Terschelling (Autosub / Simpson) 2006 Cruise Report

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Fig 1. Autosub being recovered onto Terschelling after mission 406 (SWIS) in the western Irish sea.

Introduction and Acknowledgements

The purpose of this document is to serve as a rough working record of the Autosub operations from July 13th to July 21st, on the RV Terschelling in the Irish sea. It can be edited down for inclusion into a more extensive general cruise report.

Simultaneously with the Autosub/Terschelling operations, the RV Prince Madog carried out very extensive oceanographic measurements in the same area. This was as part of the NERC funded project "Structure of turbulence in shelf seas", a joint project between the University of Wales, Bangor, and the National Oceanography Centre, Southampton.

Many thanks for making this such a successful cruise to the PI, Professor John Simpson (Bangor), Dr Alex Nimmo Smith (University of Plymouth), and to all the hard working scientists and crew aboard the Terschelling and the Prince Madog.

Autosub Missions

Autosub ran four missions in the Irish Sea. Total Autosub running time was 172 hours (with 20 hours in reserve). The average speed was 1.22 ms^{-1}, and the Autosub ran a total of 751 km through the water. This was achieved without the need for a battery change.

All missions were completed according to specification except the 2nd Mission (the MLB, first science mission, see Table 1), where the Autosub speed averaged at 1.0 ms^{-1}, 20% less than the specified 1.2 ms^{-1}. The consequence of this was that only 5 of the asked for 6 complete circuits were completed. The cause for this is still being investigated and further testing will be carried out back at NOC. Initial tests would seem to indicate a problem with the wiring to the propulsion motor (See Appendix 3). This was repaired after the SWIS mission.

The Autosub was fitted with a Turbulence sensor package, a dual Seabird 911 CTD system, with Fluorometer, and dual ADCP system, (300 kHz upward looking, 150 kHz downward looking). These are described in detail in later sections.

The missions are summarised in Table 1.

Table 1: Missions Summary

The start times are the times that the mission was started. Dive times are 130 seconds after this.

#	**Start Time** **End Time**	**Start Position** **End Position**	**Description and comments.**
M405 TRIAL	13/7/6 06:46:32 13/7/06 07:16:13	N: 53 39.648, W 4 10.68 N: 53 39.582, W 4 10.66	Test Mission. Dive at WP1. Run back to WP1 then to WP2 , which is 1km west, at 10 m altitude demand. When there then turn around and head back to WP1. Mission completed successfully. Average speed of 1.3 ms^{-1} and 2.3 km completed.
M406 MLB	13/7/06 10:26:11 15/7/06 12:35:16	N: 53 39.66, W: 4 10.64 N: 53 42.39, W: 4 05.22	50 hour mission. Travel at 1.2m/s around a 5 km square. At altitudes of 6m, then depths of 35, 20, 10 m. Mission length limited to 50 hours. Depth changes after passing WP8, then at WP15, WP22. Due to lower than planned average speed of 1.0 ms^{-1} rather than 1.2 ms^{-1}, the mission did not complete the final 10 depth m circuit. 107 km run over the ground.
M407 SWIS	15/07/06 21:57:20 18/07/06 09:59.07	N: 53 48.432, W: 5 32.514 N: 53 48.408 W:5 32.508	Run at 1.2m/s between two waypoints at 15,20,25,30,35,40 m. Change depth at the start waypoint. Mission ends on timeout exactly 60 hours after the mission start. 214 km run over the ground. Only 5 out of the 6 circuits were complete. This was due to the tide being higher than anticipated, and the Autosub getting stuck in a pattern where the tide was against it for all the legs.
M408 FR	18/07/06 22:07:06 21/07/06 11:35:29	N:53 40.892, W:5 25.055 N:53 45.600, W:5 14.970	Constant heading (104 degrees) for 5 hours, then reciprocal (284) for 5 hours. 12 legs total. Alternating 15m out 45 m back depth. After 12 legs run towards the start waypoint for 1 hour, then surface. Although Autosub performed as expected, it drifted 20 km north east of the start position, due presumably to a residual non-tidal current.

Navigation performance.

Table 2: Navigation

Mission	Distance travelled over ground	Average speed thru water	Duration	Nav Error at end of mission	Drift rate as percentage of distance travelled.
M405	2.5 km	1.3 ms^{-1}	0.49 hours	12 m	0.48 %
M406	104 km	1.0 ms^{-1}	50 h ours	170 m	0.17 %
M407	204 km	1.3 ms^{-1}	60 hours	22 m	0.022%
M408	302.5 km	1.3 ms^{-1}	61.5 hours	110 m	0.036%

Navigation and Depth Profiles

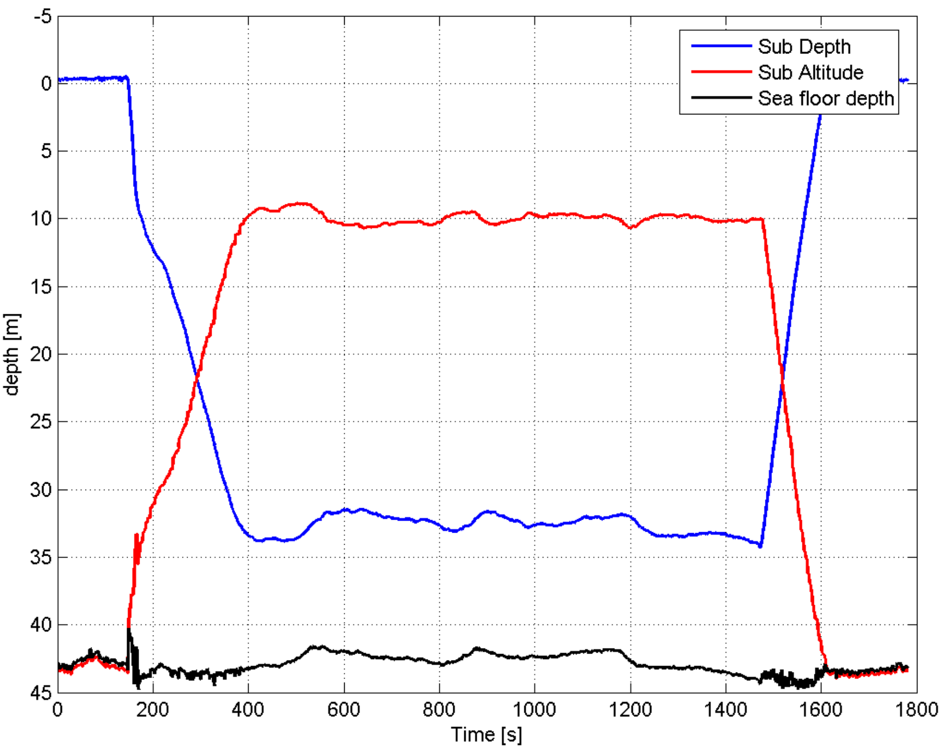


Figure 1. Depth Profile for Mission 405 (TRIAL). The vehicle was run at constant altitude mode (10 m), as a test that close to seabed altitude control would be safe for the later missions.

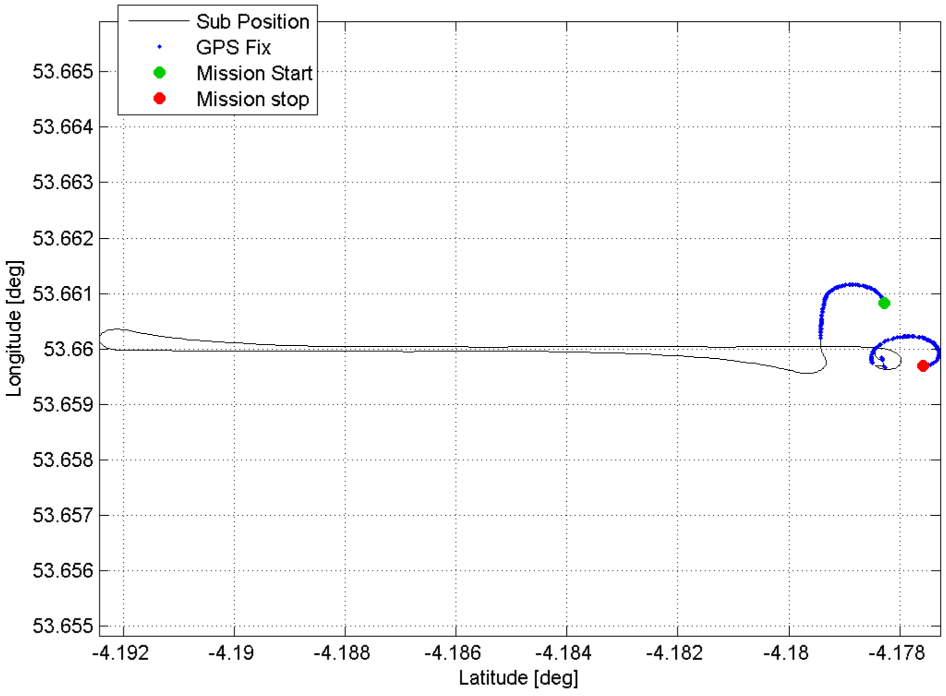


Figure 2. Navigation plot for Mission 405 (TRIAL). The navigation is raw (uncorrected), hence the small jump in position at the end of the mission.

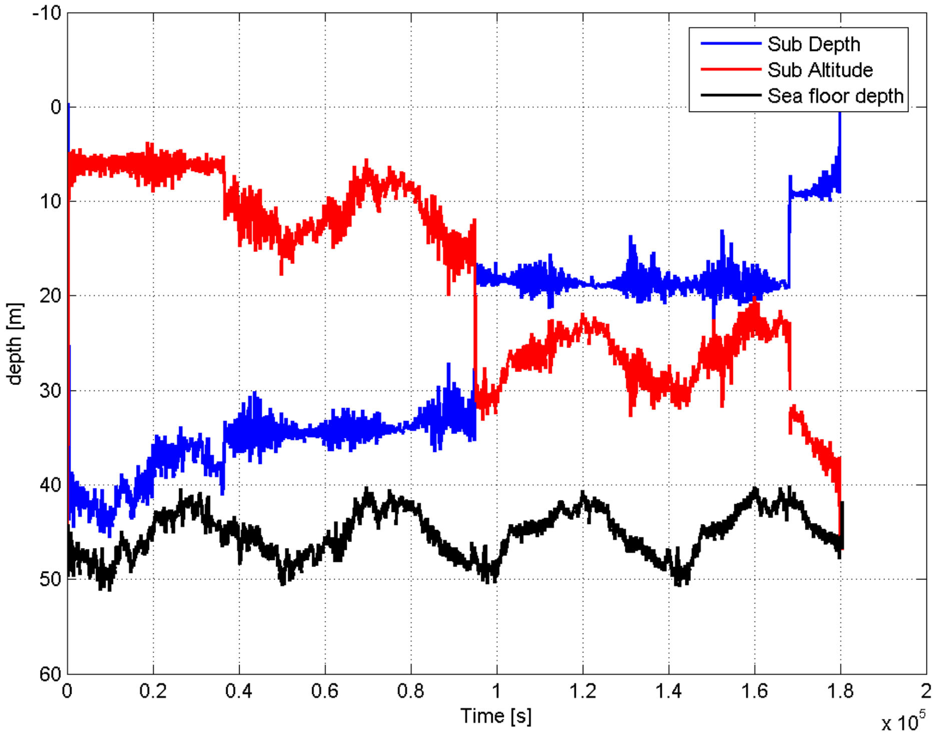


Figure 3. Depth profile for mission 406 (MLB). Minimum altitude was set to 6m for the first leg. The variations in depth seem to be correlated with the state of the tidal flow, and presumably turbulence. The 7 m variation in water depth due to the tidal range is clear (black trace).

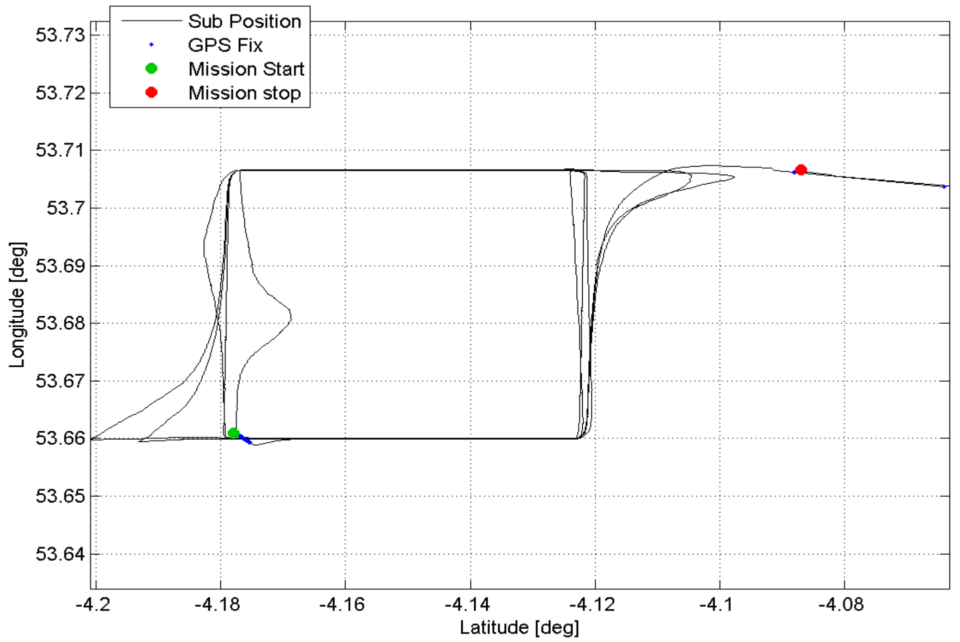


Figure 4. Navigation plot for mission 406 (MLB). Note the large excursions from the planned track due to currents. The mission ran anti clockwise starting from south west waypoint (heading east). The large apparent excursion in the North East corner was due to a single outlier GPS fix at the end of the mission.

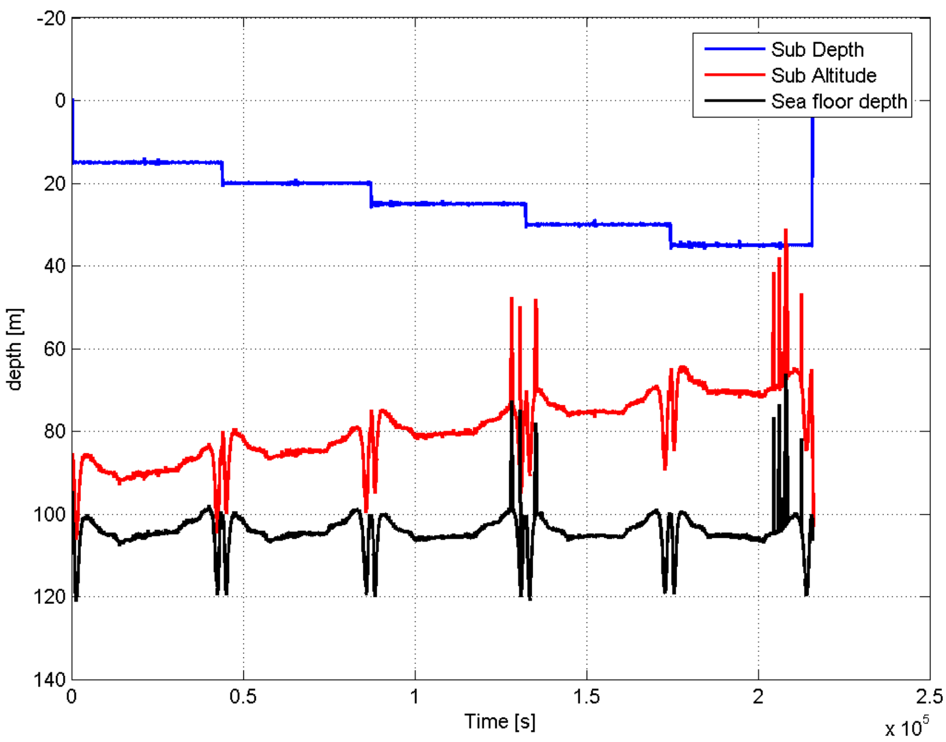


Figure 5. Depth profile for mission 407 (SWIS). The excursions of altitude and water depth at the depth changes are artefacts due to the changing pitch of the vehicle at depth changes. Note the much improved depth control compared to the previous mission.

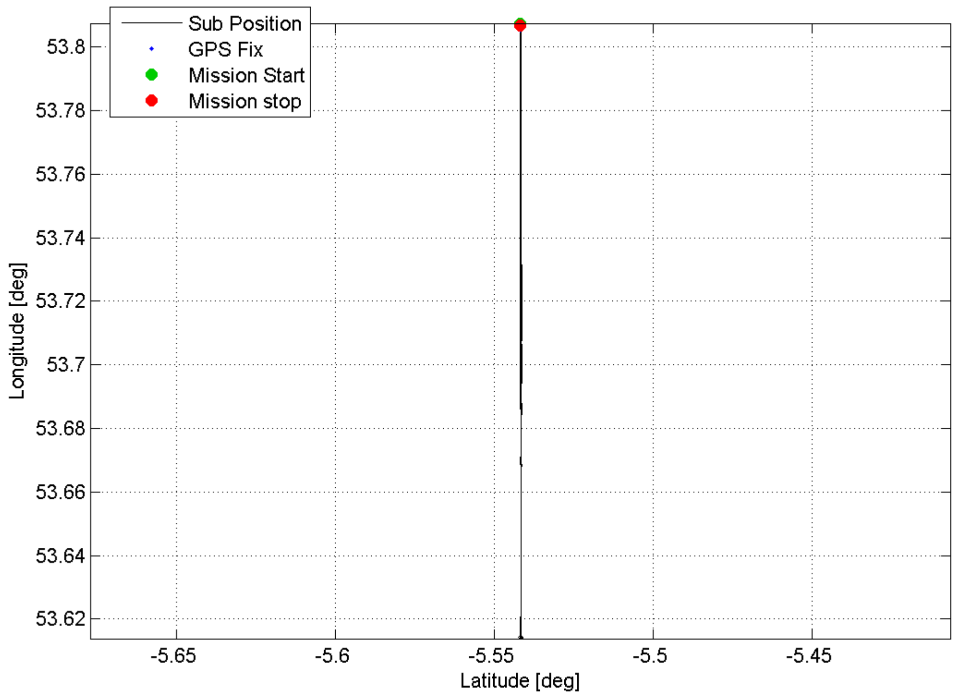


Figure 6. Navigation for mission 407 (SWIS) (uncorrected).

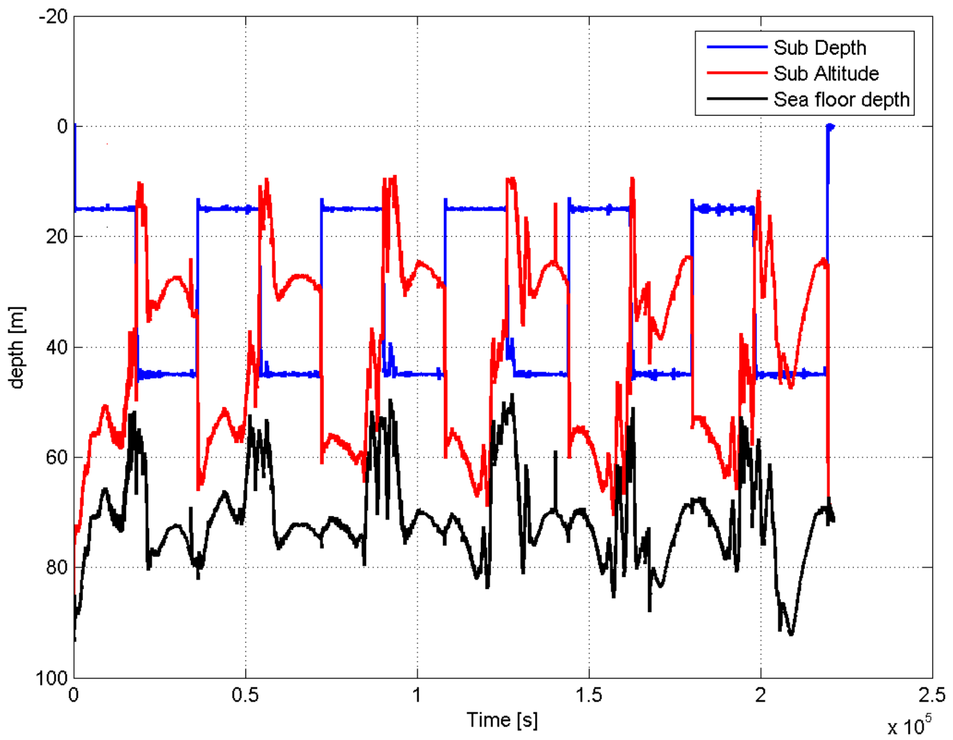


Figure 7. Depth profile for mission 408 (FR).

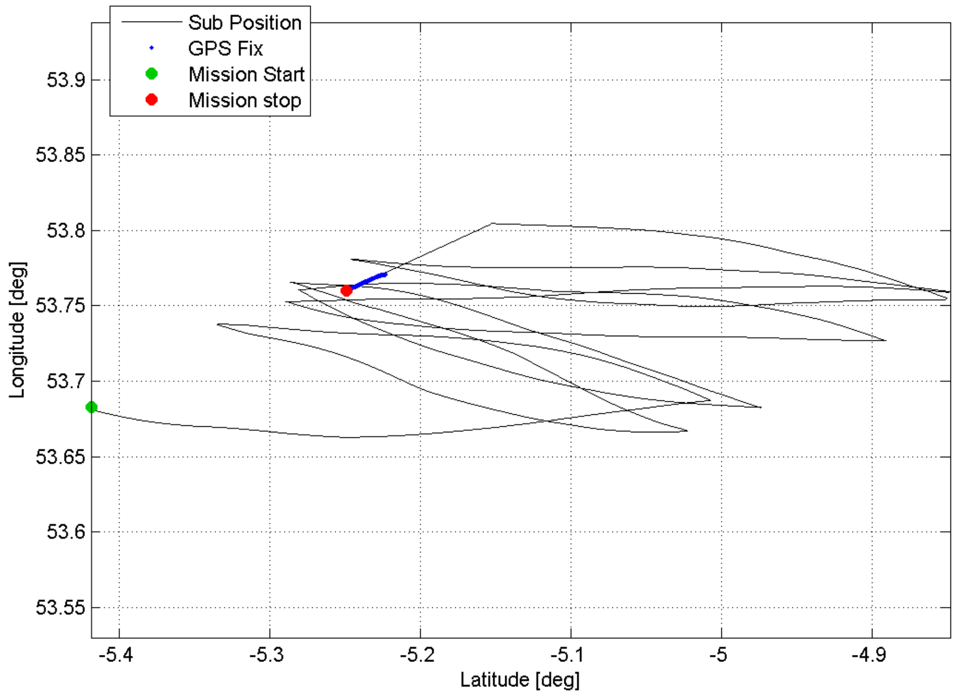


Figure 8. Navigation (uncorrected for mission 408 (FB).

Autosub Scientific Sensors

For Terschelling 06b (Simpson/Autosub) the Autosub vehicle was fitted with the following scientific sensors:

- RDI 150kHz ADCP looking downwards
- RDI 300kHz ADCP looking upwards
- Seabird 911 CTD system.
- Turbulence Package

The data from these (with the exception of the Turbulence probe, which self records), plus the navigation data, and clock synchronisation data, will be made available to the cruise PI's on a DVD.

These instruments are described separately in the following sections. The table in Appendix 1 of this report shows the exact sensor locations. All the electronic systems on the vehicle are connected to a single control network. The data from all sensors apart from the turbulence probe are recorded on the Autosub data logger. The Autosub logger uses a proprietary data format but the data is translated into standard ASCII text files using the Logger File Translator software running on a PC. The resultant ASCII file is then imported into the Axum processing software and a standard script is run to produce the general post processed navigation file (Mxxx.bnv file). (Appendix 2).

Sensor Synchronisation

The Autosub TimeSync monitoring software is run during each mission in order to monitor the clock drift between underwater systems and various shipboard systems. The results are stored in the TimeSync directory for each mission. The .txt file is the more verbose version while the .dit file contains the differences in an ASCII table which can be read by most data processing software. The Autosub control computer was synchronised with GPS time.

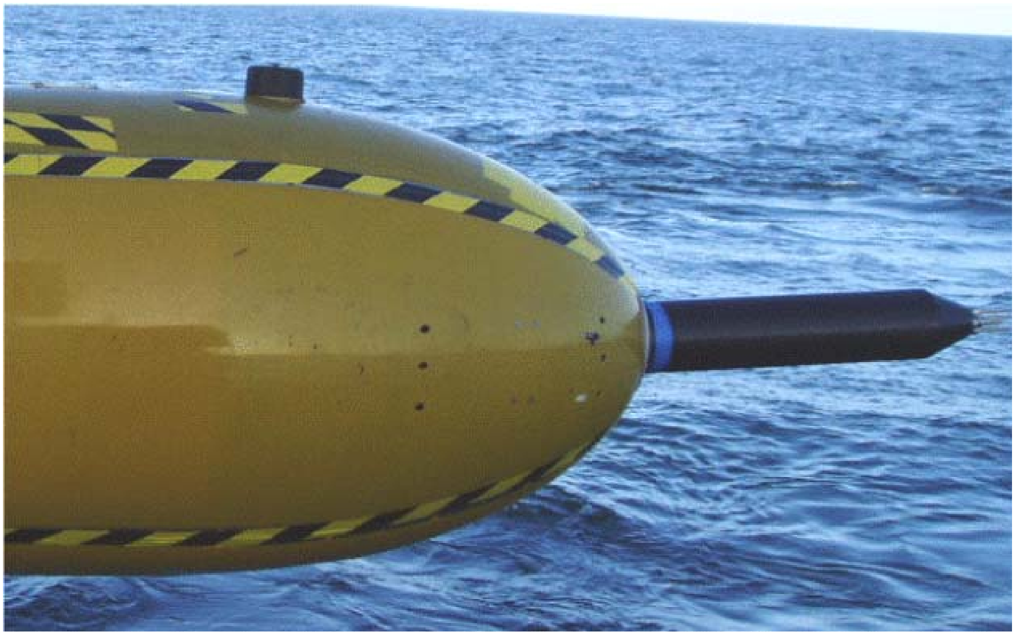
Seabird 911 CTD system

Autosub is fitted with a Seabird 911 CTD system which includes two sets of conductivity and temperature sensors. These are mounted in a ducted system with sea water pumped through them at a precisely known rate. Depth is measured by a Digiquartz pressure sensor. In addition, a Wetlab Wetstar Fluorometer is fitted which is situated in the same duct as the secondary CT sensors. The output from these sensors is recorded at a rate of 24Hz.

Sensor	**Location**	**Serial Number**
Primary Temperature	Port Side	4458
Primary Conductivity	Port Side	2937
Secondary Temperature	Starboard Side	4457
Secondary Conductivity	Starboard Side	2938
Fluorometer	Port Side	WS3S-431P, Calibration date: 08/17/98, vblank 0.000, scale factor 1.000

Data from the system is continuously logged whenever Autosub is switched on but, in order to prevent excessive wear on the pump, water is only pumped through the C/T sensors once a predetermined pressure threshold has been exceeded. The data is stored on the Autosub logger in a proprietary format but is translated into a Seabird format data file (.dat) at the end of each mission. This data file, together with the necessary configuration file was then passed to the scientific party for further processing. Sensor calibration data is stored in a separate file with the .con extension. For the Terschelling / Autosub/ Simpson 2006 cruise the data was processed using “Tersch06b\CTD setup\D306 Fluorometer on V0.con” file which contained calibration data from March 2005.

Turbulence Probe



The Osborn turbulence package was mounted on the Autosub as shown above. It was angled up by 0.7 degrees (relative to the INS pitch reference), so that it was as near horizontal during normal flight as possible.

ADCPs

Physical Arrangement

Autosub has two RDI ADCPs, both mounted in the tail section:

A 300 kHz RDI Workhorse pointing upwards.
A 150 kHz RDI Workhorse pointing downwards.

Both can provide velocities in bottom tracking mode (or ice tracking, if appropriate, for the upward looking ADCP), as well as current profiling. The range information for the four beams is also used in the control of the vehicle, where it is set to keep a constant distance from the seafloor. The collision avoidance system also takes input from the ADCP beam ranges. Both were set with 4 m profiling bins.

Files
The ADCP data is contained within the ASCII mxxx.ls2 files, where xxx is the mission number.
The first line of this file is a header of field names). The second line are the units used. The data is 2 seconds sorted (new set of data each 2 seconds).

This file also contains Autosub engineering and (unprocessed) navigation data, some of which might be of interest.

For post processed (more accurate) navigation data, you might want to use the Mxxx.bnv (best navigation) file which is described in a separately.

Where there is no data within a 2 second period the missing data value is represented by –999

The ADCPs produce new data every 2.6 seconds. This explains why, in the 2 second binned data file (ls2), there are regular missing data values (-999).

The ADCPs themselves use –32678 to represent no or bad data.
ADCP Data Fields in the Mxx.ls2 files

Table 1. ADCPbin[0] Frame 0 is a special frame with ADCP configuration data

Field Name	**UNIT**	**Description**
CellIdx0*	0.24 dB	ADCP beam 3 intensity for bottom target
Inten0*	0.24 dB	ADCP beam 1 intensity for bottom target
Veast0	mm/s	Starboard velocity relative to seabed
Vnorth0	mm/s	Forward velocity relative to seabed
Vdown0	mm/s	Down velocity relative to seabed
Verr0	mm/s	Error velocity
ADCPVersion		RDI firmware version and revision
ADCPRev		
HeadingBias	0.01 deg	Always set to 0.
Number of Water Pings		Number of water pings per ensemble. Usually set to 1.
Size of cell	Cm	Vertical length of profile cell in cm.
Blank after TX	Cm	Blanking distance. 1st bin begins after this.
Number of Cells		Number of profiling bins. Up to 48.
Minimum Threshold		64 usually
Heading Align	0.01 deg	4500 for the down. –4500 for the up. The ADCPs heading axis are rotated 45 degrees relative to the vehicle.
Salinity		User set Salinity used in velocity calculation. Eg. 35
SoundSpeed	m/s	Calculated by ADCP based on Salinity (fixed), temperature (measured in ADCP and, and depth (externally measured).
ADCPTemp	(0.1 Celsius)	ADCP measured temperature.

Table 2. ADCP water profiling data bins[1 to N]. Example shown for the first bin (index 1)

Field Name	**UNIT**	**Description**
CellIdx1*	0.24 dB	ADCP beam 3 intensity.
Inten1*	0.24 dB	ADCP beam 1 intensity.
Veast1	mm/s	Water profile velocities are in levelled ship frame of

Vnorth1	mm/s	reference, relative to the PHINS forward axis. starboard, forward, down, and error.
Vdown1	mm/s	
Verr1	Mm/s	

For the Upward looking ADCP, the field names have '_2' appended.

Table 3. Other Data fields in the ls2 files which are of interest to users of ADCP data

Field Name	Units	Description
Date	e.g.7/07/2006	Date
Time	e.g. 09:40:02	Time of day (UTC)
Seconds	e.g. 1092735602.0000	Seconds since 1/1/1970
Roll	Radians	Roll angle of Autosub. (+ve to starboard).
Pitch	Radians	Pitch angle. +ve is nose up.
Heading	Radians	Heading. In Navigation convention. Heading north is 0. East is pi/2.
INSLat	Degrees (decimal)	Latitude (not post-processed)
INSLong	Degrees (decimal)	Longitude (not post-processed)
DpCtlDepth	Metres	Depth of Autosub (m).

* There is a bug in our logging software, which causes the intensity values to "wrap around" for values greater than 127. The correction, easily applied in Matlab is :

```
// for all val..
if(val <0); val = val+256; end;
```

Hints for processing the ADCP data.
You'll only get good current data when the down ADCP has bottom track.
Processing steps:

- Transform "Ship Levelled" to geographical.

  e.g.

  Vnorth = Vfwd*cos(heading) -Vstbd*sin(heading)
  Veast = Vfwd*sin(heading)+ Vstbd*cos(heading).

(In the ls2 file : Vfwd is *called* Vnorth , Vstbd is *called* Veast).

- Produce Current profiles from the vector equation. Vwater(geog) = Vbottomtrack(geog)+ Vcurrent(geog).

- Map the current profiles to real depths, by adding on the Depth sensor reading to the profile depths (based on bin size, bin number, blanking distance).

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Appendix 1: Physical arrangement of sensors mounted in the nose section

Autosub is fitted with twin Sea Bird 911 CTD suite as standard, in addition to this a Wet Labs Fluorometer was plumbed into the port CTD (fig1)

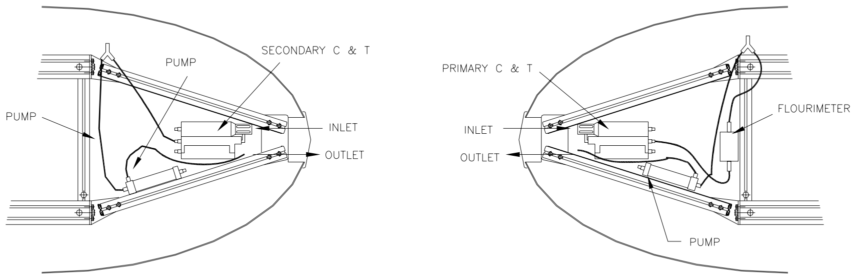

Figure 1. Physical arrangement of CTD and Fluorometer sensors mounted in the nose section

Appendix 2: Autosub Post processed navigation data format

Post processed navigation data is provided in a file Mxxx.bnv, where xxx is the mission number. The file is ASCII text with comma separators. The first line is the column headers names (comma separated). Missing data is represented by “–999”. The frequency of data output is once every 2 seconds.

Table 1. Data Field Definition Table

Field	**Units**	**Description**
Date	m/d/yr	mm:dd:yy Julian Data.
Time	hr/mn/s	Hh:mm:ss. UTC
Seconds	s	Seconds Since 00:00:00 1/1/1970
Elapsedtime	s	Since start of navigation file.
Pos_E	degrees	“Best estimate” Longitude. (jumps at GPS fixes removed)
Pos_N	degrees	“Best estimate” Latitude. (jumps at GPS fixes removed)
Depth	m	Depth of vehicle.
Vel_E	ms^{-1}	“Best estimate” East Velocity component.
Vel_N	ms^{-1}	“Best estimate” North Velocity component.
PosRaw_E	degrees	Raw (unprocessed) Longitude.
PosRaw_N	degrees	Raw (unprocessed) Latitude.
PosError	m	Estimate of the position error.
Posfix_E	degrees	GPS Fix: longitude
Posfix_N	degrees	GPS Fix: latitude
FixType	enumeration	GPS fix type. Obsolete. All GPs fixes are 3 D.
TSLF	s	Time since the last accepted GPS fix.
ADCPVelMode	enumeration	ADCP mode of operation: 0,1,2 0 – bottom track, 1 water track, 2 – based on propeller RPM (essentially a fault condition).
ADCPVel_E	ms^{-1}	East Velocity output by Autosub ADCP (down looking).
ADCPVel_N	ms^{-1}	North Velocity output by Autosub ADCP. (down looking).
ADCPAlt	m	Altitude measured by ADCP.
Driftrate_E	ms^{-1}	North Drift rate (or current) estimate.
Driftrate_N	ms^{-1}	East Drift rate (or current) estimate.
Travelled_km	km	Distance traveled (over ground) in km.
LPVel_E	ms^{-1}	North component Low pass filtered (smoothed) velocity.
LPVel_N	ms^{-1}	East component Low pass filtered (smoothed) velocity.
Vwater_E	ms^{-1}	North velocity through water.
Vwater_N	ms^{-1}	East velocity though water.
WaterSpeed	ms^{-1}	Speed through water.
LPGroundSpeed	ms^{-1}	Ground speed. Low pass filtered (smoothed).
LPWaterSpeed	ms^{-1}	Through water speed. Low pass filtered (smoothed).
Pitchdeg	degrees	Pitch of vehicle (degrees)
Headingdeg	degrees	Heading of vehicle (degrees)
Rolldeg	degrees	Roll of vehicle (degrees).
Splanedeg	degrees	Stern Plane degrees
Rudderdeg	degrees	Rudder degrees
prop_rpm	Rev per minute	Propeller Radial Speed
WaterDepth	m	Depth of water. Is Depth + ADCPAlt. Is “-999” , if vehicle is out of bottom track range (400m) of seabed.
Total Power	Watts	Total electrical power usage.
battery_V	Volts	Battery Voltage.

Appendix 3: Fault log for Autosub Missions

Mission	Duration	Symptoms of Fault	Fault Diagnosis and Correction
M405 - PRE		LXT tracking transducer found to have leaked, presumably during Discovery 306, explaining lack of any tracking during that cruise.	Replaced with the spare one.
M405 - PRE		Stbd Sternplane and lower rudder found to be loose prior to m405 (deck tests).	Tightened. Put “check tightness of planes” onto checklist.
M405	0.5 hrs	No problems during this test mission.	-
M406	50 hrs	Autosub Ran slower than expected (1.0 cf 1.2 ms^{-1}), and speed dropped off during the mission. Ref Fig 1.	Motor was dismantled following mega test. Separated windings and wiring to the bulkhead and components passed 500 Volt mega test. Suspect the wiring from bulkhead to the windings were possibly trapped or damaged (assembly of motor was somewhat hurried in Cork). Motor reassembled and retested. Glass Fibre sleeve also replaced in case it had become porous. Passed 500 V mega test
M406	60 hrs	Current spikes of 3 amperes, combined with drop in battery voltage, particularly during first few hours of the mission. Ref Fig 2.	
M406 - POST		Propulsion motor Megared after recovery and failed at 500 volt test (windings to case short).	
		Battery currents indicate that one of the packs had an intermittent connection. Ref Fig 3.	Not critical for these missions. Need more careful checking on assembly.
M406		Seapam 99631 gave no replies of any kind during 406.	Replaced with Seapam D0059. Tested on deck pre 407.Seemed Ok.
M406		Following surfacing, first GPS fix was out by 1.2 km.	Needs some investigating. Suspect that the receiver is accepting the minimum number of satellites for its first fix, which could have bad geometry (i.e. all on one side of the sky). The fix was accepted by the sub because of the long time that the sub had been submerged. Some extra filters and sensibility checks need to be implemented (e.g. : do not accept the first few fixes received after long break, increase the minimum number of satellites needed for a fix (currently 4), tighten the allowed altitude error for a fix (currently 20 m), more sophisticated drift estimation and consequential tighter allowed error bars.
M406		Spikes in motor RPM of 47133 rpm. Spikes in motor RPM of 471.133 rpm	This corresponds to a single count of the software RPM counter, between Hall transitions (ie a short spike on the Hall sensor output). Corresponds to exactly 100 counts of the software timer. Code inspected, but we couldn’t see any reason why this should occur. Version 5.2 of MotorControl code loaded for Mission 408,

			which filters out such RPM values.
M407	61 hrs	No replies of any kind from SeaPam D0059 during mission M407. No tracking, no telemetry. Post mission some Verdigris found on pins 5 and 7 (+48 volt) of the network connector to the SeaPam.	Tried other transducer. No improvement. Dave White tried repairing both Seapams. Seems that there is a problem with the power regulators on both Seapams (see later report). Seapam 99631 repaired with new power regulator and installed for mission 408. Problems with the bulkhead connector would not prevent the Seapam from transponding. It is not clear when the green deposit on the power pins occurred. Was reported (by DW), that this was due to a storage problem (water trapped under a protective cap) and had been noted prior to the cruise – but I'm a bit surprised that the connector would not have been cleaned more effectively if this had been noticed prior to installation.
M407		Noise spikes noted on both channels of the shear probe data. Started 5 hour into mission. Pulses of approximately 0.03 sec, every 1.55 seconds.	The repetition rate makes it suspicious that the Autosub acoustic transmitters (which are synchronised to transmit at 1.56 seconds repetition period) are implicated. Since both channels record almost exactly the same signal, and nothing appears on the accelerometer traces, it is thought to be caused by some sort of electrical interference (ground reference problem?). We looked at the Autosub data but nothing obviously changed between the period when there is no noise and after the noise begins. No such problem was noticed on mission 408. Something to do with the Seapam fault ?? - however the SeaPam does not transmit at 1.56 seconds interval , it responds at approximately 8 second or 16 interval, when interrogated by the mother ship.
M408 - PRE		Propeller Motor felt slightly rough when hand rotated.	Both motor bearings replaced pre launch
M408		Initial Mission Aborted at 50 m due to over-depth.	A mission programming mistake which was not detected by the pre launch check by either sdm or jrp. Following a dive, there was no commanded depth mode, hence vehicle continued until it hit the abort depth limit. Vehicle was recovered with the help of the small boat, and was deployed again 1 hr later.
M408		No telemetry from the Seapam	Perhaps the Switched Mode Power Supply which had been used to replace the failed linear regulator was noisy? – effectively deafening the Seapam (see later section on performance of acoustics).
M408		Difficulty in stopping the Autosub at the end of the mission by radio command.	This was caused with problems with the two WiFi radio access points. The (high gain) Marport Access point started to work after 15 minutes (it is not clear why it took so long to access the Autosub, as the signal strength was high). The Orinoco access point would not make contact. Finally, to get the Orinoco access point working, it was necessary to reload a configuration file (stored in asubsys\software\WiFi\Orinoco).
M408		Still noise spikes on motor RPM. These occurred when the vehicle was on the deeper part of the mission (45 m), but not on the shallower0.	There appears to be a pressure related problem with the RPM noise spikes. This, in itself, does not cause problems with the propulsion system, but is potentially indicative of a more serious pressure related problem with the motor or the connecting leads, and needs to be investigated.

Appendix 4. Performance of the Acoustic Telemetry System

Two SeaPam acoustic telemetry devices, S/N D0059 and S/N 99631 were used on Autosub-3 over the course of four missions in the Southern Irish sea in July 2006. We used the LXT deck unit for transponder operation, with display on the IPS software and the Trackpoint II for digital and analogue telemetry as usual. Neither SeaPam performed satisfactorily.

M405
For this mission S/N 99361 was mounted on the vehicle. This two hour mission was to test the vehicle. Digital transmission and reception was seen to work at the start of the deployment, but there were no returns from the transponder at all. This was traced to water in the LXT transducer on the ship. The transducer was changed for the spare and this worked for the remaining missions.

M406
S/N 99361 remained on the vehicle. This 50-hour mission was run with the ship keeping an eye on the vehicle’s progress, as in the subsequent missions. No reception or returns of transponder, analogue or digital telemetry were obtained.

After the mission it was removed, S/N D0059 was mounted on the vehicle and 99361 was opened up to try and effect a repair. It was observed that there was no 12V output from the 7812 on the Telemetry Tx board. The regulator was replaced but D2 also had to be replaced before the regulator would function. The unit still failed to transpond and it was found that the 7805 that provides all the power to the other boards, from the 16V battery pack (typical voltage = 17.5V to 18V). Replacing it the current drain was found to be too great and the voltage sagged to 3V as the regulator overheated. An intermediate 7812, to try and reduce the wasted power radiated by the 7805 was insufficient, and the only solution available was to replace it with a DC-DC converter. This ran the board and the unit transponded and could be made to transmit digital data by the vehicle. It was also observed that the AD7864 seemed to run unreasonable hot, but the reason could not be ascertained.

M407
This 60 hour mission was run in a similar manner to M406. S/N D0059 was used while S/N99361 was being repaired. It was tested on deck and it transponded and could be made to transmit digital data. After deployment, no digital or analogue telemetry was observed, nor did the unit transpond.

After the mission the units were again swapped, with D0059 being opened up for inspection. The Telemetry Tx board appeared intact but the 5V regulator had apparently exploded. The unit was powered up and a 5V power supply was substituted, the AD7864 did not get hot but the 5V line drew 1.2A, which rose to 1.75A when the LXT transmitted an interrogation pulse. This would mean that the 7805 was trying to dissipate 31.5 Watts at full voltage, which seems rather excessive.

M408
This was another 60 hr mission, with the ship shadowing the vehicle more closely, rarely more than 3km from it. The repaired S/N33961 was used. The SeaPam transponded to the LXT throughout the mission, although it was only reliable to about 200m range, with intermittent returns to 800m and occasional ones beyond that. By comparison the dumb transponder, which ran faultlessly for all four missions, was reliable out to 800-1200 metres range, with intermittent returns up to 3500m on this and previous missions. No digital telemetry was observed, even at very close range (overhead). The analogue telemetry through the Trackpoint II worked reliably up to a range of 100m, with some returns up to 300m but the values were stuck at depth = 0.04, heading = 217 and altitude = 91.9, regardless of the heading or depth of the vehicle.

In conclusion there are faults on both SeaPam units, including an inability of the 5V regulator to supply the receiver, DSP and other boards as well as possible damage resulting from the failure of this component, particularly in S/N 99631. The spare LXT transducer worked adequately after it was cleaned up, but several components have suffered corrosion damage, especially some PCB mounted connectors, and should be replaced before the unit is accepted back into service.