuators failing on rough recoveries.	This is as designed. Whether they are set to fail at a level practical for long term deployment is another matter, and will be reviewed.

Gearwheel failure on rough recoveries or following impact	The final actuator drive gearwheel fails for rough recoveries. Note that the shear pin failing did not protect this.	We need to review the design fail points in the system with regard to the maximum stresses expected during operations (e.g. on the surface in a force 11), and during launch and recoveries. There are conflicting requirements of minimising the spread (and cost) of damage caused in a rough recovery, versus the cost of rescue (or in worst case loss of vehicle) following a potentially unnecessary failure during a long mission.
Salt crystals binding Actuator bearings	Salt crystals binding the actuator bearings post missions .	This would dissolve out when deployed, but an inconvenience during the trials. A way is needed to either prevent this happening , or make easy access for flushing with fresh water.
Actuators seem to lack torque	At times the actuators did not seem to have enough torque enough for the task. However much of the problem can be explained as due to a) salt crystal problem during test on deck, b) an initially incorrectly calculated maximum PWM setting for the actuator.	We need to review the settings and gear ratios, but later tests seemed to indicate that the problem may have been solved by increasing the PWM, and flushing the bearings

Autosub Missions Summary Table

#	Date	Duration	
1	22/1/2011 1022	30 s	Test run on surface. ADCP read problem causing crash of main control programme. Once this problem had been solved the mission was run again. Ground fault was detected automatically and the mission aborted with ballast weight drop.
2	23/01/2011 1130	10 min	Dived successfully but unstable flight due to high control gain setting.
3	23/01/2011 1500	2 min	Aborted due to I2C stuck fault on dive run up, causing abort script to run.
4	24/01/2011 1150	5 minutes to fault, 40 minutes submerged	Sternplane PIC code malfunction caused actuator to stick, causing uncontrolled dive. The event 'I2C stuck' was detected by the system, turning the AUV motor off. The abort timeout occurred before the AUV reached the surface, causing the ballast weight to be dropped. The fault was thought likely due to the PIC receiving incorrect configuration data due to a weakness in the strength of error detection for messages sent over the I2C network. This uses a simple checksum. Work around on the cruise was to introduce a lock system for the configuration data. Once a particular variable is set, then configuration data cannot be changed. Longer term solution is likely a stronger code, e.g. CRC.
5	26/01/2011 0915	00:51:26	Dive with multiple control coefficient settings for controller tuning. On first attempt at this mission, the AUV control crashed, causing an abort. Reason was that the operator had loaded 2 instances of the control program. 2nd attempt at mission was without incident, but due to an incorrect scaling factor in the mission control main code the varying speed runs were not effective, all runs being at full power.
6	26/01/2011 15:03:00	NA	During launch the AUV collided with the ship, badly damaging the propulsion motor , sternplane and rudder controllers (motor drivers all beyond repair).
6	30/01/2011	NA	Mission aborted as a change had been made to a structure within mission support dll, this causing incorrect pointer referencing from the abort script.
7	30/1/2011	NA	Tried running at high power. The I2C to become stuck during dive run up. In the process of trying to clear the I2C by rebooting the system the abort weight was dropped.
8	30/01/2011 13:32:00	00:08:20	Attempted to dive @ 0.8 motor power (~68RPM) failed to dive as abort weight already dropped (we did not know that at the time).
9	31/01/2011 15:39:00	00:36:35	Straight run @ ~20m depth and 0.8 PWM to test control configurations. First part of dive was a success (@ 0.8 PWM) but the Control planes locked in position after 1085s for rudder and 1910s for stern planes. Caused the sub to surface aborting the mission. Cause was I2C lockup.
10	31/01/2011 00:00:00	01:00:00	Straight run @ ~20m depth to test control configurations at low speed (0.6 PWM). Was successful. AUV was recovered at night, without problems.

6. HyBIS operations: Cruise D360

Bramley J Murton

Objectives of this mission were to test deep-tow floatation and its effects on the handling of the HyBIS vehicle, test new video recording via iMac computers and Canopus ADVC110 video digitisers, and to train personnel in operating and maintaining the system.

The use of five 10L syntactic foam floatation buoys attached to the deep-tow cable worked well with easy attachment and detachment to the cable during vehicle deployment and little discernable effect on the vehicle handling.

The Canopus / iMac / 2Tb USB2 disc storage video recording set-up worked well, via iMovie, although the real-time video display via iMovie was a little jerky due to buffering of the i/o data stream. This did not affect the recorded vide, but was annoying to watch for the vehicle operators.

The trainees spent almost the entire dive time piloting the vehicle and managing the data. They also spent time servicing the deep-tow termination bottle and the electronics pod.

Pre-Dive preparations:

Following low-voltage deck tests of the HyBIS vehicle and top-side controls box, video recorders and displays, the vehicle was made ready for launch. This required a fibre-optic termination to be completed on the ship-side deep-tow cable. Unfortunately, the ship-side termination kit was found to be incomplete with no activator for the setting compound or cleaving tool for the fibre. Regardless, the termination of the fibre was made good using super glue and araldite.

Dr Bramley Murton (yellow boiler suit) at the HyBIS nerve centre

Date: Sunday 22nd January 2011; Latitude 23°560N; Longitude 20°42’W; Depth 1100m

At 23:00h GMT the vehicle was tested through the deep-tow cable and low-voltage deck power pack and found to be working. On switching to the high-voltage supply through the deep-tow cable, a ground (earth) fault was detected by the HyBIS power transformer. This was traced to the termination bottle where a stray strand of copper conducting wire appeared to have broken through the insulation. The bottle was opened, the fault corrected, new insulation put in place, tested, the bottle reassembled and filled with oil. By this time it was 4:30 am and the dive postponed as the dive window was closing at 7am. However, the fibre-optic link in the bottle was found to have failed. We opened the bottle, cut the ST connector and reterminated the fibre including polishing it. Unfortunately, the ship’s fibre-optic termination kit was incomplete with no cleaving tool or fibre glue. The fibre was eventually fixed and polished, tested and the bottle secured.

The next day, when testing the vehicle on deck through its high-voltage power supply, another earth fault was detected by the top-side transformer’s GFI. The bottle was checked for insulation using a mega meter and found to have reduced insulation at 1000V. The bottle was opened, and the wiring remade with crimps, over insulated with heat shrink and re-tested. The insulation was still reduced at 1000V, so the entire high-voltage termination assembly inside the bottle was wrapped inside a 0.5mm thick polycarbonate cylinder. This proved sufficient to ensure good high-voltage insulation.

However, the fibre optic termination was found to be poor with the fibre loose inside the ST connector. This is almost certainly a result of the inappropriate glue being used (the correct fibre glue was missing from the termination kit). The fibre was cut, stripped and a new ST connector glued on. The fibre then was re-polished and tested resulting in a 3db loss over the length of the deck cable. The termination bottle was reassembled, tested and attached to the HyBIS vehicle where it was tested again at high-voltage and through the fibre-optic core.

Date: Sunday 22nd January 2011; Dive 30; 23°560N; 20°42’W, 1100m

2300H. Vehicle pre-checked and ready. Deployed with five floats on deep-tow cable. First float attached at 10m w/o. Then subsequently at 3 m intervals. Stopped at 50m and powered up vehicle. All systems ok. Proceeded to veer winch at up to 40m/min to the seafloor at 1004m. Flat and muddy seabed. Ship drifting to SW at a maximum of 0.3kts. Vehicle behaved well, with manoeuvrability of ±50m. USBL not working dues to wrong transponder ID code. Spot light on forward looking light bar caused over saturation in centre of field of view. Moving slowly into progressively deeper water.

0513H, 23rd January 2011, depth 1410m, edge of steep cliffs. Lava tubes, sheet flows and fissures on near vertical walls. Cliff is steps of 200m vertical ascent followed by wide ledges of up to 100m.

0552H: End of dive, started recovering vehicle.

DIVE 31: Date: Sunday 22nd January 2011; 23°54.11N; 20°43.13’W, 1100m

Pre-dive preparation involved rotating downward looking camera to ensure the front of the vehicle faced towards the top of the video screen. The HD camera inside its pressure bottle had to be adjusted for position to avoid vignetting in stills mode. Swapped the forward spot light for a flood light to homogenise the field of illumination.

16:25H, deployed HyBIS with five cable floats. At 50m, the vehicle was powered up and the USBL with the correct ID code was now tracking. Descended to 1138m on to a rocky but smooth seafloor. Ship drifting at 0.5kts to the SW, causing reduced manoeuvrability of the vehicle. Sheet flows and sediment. Some coral and sponges. Attempted to grab some loose boulders. Very difficult to control vehicle with a remote winch operator. Also speed of movement caused the vehicle to be pulled away from the grab sites before we could close the grab. When on the bottom, the winch veered out a further 2 to 3 metres of cable – the cable floats seemed to be able to keep this loose cable free of the vehicle which remained stable.

17:40H, at 1161m, the vehicle lights thrusters, hydraulics, control telemetry and compass card failed and stopped communicating. The vide feeds remained on, as sis control to the HD camera. Powered off the vehicle and initiated recovery.

Diagnosed a 24V power supply failure inside the electronics pod. Removed the pod from the vehicle and opened it on the work-bench. Found ~10ml of water inside the pressure tube. Checked continuity of the 24V supply wires and 24V PSU. Removed the PSU and powered it directly on the bench with 110V ac in (from the HyBIS deck box) and confirmed zero volts output. Checked with HydroLek Ltd. whether the lower powered PSU (50W instead of 100W) will suffice. Changed the PSU for the lower powered version, and powered up with 110V. The PSU produced the required 24V and the internal electronic boards became live (diagnostic LED's lit up). Tested communications on a fibre-optic deck cable and all systems found to be working.

Checked the pod for evidence of low-pressure leaks. Some water was found behind the DGO'Brian bulkhead. Some long head-hairs were also found crossing the end-cap O-ring seal. Found several scratches crossing the o-ring face seal on one end of the pressure tube. The scratches are deep enough to cause concern. Close inspection of the pressure tube revealed a pre-anodising scratch on the opposite face seal outside of the O-Ring face. Also tool marks on the end-cap where the piston seal screw caps are seated and inside the piston seal hole into which the pistons seals are set.

After taking advice from Kevin Saw (Design engineer on board) we decided the pressure tube and end-cap need re-facing and re-anodising. Documented and disconnected the bulkhead leads from the terminal rails on the electronics chassis and removed it to safety. Wrapped and sealed the electronics chassis in bubble wrap and cling film. Vehicle ready to be decommissioned.

On inspection of the grab bucket, it was noticed that there is a slight bend of the leading edge of the over-bite jaw. This will need straightening at the NOC workshop.

Other issues: The HD camera needs to be removed fro its pressure pod and set to '*show data on video*' by operating the touch screen on the camera body. This setting is stored, but only for 3 months. Other settings such flash, focus, face recognition, demo mode, etc. have to be reset each time the camera is used.

Conclusions:

At the start of the trials, the HyBIS vehicle was found to be working perfectly on deck.
The termination of the deep-tow cable proved problematic without the correct components in the ship-supplied termination kit.
The termination bottle also developed an earth leak at high-voltage, the ultimate cause of which remains unknown, but was overcome with the use of additional insulation.
The deep-tow floatation buoys worked well.
A low-pressure leak, possibly caused by a scratch on the pressure tube o-ring face, caused us to terminate the vehicle trials. The cause of the scratch is unknown, but was found upon opening the pressure tube for the first time on this trial.
Other manufacturing defects were found on an end cap, although these have not leaked in the past and, they are not desirable and are probably stable.
The 24V PSU failed, possibly a result of water damage.

Recommendations:

The pressure tube and end-cap must be re-ground and re-anodised.
Better insulation is required for the high-voltage termination bottle connections.
Spare boards are required for the electronics and power pods. These include spare PSUs.
Ideally, professional video recording decks should be purchased.
The three laser ranging devices need to be refurbished with a more secure oil-filled box for the batteries.

7. Ellsworth HD camera trials

Lee Fowler

The objective s of the trials were to test the HD video camera and lighting system for the Lake Ellsworth project.

20/01/11 Dive 1

20:06 off deck – Target depth of 4013 meters

20:08 Wet – out at 30m/min

20:42 Lost video and control communications with vehicle at 1158 meters – dive aborted with vehicle recovery necessary.

21:36 Trials rig on deck.

Fault found with the fibre optic link within the HyBIS termination bottle and a re-termination was necessary, OTDR indicated a total loss of fibre connection. Fibre and electrical connections was re-made with point to point reading from the main lab junction box to the HyBIS termination pot of 3.5db 1310nm and 2.8db at 1550nm.

21/01/11 Dive 2.

03:05 off deck – Target depth of 4027 meters

03:08 Wet – out at 40m/min

05:10 Veer speed reduced to 5m/min at 3950 meters

0518 On bottom at 4036 meters – Light L1 – DM252-MR11 20watt @ 10 deg

05:25 Light L2 – DM252-MR11 20watt @ 30 deg

05:30 Light L3 – DM252-MR11 35watt @ 20 deg

05:33 Light L4 – DM252-MR11 35watt @ 30 deg

05:46 Recover at 40m/min

07:10 Winch fault at 97 meters – all stop

07:40 Winch fault cleared, continue recovery

07:45 On deck

Video from the IK-HD1H was found to be excellent with good definition at all illuminated heights of bottom.

Problems found with the Ellsworth camera trials rig on dive 2.

1 - Narrow lighting angles were chosen for the first dive because the altimeter chosen for the Ellsworth probe was unavailable for this cruise and therefore only visual bottom detection was available for off bottom height. It was found that these lighting angles only illuminated about half of the cameras field of view and that wider angles would be necessary on future dives. The power outputs of the lighting were found to be sufficient to produce good lighting density for the standard 40 dB version of the IK-HD1H camera. The Ellsworth probe cameras will be 54 dB military versions and a controllable light source would be needed for this higher gain unit.

2 - The Convergent design nanoFLASH HD recording unit was borrowed from Polecam Ltd for this cruise to trial this type of recording device for possible use on the Ellsworth probe. It was found to be a version manufactured before October 2009 without the power down mods found on later versions. This old version lost setting when powered down so the unit reverted back to its default settings which included a recording file format of raw HD *.Mov. Currently this unit is fitted with 2 x 32GB ST cards and this proved insufficient capacity to record video once the vehicle reached the bottom on

dive 2 – 133 minutes total record time for both cards. Modification to this unit have now been done to retain a *.mp2 file format and also offer surface control of these recording options. Test has shown a recording time of over 4 hours with the new modifications to the nanoFlash.

25/01/11 Dive 3

02:40 off deck – Target depth of 1085 meters – Veer at 40 m/min

03:20 Depth 100 meters – reduce veer to 5 m/min

03:40 On bottom – Light L2 - DM252-MR11 35 watt @ 20 deg

03:50 Light L3 – Solarforce high pressure Xenon

04:00 Light L4 - DM252-MR11 35watt @ 20 deg

04:11 Light L1 -MR16WT15 50watt @ 60 deg

04:26 Recover – problems with winch during recovery

06:20 On deck

A successful deployment of the Ellsworth HD camera test rig with full control of lighting and video recording modes produced excellent quality HD video. All lights producing good illumination with Light L1 producing the most effective lighting results with over illumination only occurring at 0.5 meter or less. Dimming capability would therefore be needed with this current lighting scheme.

Results show that a single 40 – 50 watt @ 50 – 60 degree lighting angle would be optimum for the Ellsworth probe.

26/01/11 Dive 4 (45deg camera angle)

21:58 off deck – Target 3860 meters – Veer at 60m/min

23:14 Reduce veer to 10 m/min at 3800 meters

23:16 Reduce veer to 5 m/min at 3850 meters

23:33 On bottom at 3909 meters – Light L2 - DM252-MR11 35watt @ 30 deg

23:40 Light L3 – Solarforce high pressure Xenon

23:45 Light L4 - DM252-MR11 35watt @ 20 deg

23:50 Light L1 -MR16WT15 50watt @ 60 deg

24:00 Recover

02:30 On deck

As with dive 3, lighting and the video were near perfect with L1 giving the best definition.

27/01/11 Dive 5 (Bait bag attached)

21:42 Off deck – Target 4048 meters

12:20 Winch stopped with scrolling problems at 3947 meters

01:20 Winch fixed – veer at 5 meters/min

01:33 On bottom at 4049 meters – light L4

01:38 Light L3

01:42 Light L2

01:44 Light L1

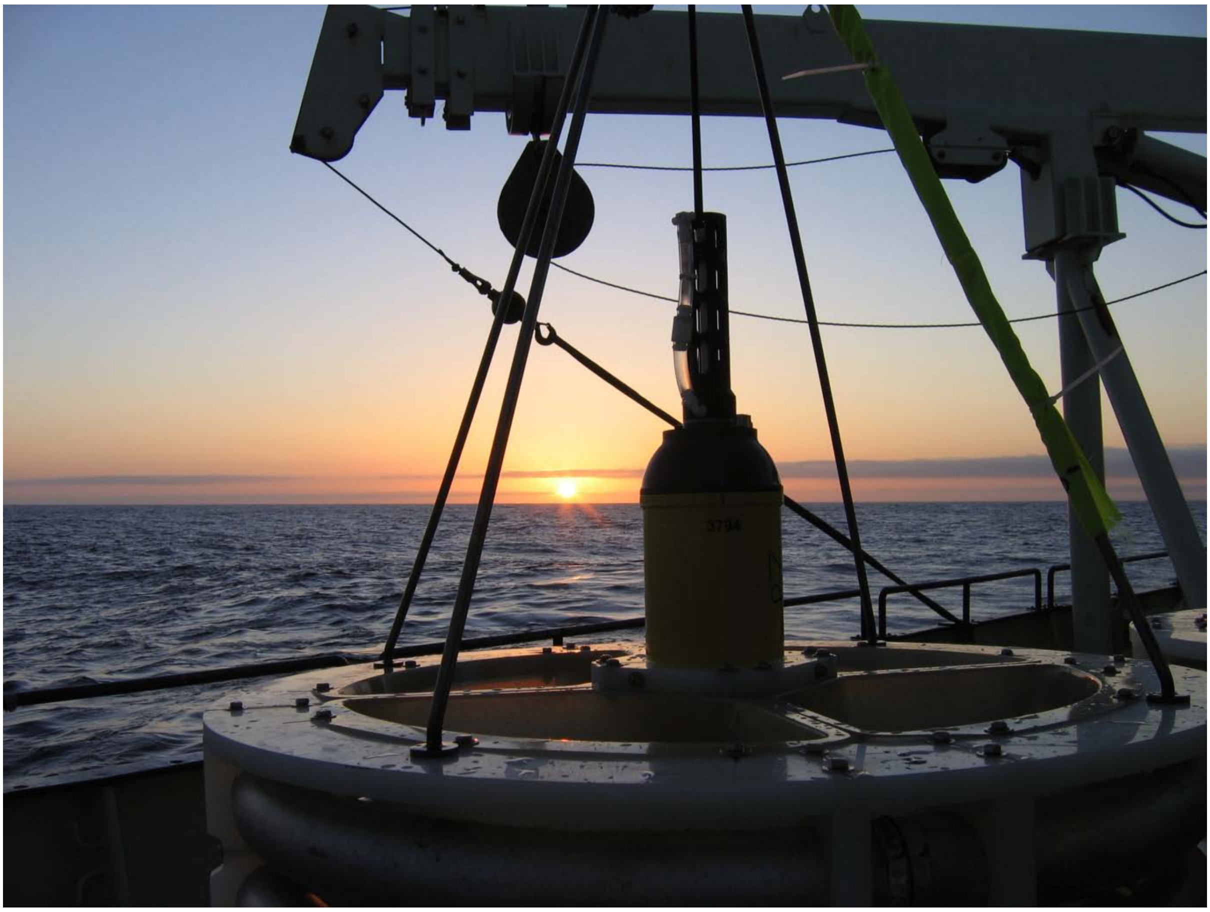
01:49 Recover at 40m/min

04:50 On deck

Final trials dive with the camera rig fitted with a bait bag to see if any biology could be filmed. The IK-HD1H camera once again performed faultlessly throughout but no biology came into view.

8. Pelagra Operations

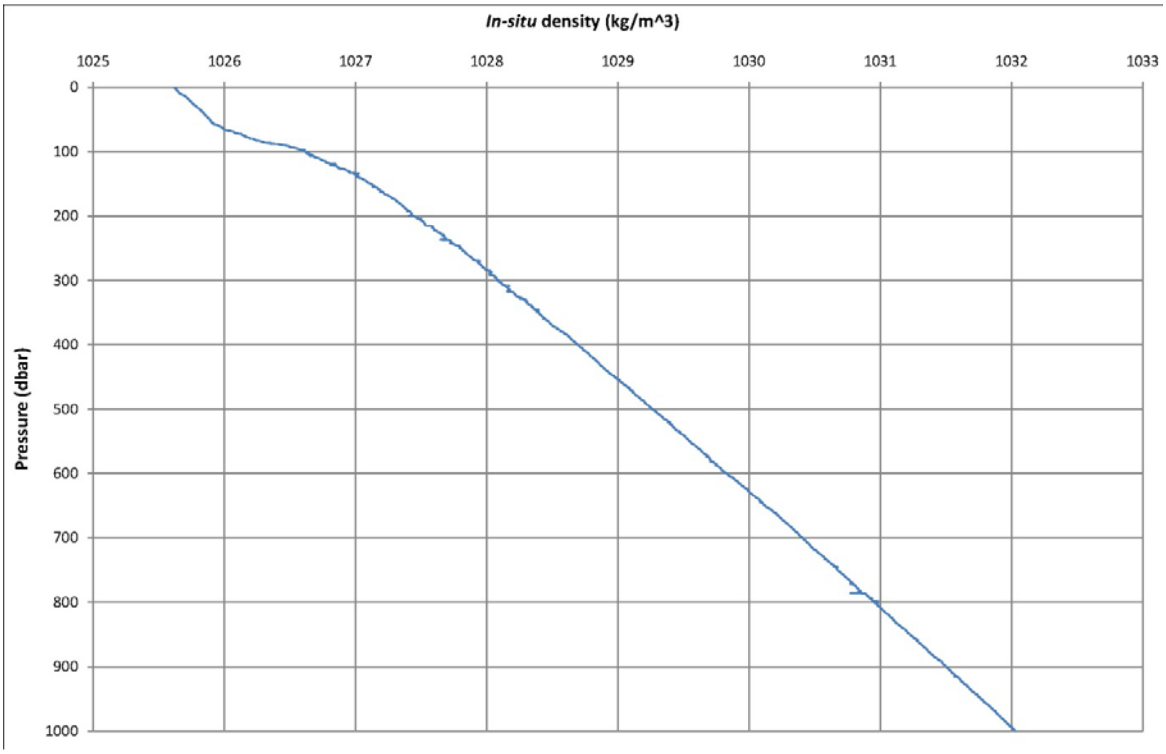
Kevin Saw and Sam Ward



20.01.11 Deployment 1

1810h Idronaut Ocean Seven 304 CTD logger (s/n 0605070) deployed on deep-tow wire at position 24.250°N, 20.505°W to 1000m.

1919h CTD deployment all finished.



2230h Pelagra P6 (isopycnal mode) deployed at position 24.268°N, 20.512°W. Target depth 300m. Scheduled to surface at 1705h on 22.01.11. Three opening cups and one blank.

No tag lines were used during deployment resulting in significant swinging. Trap reluctant to sink once released leading to suspicion that one or more weights had been dislodged as trap swung on entry to water.

2300h Pelagra P7 (isobaric mode) deployed at position 24.271°N, 20.508°W. Target depth 300m. Scheduled to surface at 1735h on 22.01.11. Three opening cups and one blank.

Tag lines used resulting in controlled deployment. Trap sank promptly as expected.

2310h Pelagra P6 still visible at surface.

2330h Pelagra P8 (P4) (isopycnal mode) deployed at position 24.273°N, 20.503°W. Target depth 300m. Scheduled to surface at 1805h on 22.01.11. Three opening cups and one blank.

Tag lines used resulting in controlled deployment. Trap sank promptly as expected.

21.01.11

0024h Pelagra P6 still visible on surface so recovered to deck at position 24.175°N, 20.505°W.

Trap was floating very low with waterline approximately level with base of flash light. Trap was grappled and transferred to a lifting strop. Once clear of water it was apparent that all weights were in place. Base of trap suffered major strike on ship's rail when swung inboard - no apparent damage but Apex float was found to have slipped down in its clamps once on deck; this is easily rectified. No obvious reason has been found for failure to sink - investigations are ongoing.

22.01.11

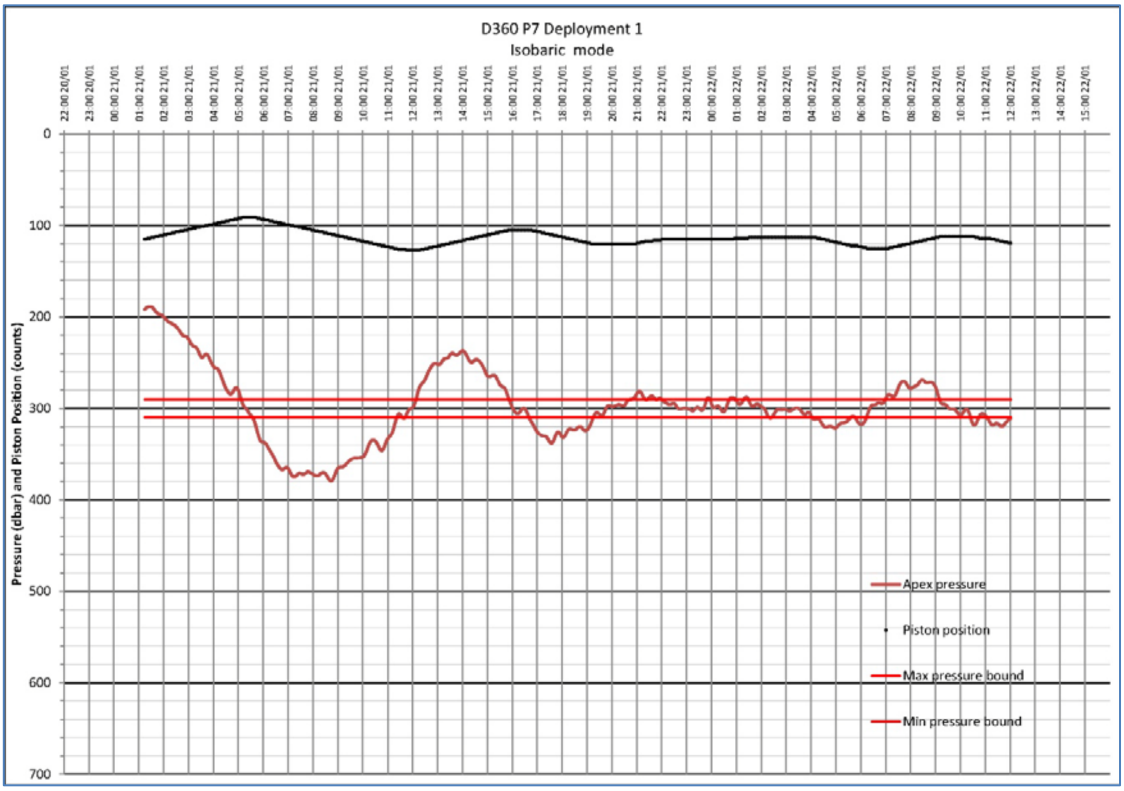
1601h First surface position received from P7 at 24.285°N, 20.394°W. P7 was not scheduled to surface until 1735h so this was an indication that something was not right.

1853h First surface position received from P8 (P4) at 24.284°N, 20.354°W.

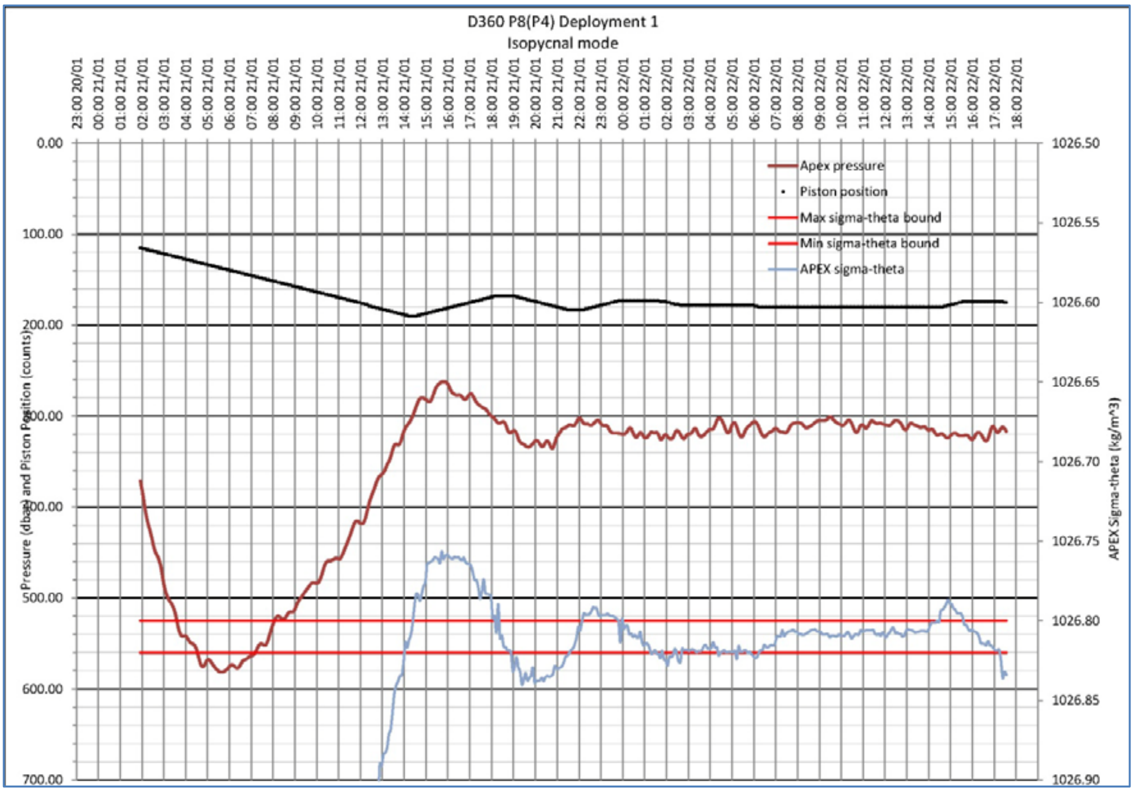
Surface positions for P7 and P8 (P4) were 7 and 10 nm respectively on a bearing of approximately 84° from the deployment position. It was expected that the traps would follow the Canary Current in a south-westerly direction but this was not the case.

1900h P7 recovered at 24.263°N, 20.382°W. The sample cups were found to have opened but not closed. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. No significant sediment was collected probably due to wash-out on ascent.

On inspection, P7's APEX float was found to have terminated its profile and initiated ascent 5 hours early. This erroneous behaviour has been seen before and will be investigated. Sample cup operation was subsequently checked on deck and found to be trouble free; it is not clear why they did not close during the mission.



1945h P8 (P4) recovered at 24.277°N, 20.350°W. Sample cups had operated as expected. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. An amount of sediment and a few comb jellies were collected in the three sample cups. No sediment was visible in the blank.



24.01.11 Deployment 2

0000h Pelagra P7 (isopycnal mode) deployed at position 23.918°N, 20.470°W. Target depth 300m. Scheduled to surface at 1835h on 26.01.11. Three opening cups and one blank.

0030h Pelagra P8 (P4) (isobaric mode) deployed at position 23.915°N, 20.470°W. Target depth 300m. Scheduled to surface at 1905h on 26.01.11. Three opening cups and one blank. Park Band, Mbd, set to +/-5 dbar.

Textbook deployments, both traps sank promptly as expected. Deployed for 24 hours longer than previously to check if depth stability improves over time.

26.01.11

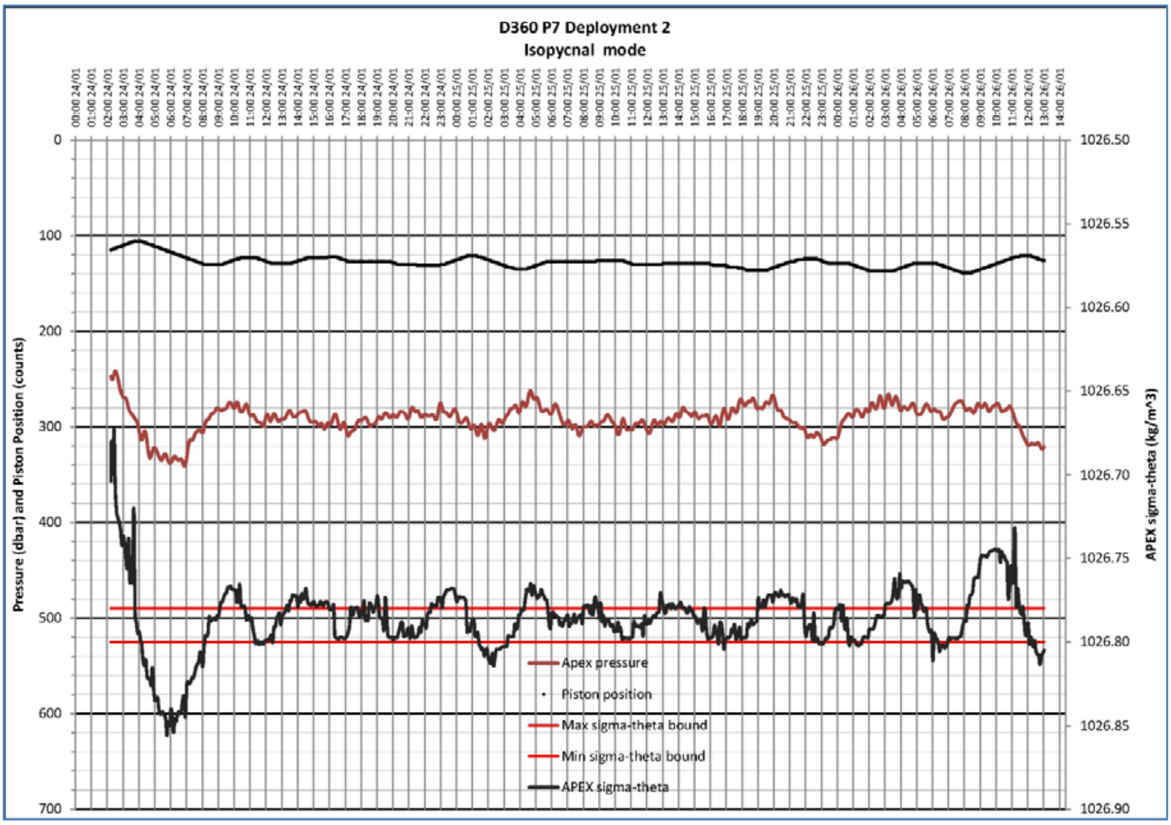
1701h First surface position received from P7 at 23.821°N, 20.308°W. P7 was not scheduled to surface until 1835h thus indicating that it had terminated its mission early again.

1952h First surface position received from P8 (P4) at 23.821°N, 20.310°W.

Surface positions for P7 and P8 (P4) were 13 nm on a bearing of approximately 123° from the deployment position.

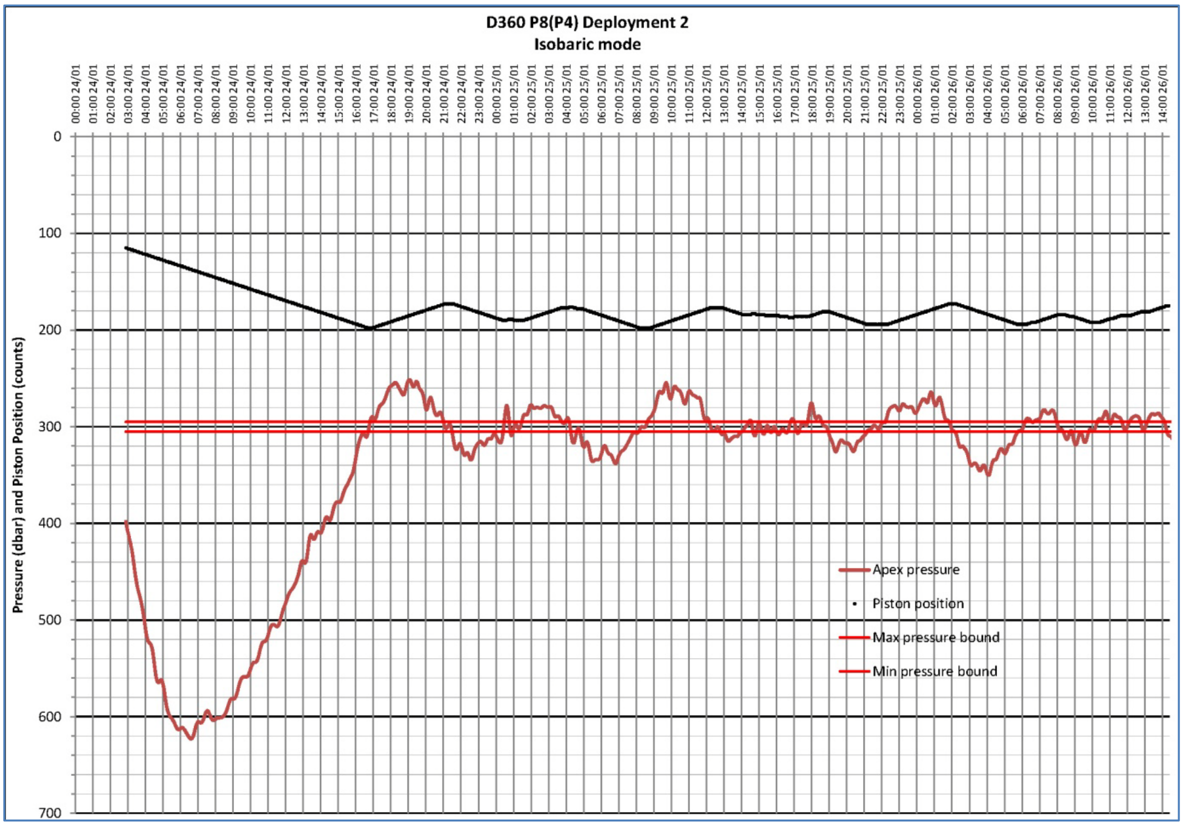
2003h P7 recovered at 23.795°N, 20.308°W. The sample cups were found to have opened but not closed. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. No significant sediment was collected probably due to wash-out on ascent.

Base of trap suffered major strike on ship's rail during swing but appears to be undamaged. On inspection, P7's APEX float was found to have terminated its profile and initiated ascent 5 hours early as in Deployment 1. On inspection it was thought that the driving worm was a little tight to the worm-wheel so the gearbox position was adjusted.



2048h P8 (P4) recovered at 23.813°N, 20.315°W. Sample cups had operated as expected. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. An amount of sediment was collected in the three sample cups. No sediment was visible in the blank.

P8 (P4) was recovered along starboard side tight to the ship's side rather than being swung round to the after deck. This gives a much more controlled recovery.



27.01.11 Deployment 3

2000h Pelagra P7 (isobaric mode) deployed at position 24.177°N, 20.533°W. Target depth 300m. Scheduled to surface at 1935h on 29.01.11. Three opening cups and one blank. APEX float was set up with a Park Band, Mbd, of +/-100 dbar (max of available range) with the intention of investigating the traps behaviour in 'passive' mode, i.e. no buoyancy adjustments. It was realised that P7's Deep Profile Descent Time parameter, Mtj, was set to 300 minutes (5 hours) whereas P8's was set to 0. Given that P7 had consistently terminated its mission 5 hours early and P8 had not, it seemed likely that the Mtj parameter was to blame; this was set to 0 to test this theory.

Deployed using longer release strop than usual. The strop consequently snagged on Iridium antenna on release. Strop was eventually dislodged using long pole - no apparent damage was caused and trap sank promptly as expected.

2030h Pelagra P8 (P4) (isobaric mode) deployed at position 24.177°N, 20.533°W. Target depth 300m. Scheduled to surface at 2005h on 29.01.11. Three opening cups and one blank. Piston Adjust Period, Mbx, set to 10 minutes and Park Band, Mbd, set to +/-10 dbar.

Textbook deployment using the usual short release strop, trap sank promptly as expected.

2145h Pelagra P6 flashing light beacon deployed at position 24.215°N, 20.627°W on Ellsworth video camera for pressure switch test. Light switched off at 23m on descent and back on at 16m on ascent.

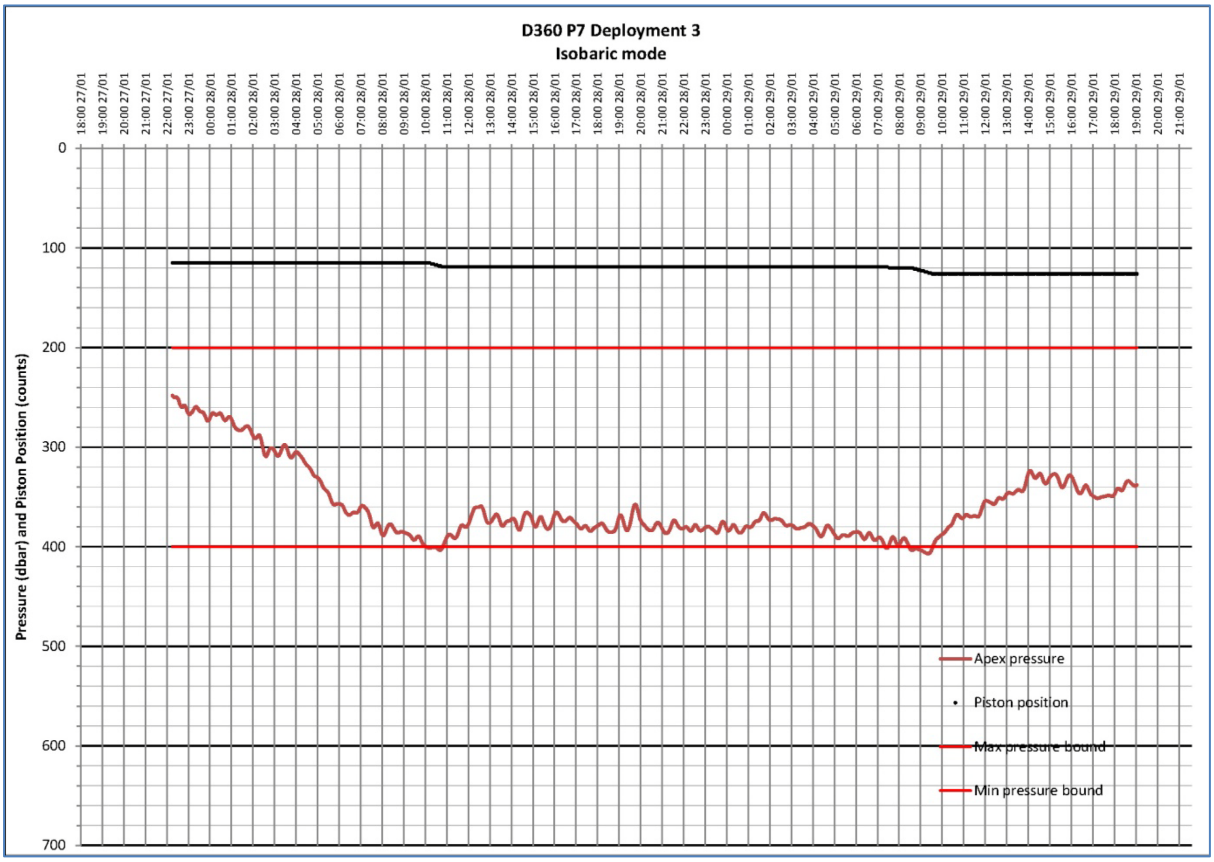
29.01.11

2028h First surface position received from P7 at 24.115°N, 20.416°W. It does not appear that P7 has surfaced early as before.

2033h First surface position received from P8 (P4) at 24.125°N, 20.428°W.

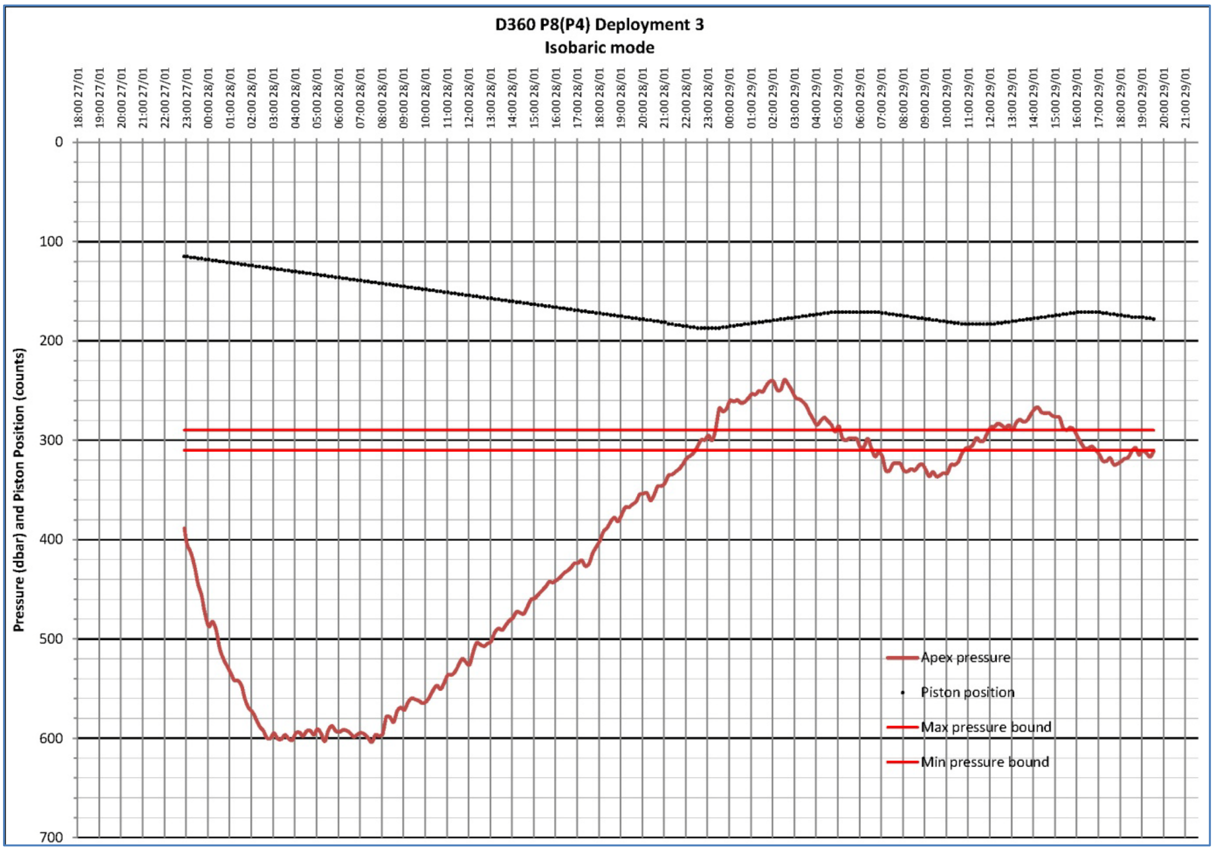
Surface positions for P7 and P8 (P4) were 9.5 and 8.4 nm respectively on a bearing of approximately 120° from the deployment position.

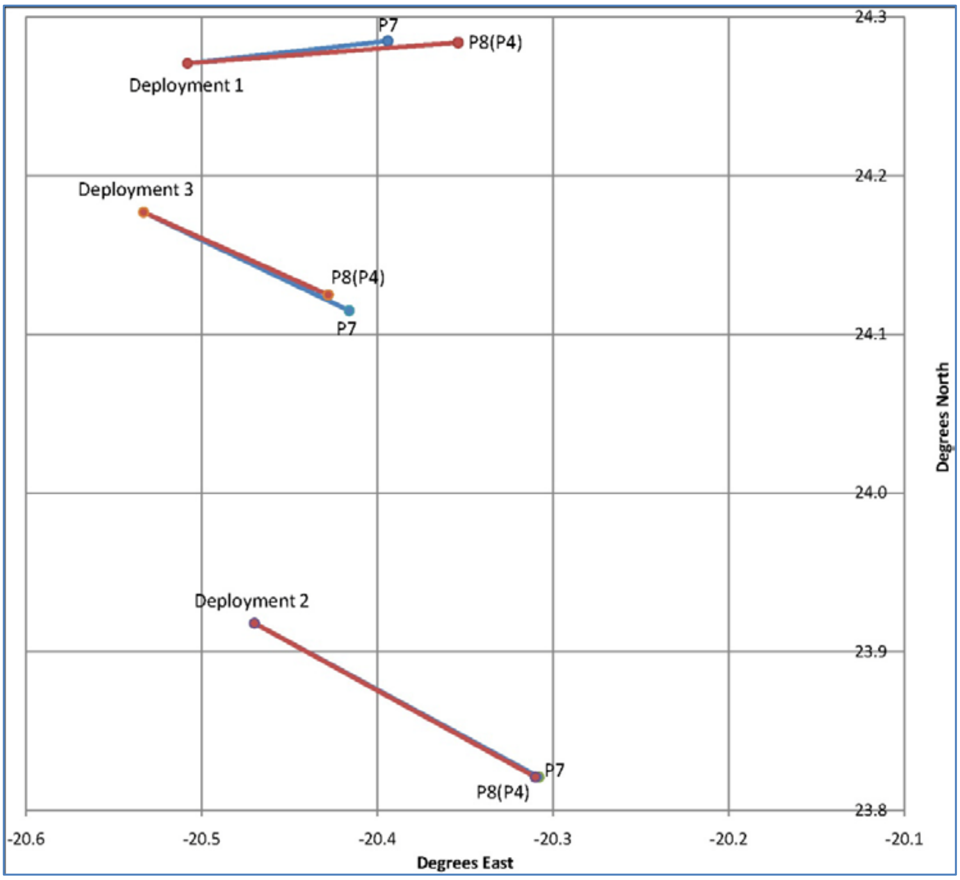
2248h P7 recovered at 24.090°N, 20.403°W. Sample cups had operated as expected. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. Very little sediment was collected in the three sample cups. No sediment was visible in the blank.



2048h P8 (P4) recovered at 24.097°N, 20.417°W. Sample cups had operated as expected. Depressor weight and end-of-mission abort weights were both absent and the over-depth abort weight was in place as expected. Very little sediment was collected in the three sample cups. No sediment was visible in the blank.

Both traps were recovered along starboard side tight to the ship's side rather than being swung round to the after deck making for well controlled recoveries.


D360 P8(P4) Deployment 3
Isobaric mode
Pressure (dbar) and Piston Position (counts)
Apex pressure
Piston position
Max pressure bound
Min pressure bound


Deployment 1
P7
P8(P4)
Deployment 3
P8(P4)
P7
Deployment 2
P7
P8(P4)
Degrees East
Degrees North

Summary of Pelagra Operations

The primary object of D360 for the Pelagra project was to test the APEX float control firmware following the latest in a series of rectifications and improvements carried out by the supplier, Teledyne Webb Research. Specifically:

To address the inability to respond to exceeding limits of a +/-0.01 sigma-theta horizon
Two isopycnal missions were run using P7 and P8. Both APEX floats responded to sigma-theta limits correctly.

To extend the mission data-logging capacity to cover the whole mission
Data-logging was complete for all six missions, the longest being three days.

To provide the ability to choose between isopycnal and isobaric missions
Both isopycnal and isobaric missions were run and functioned as expected.

To provide date/time within the filename for all log files to avoid over-writing on subsequent missions
Date/time has been added to all log files.

To add piston position as logged data in the mission .msg files
Piston position is now logged in the mission .msg files.

To address the issue of some floats prematurely terminating their missions
Teledyne reported that they could find no reason for some floats to terminate their missions prematurely. During this cruise it was realised that mission parameter Mtj, Deep Profile Descent Time was set to a positive number on P7 (0300) which had previously been affected. Setting Mtj to 0000 has cured the problem.

Some minor mechanical improvements had also been implemented. Specifically:

Replacement of lower 'legs' with larger diameter ones to improve sturdiness
Replacement of all wire thread inserts with bar nuts
Addition of ball bearings to sample cup cam ring support rollers
All of the above appear to have functioned as expected.

Pelagra recovery at dusk

9. MYRTLE-X system tests

Steve Mack and Geoffrey Shannon

Geoffrey Shannon and Steve Mack (Right), with the rig for testing the MYRTLE-X systems.

21/1/2011. MYRTLE- X wire test 1.

1200 All running in lab on frame....Logger scanning telemetry ok acoustics ok 1310 Wire test frame in water descending to 3000m Telemetry working fine, communications with modem good and communications with acoustic releases good.

1330 Didn't hear expected transmission from acoustic modem...direct telemetry working fine

1335 tried more commands to assess problem..no response from second unit but direct telemetry still good.

1340 decided to bring it back up to assess problem. Looked like problem with communication between the two units hence the modem telemetry ok but the data transfer and other functions not working.

1355 @~100m tried commands again and communications between the two units now working.

1400 Back on deck, all working ok.

Suspect communications cable that links the two units to be giving problems intermediately or under pressure.

Removed cable and re-made all joints. Leaving overnight to set and will be good to go from 22nd to asses if this has solved the problem.

22/1/2011 MYRTLE X Wire test 2

1315 All powered up and initialised in Lab

1330 All set up on deck ready to go

1357 In Water

1420 All ok down to 500m Communications problem from wire test 1 better.

Pod release commands getting across the 2 units but logger data not.

1440 At 1000m release commands responding ok

1551 Down at 3000m.

Fired Pod4 release command, all received and responded ok

Fired Benthos acoustic release at 11.5kHz code D, responded as expected.

1600 Logger data scan came through although none have been seen when expected previously.

1615 Still at 3000m. No logger scan received. All release commands still operational.

1708 Back at 1000m Release commands ok. No logger transmission at 1715.

1745 Back on surface.

The pod release fired had partially burnt through the burnwire. Suspect this to be due to the distance from the burnwire loop and its ground and the alignment of the two.

The 10" Benthos acoustic (11.5kHz D) had not fired. Can only surmise that the wire exposed on the burnwire loop was not sufficient to make a god connection with the ground.

The acoustic was fully operational on deck and was showing a burn voltage at the burnwire when activated!

Plan:

To shorten cable data cable that links the two units.

To re-align pod release burnwire and expose more wire to burn To re-align burn wire within release module and expose more wire to burn.

Re- do wire test down to 3000m and assess results.

23/1/11 Wire Test 3:

Test with 3 Benthos acoustic releases and MYRTLE-X Telemetry and release burnwires.

2000 Delay in test due to winch AC failure. This was resolved and winches now ok to use.

2030 Wire test frame in water heading down to 3000m Pod release command ok and all other telemetry ok but data telemetry not being received.

2047 At 3000m

2148-2150 Fired all 4 pod release burnwires...all acknowledged.

2154-2156 Fired all 3 Benthos acoustic releases...all acknowledged.

2157 heading back up to surface.

Intermittently picked up scan telemetry on way up. All other telemetry working fine.

2230 Frame back on deck.

All 3 Benthos acoustic fired, even the one that hadn't fired on wire test 2 Only one pod release burnwire had fired despite all acknowledging burn and being the same set-up.

After some assembly on the frame. The system was powered up and initialised.

It was noticed after a period of time that the data from the Infra Red transmitters was being corrupted.

Numerous tests and re-programming were undertaken to find the cause and alleviate it, but to no avail.

These data transfers are what control the timing of the Iridium data transfer after the pod has released

therefore without the correct data, the pods would begin transmitting on the sea-bed.

Given the nature of these problems and the uncertainty of the various burnwire releases it was decided not to deploy the lander.

More tests would be carried out to try to shed some light on the release issues.

27/1/11 Wire tests 4:

In order to try to assess the problems with the acoustic releases and burnwires it was decided to do a couple of wire tests, just with the Benthos acoustic releases.

Test 1:

2 off Acoustic releases

10.5kHz, 14.0kHz. Both had braided burnwire as standard with minimal wire exposed.

These were housed in the fittings as would be on a frame for deployment.

Both of these acoustics have worked over the previous wire tests.

1235 In water. Heading down to 3000m

1401 At 3000m

1402 Fired both releases. Both Acknowledged as burning

1404 Heading back up to surface.

1449 Both acoustic timed out as expected

1510 On Deck. Both Acoustics had fired ok.

Test 2:

2 off Acoustics.

14.0kHz was replaced with the 11.5kHz which was fitted with a standard braided burnwire with minimal wire exposed.

The 10.5kHz acoustic had only the burnwire replaced with a standard 'inconel' burnwire.

The 11.5kHz had a burnwire that had not fired on wire test 2 but was ok on wire test 3 The 10.5kHz acoustic had fired on all previous tests.

1530 In water

1718 At 3000m

1719 Fired 11.5kHz and 10.5kHz. Both acknowledged as burning ok.

Stayed at 3000m for full duration of burn (~50mins)

1804 Both acoustics time out as expected.. Heading back to surface

1920 On Deck

11.5kHz acoustic had burnt ok. It had done this on the last occasion but not on the previous one.

10.5kHz had not fired the burnwire which was fully intact. This acoustic had fired its burnwires successfully throughout all tests so far.

10.5kHz acoustic was fired on deck and a burn voltage was present at the burnwire. +28V The burnwire module was then put in a bowl of sea water and burnt as expected.

Initial conclusions are that there is some pressure related problem but it is intermittent?

The only thing changed from the time it did burn on the previous test (a couple of hours before) was the burnwire itself.

Need further investigations back at the lab, preferably pressure tests to try to shed some light on this problem.

There, as yet, are no obvious signs of where the problem lies.

Foreground: MYRTLE-X. Background: Pelagra (having just been landed on the aft deck of RRS Discovery)

29/1/2011 Wire test 5. 'FETCH'

The 'FETCH' Is a new Sonardyne product based on their existing range of acoustic modems and releases.

The new instrument is contained within a 17" glass sphere and is intended as a lander, mounted on a

ballast weight to be release and recovered at the end of it deployment. The Instrument measures bottom pressure and temperature via a Digiquartz pressure sensor.

The unit has had limited trials so it is very useful to trial this instrument prior to further procurement and deployment.

The Instrument features acoustic telemetry and a mechanical 'screw' release and is planned to be

incorporated into MYRTLE-X in the future to provide an additional telemetry and release option.

Sonardyne Wire test:

Unit set up in lab and logging as of 1830 Z Test plate fitted to mechanical release to simulate ballast weight.

2330 Frame into water

Communications all ok and status updates received ok.

0003 At 1000m

All communications ok and status updates all ok.

0015 All data was received from the sea-bed acoustically. All transferred ok.

0018 Release was armed and fired.

Release response acknowledged by unit.

0020 Test of communications ok

0023 Heading back up to surface.

0028 At 500m all communications and status updates ok

0043 On Surface

Release had operated ok and test plate had detached from the instrument.

0048 Until logging halted and brought back into lab.

Successful trial, both in the lab and in the water. A few problems seen in previous trials have been overcome and this was a very good test of the system.

---

10. Acknowledgements

The successes of the Oceans 2025 technology trials cruise D360 are in no small part due to the tremendous effort and contribution of every person who sailed on the *RRS Discovery*. I would particularly like to thank the Master, John Leask, and his crew for all their efforts on our behalf.

Stephen McPhail, Principle Scientist.