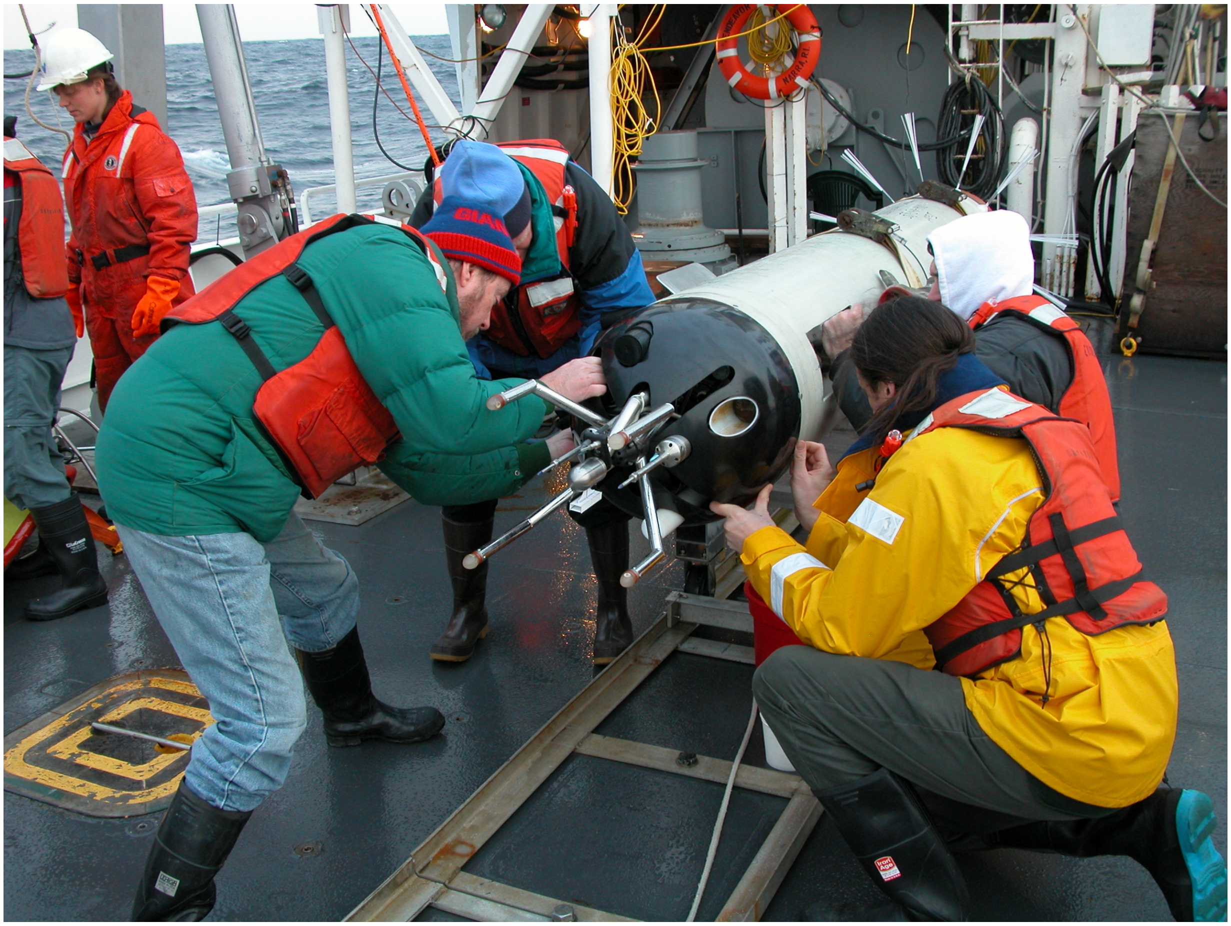
HRP-II summary:



Hardware Configuration, Operational Overview, Test Cruise Summary, Future work

Ellyn Montgomery, September 2004

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Acknowledgements-

First and foremost, thanks tot the National Science Foundation for funding this instrument development effort. This new deep ocean capable microstructure profiling vehicle should obtain data that facilitates many years of new scientific insights.

This project would have not succeeded without the involvement of engineers from WHOI’s Advanced Engineering Laboratory. Ken Doherty, Terry Hammar, Ed Hobart, Bob Petitt, Robin Singer and Fred Thwaites all contributed greatly to making HRP-II a success. Dave Wellwood made all the mechanical systems work and assured that all the spares needed were on hand. Scientific guidance was provided by Kurt Polzin, Ray Schmitt and John Toole.

The officers and crew of the R/V Endeavor worked diligently to make the test cruise a success. The cold weather challenged everyone, and despite the uncomfortable conditions and icing, operations went smoothly.

Introduction

A new deep ocean capable profiling vehicle was developed at WHOI during 2002-2003. It was modeled after the High Resolution Profiler, a robust data acquisition system for studying mixing in the deep ocean. A test cruise was planned for November 2003, but foul weather delayed it until January 2004.

To minimize vibrations that would contaminate the data collected, the new instrument is a free vehicle, like its predecessor. The vehicle uses ballast weights to descend, which are jettisoned when one of the dive termination criteria is met, then excess buoyancy in the body allows rapid ascent to the surface where it is recovered.

The new vehicle uses contemporary components and hardware, enhancing maintainability for the coming years. The sensor systems selected are highly accurate, and sample at precisely timed intervals. Each fulfills a task of describing a scale of ocean temperature, conductivity or velocity. Instrument configuration is flexible and extensible, so when newer and better sensors become available, they may be employed on the profiler. All the data is logged to memory during the dive and downloaded to a shipboard computer after recovery.

Since the HRP-II controls its own operation, several levels of redundancy in terminating each profile were incorporated. First, as soon as any of the dive termination criteria is met, the weights are released. For additional robustness, a second computer monitors the main computer to assure its operational status, and can also release the weights independently. A low power condition triggers weight release if the voltage is below a threshold. In addition to these logical methods of dive termination, several mechanical back-ups are employed. Several sizes of shear pins can be used in the releases, and corrodible bolts are part of the system.

The ultimate back up system, newly implemented in this profiler, is a mud extractor. The pressure data is monitored, and if no change is detected in one minute, a 1.5 meter long plastic rod will be slowly pushed out of its housing, ideally separating the profiler from the bottom.

The completion of the new instrument with all the enhancements, and successful operation on the test cruse was a great accomplishment. Now we look forward to using it in studies of deep ocean mixing during the years to come.

Design Objectives

The primary goal was: the new instrument must function as well as original HRP or better. To keep costs low, we decided to use proven, off the shelf components and sub-systems when possible. The maintenance of the system was simplified as a result of using parts already used by others in the oceanographic community. The main exception was the CTD. One that fit our specifications did not exist, so a new design was developed for this application.

The enhancements to the system are the following:

1) improved CTD, acoustic current meter (ACM), and compass sensor systems
2) added an Electromagnetic Field (EF) sensor
3) employed higher sampling rates for improved vertical resolution
4) implemented more accurate timing of the A/D data acquisition
5) added a GPS receiver for surface position logging
6) improved altimeter control for robust near-bottom approaches
7) modified body size, shape and stiffness to push vibration peak > 30 Hz
8) employed external battery packs
9) implemented a Watchdog computer to monitor logger operation
10) employed contemporary computers of small form factor (PC104)-
    the logger was based on a 386, 200 MHz, PC104 CPU with:
        16 Mb system memory
        2 Gb of memory for data
        disk to back-up data to after a profile.
        8 serial ports
        1 parallel port
        a 10/100 baseT ethernet connection
        a 16 channel, 16 bit A/D converter
        Windows 2000
11) implemented a bottom extractor
12) increased data offload speed by employing current networking protocols
13) implemented a graphical user interface(GUI) for configuration and operation
14) potential for data logging on ascent

Along with the improvements, certain requirements remained the same for the new system. It must:

1) operate to full ocean depth (6000 meters)
2) be easy assemble and handle in low to moderate seas
3) have sensors positioned to avoid flow disturbance and wake effects
4) employ robust hardware and software and have failsafe mechanisms
5) operate with low power consumption

Then engineers involved in this development effort and their areas of responsibility are listed in appendix A.

Instrument Summary

The HRP-II is comprised of several elements, the dive control computer and logger software, the communications networks, the sensor systems, the power system, and the body with associated mechanical systems. Figure 1 is a schematic of the component systems and some of the connectivity.

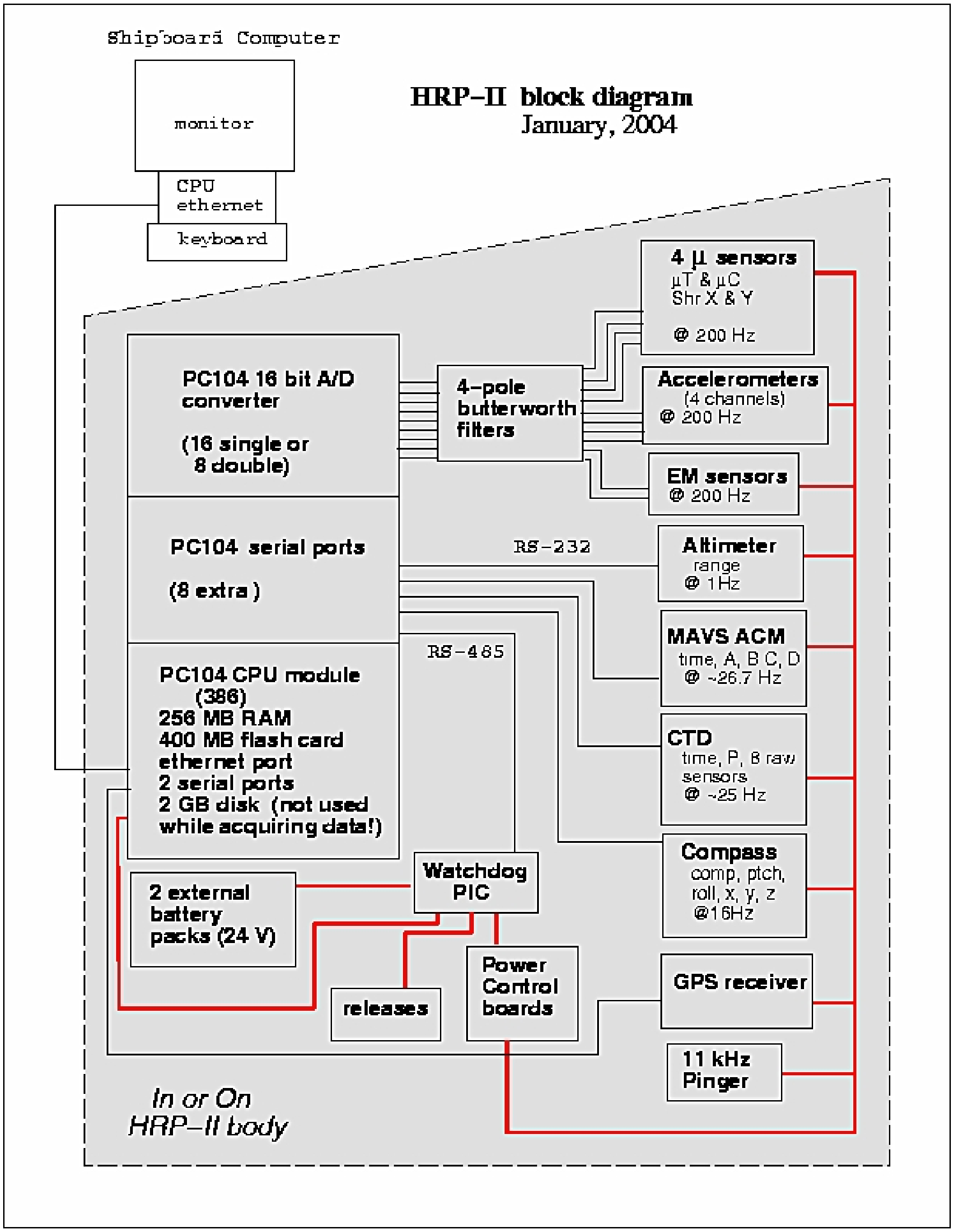
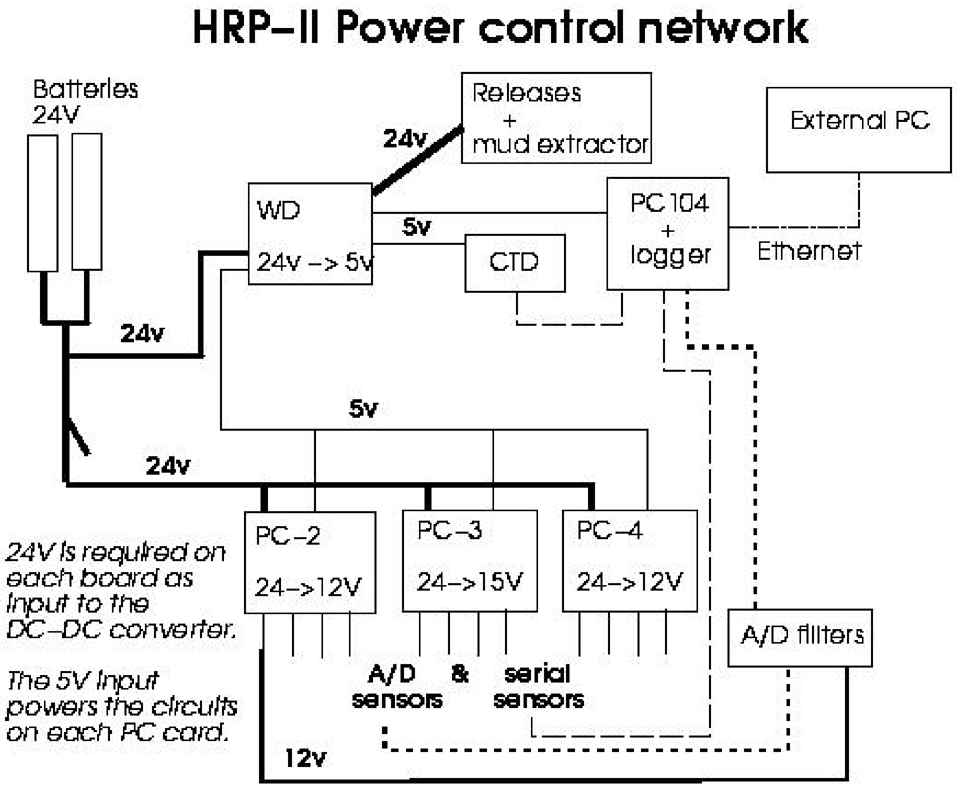


Figure 1: schematic of components and connectivity in HRP-II

Power, Power Control Boards, Watchdog

Power to the HRP-II is supplied by two stacks of lithium "D" batteries comprised of seven cells each installed in a pressure case mounted between the skin and the main pressure housing. Each stack provides 24 volts, and is specified at 15AHr @ 175mA (~500 watt-hours for both). Lithium batteries were selected for their flat discharge profile and high current capacity. The power supply is isolated by diodes from the rest of the electronics.

Four power control boards convert the input voltage to levels required by the computer and sensors. The first converts to five volts, which powers the computer and other three power control boards; these output 12, 15 and 12 volts respectively. The power control boards were designed for the profiler and run embedded software written in C to perform the appropriate switching and monitoring tasks. The power system is shown below in figure 2.



24V is required on each board as input to the DC–DC converter.

The 5V input powers the circuits on each PC card.

Figure 2: Diagram of the power control system employed on HRP-II

To allow monitoring of various system status indicators, the power control board that outputs 5 volts functions as a "watchdog" that also monitors pressure, range and time, and will release the descent weights in case the logger fails to terminate the dive appropriately. A dive would be terminated if a low voltage condition is detected, or the logger program stops running or if the pressure data from the CTD is bad.

Controller:

The profiler's main computer is a low power 200Mhz 386 PC104 with an 8-port serial card and a 16-bit A/D converter card. PC104 is a form standard widely used for small computers, so replacement parts should be available in the years to come. The computer gets power directly from the power control board that outputs five volts, since the operation of the main computer is mission critical. Figure 4 displays a picture of the PC104 stack, filter and power control boards.

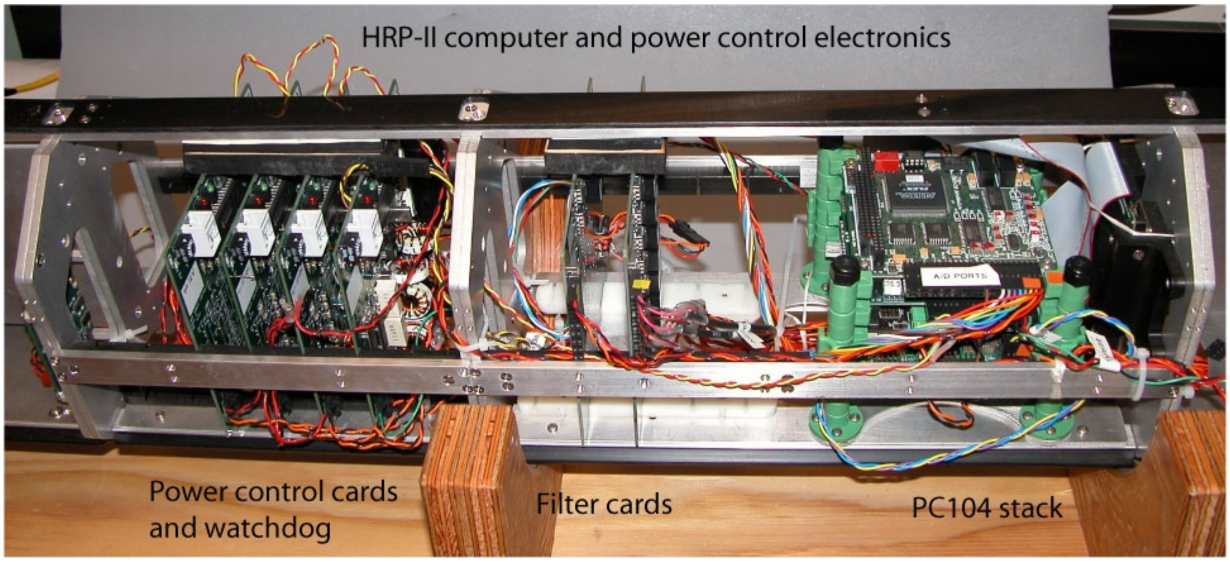


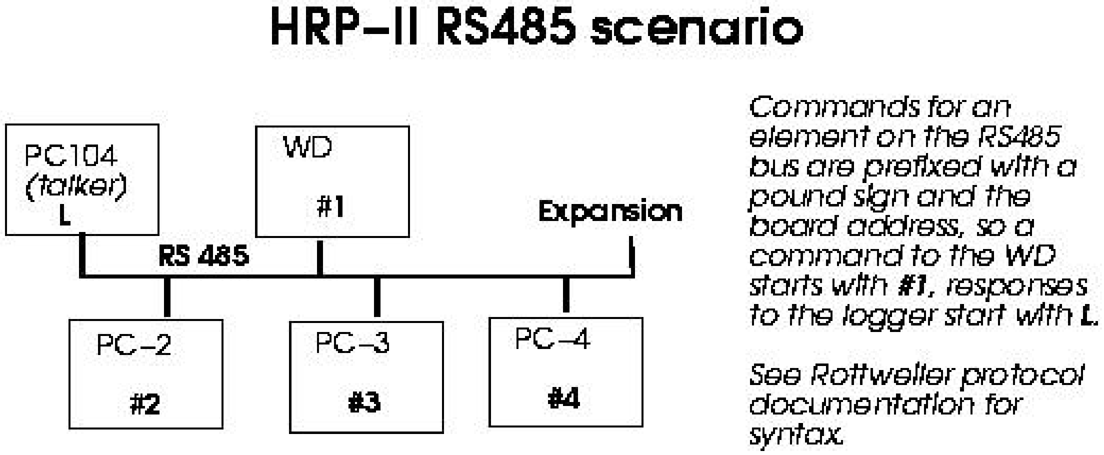
Figure 3: Photograph of the PC104 computer stack (right), A/D filters (center), and power control boards (left) used in HRP-II.

The autonomous operation of the HRP-II is controlled by “logger” software written in C running on Windows 2000. The logger program was developed using National Instruments CVI software tools, which supplies functions to handle everything from the Graphical User Interface (GUI) to the serial and A/D acquisition. The logger is the primary means of dive control. It is also responsible for dive configuration, sensor control, simultaneous acquisition and logging of data from five serial sensors and 10 A/D channels, along with real-time monitoring of pressure, range and time to terminate the dive as specified. All data is stored in memory during the downcast and written to disk at the end of the profile after the weights are released to eliminate any vibrations resulting from disk activity.

The logger was designed to allow easy reconfiguration of the sensors employed. Any sensor may be used or de-selected prior to each dive by clicking a button. Adding or replacing sensors is enabled by modifying the sensor connectivity table to include the new sensor id, port or channel, baud rate, gain, and power switch setting. An example att_tab.asc is found in Appendix B.

Internal communications

The protocol used for communications between the logger program on the PC104 stack and the Watchdog and power control boards is RS485, which allows two-way communication shared among multiple nodes. Our method is based on the logger program (controller) being the main talker, with the power control boards listening for whether the message applies to them, then acting accordingly- a block diagram is presented in figure 4 below.


HRP-II RS485 scenario

*Commands for an element on the RS485 bus are prefixed with a pound sign and the board address, so a command to the WD starts with **#1**, responses to the logger start with **L**.*

See Rottweiler protocol documentation for syntax.

Figure 4: schematic of the RS485 internal communications system.

A language for communication between the logger and the four power control boards was devised for this application and is documented in appendix C. The details of which sensor is connected to which switch on which board is presented in appendix D.

Sensors

A variety of sensors used to measure the smallest to the largest scales of mixing in the ocean were chosen for use on HRP-II. The underwater movement from the GPS data determines the largest scales, and the shear probes the smallest. Five sensors output ASCII serial data for logging, and ten sensors are connected to the A/D converter and logged as binary data. The data from each sensor is logged in a separate file, so each dive generates at least 15 files.

The synchronization of data from the files is obtained by powering up the configured sensors well before the start of logging, so startup messages have been displayed and data is streaming from the sensors well before the logger starts saving the data. Simultaneity of logging start has been verified in bench tests in the lab. Time words embedded in several of the data streams is further used to quantify drift of the various clocks.

A list of the sensors and their manufacturers is detailed in appendix E. An example of the data format output by each sensor and file names employed is presented in Appendix F. A short description of each sensor is provided below.

CTD:

A new low noise, high precision, fast response 24-bit CTD was developed for use with the HRP-II. The thermometer was encased in a stainless enclosure to protect the fragile glass tip. The conductivity sensor was based on the internal field concept, and fabricated for this application of ceramic with embedded fast response thermistors. The temperature and conductivity sensors are mounted on a sting that places them at the center of the sensed volume. The Druck pressure sensor is mounted directly on the lower endcap. The sample rate is 25 Hz, and a variable length serial data stream is output.

Acoustic current meter (ACM):

The electronics for a Nobska Instruments MAVS-3 was selected for this application, paired with a custom 3-axis transducer head fabricated minimize wake shedding, contribute to body stiffness, and measure both horizontal and vertical velocities in the same volume of water sampled by the other sensors. The accuracy of the MAVS velocities is 0.3 cm/sec with a 0.03 cm/sec resolution. The sample rate is 26.7 Hz, and the data is a fixed length serial data stream.

Compass:

A PNI TCM2 three-axis magnetometer (compass) was selected for use on the HRP-II. It is mounted internally with no external expression. Both the raw x,y,z and computed pitch roll and compass data are output for each scan. The faster sample rate of 16 Hz is employed, and the data output is a variable length serial data stream

Altimeter:

The electronics of a Benthos PSA 900 is mounted on the HRP-II chassis with the remote transducer head installed flush with the bottom nose cone. The 0-300 meter range was selected to maximize the possible bottom detection distance. Consequently, the accuracy of the measurement was 0.1 meter. The sensor is turned on 100 meters above the specified dive end pressure to avoid premature dive termination. The sample rate was 1 Hz, and the data was output as a fixed length serial data stream.

GPS:

The GPS unit selected was a Trimble Lassen SQ. A preamplifier was built for it and both are housed in a small pressure case mounted just below the antenna at the very top of the body. The antenna used is made by Webb research, and was selected because it is the only one made that withstands depths greater than 1000 meters. The variable length serial data messages are output as they are received.

Electromagnetic field:

The sensor developed by Sanford et al (19xx) for the MP was modified for use on the HRP-II. A specialized collar to hold the sensors flush to the skin near the middle of the instrument was designed and fabricated for the profiler. The two analog outputs are passed through a four-pole butterworth filter before being sampled by the A/D at 200 Hz.

Accelerometers:

An orthogonal pair of Honeywell Q-flex accelerometers is mounted in a rigid housing on the inside of each endcap. The connection between the lower endcap and chassis to the upper endcap can only be made in one orientation, so the lower accelerometer pair is always aligned with the upper pair when the instrument is assembled. The four analog outputs are passed through a four-pole butterworth filter before being sampled by the A/D at 200 Hz.

Shear probes:

The design and methods of R. Lueck were used to fabricate the shear probes in our laboratory. The sensors are mounted on custom-made stainless steel pressure cases that house signal preamplification electronics. The canisters are mounted on the base of the ACM sting so that the sensors sample the same water as the other sensors. The two analog outputs are passed through a four-pole butterworth filter before being sampled by the A/D at 200 Hz.

Micro Temperature and Micro Conductivity:

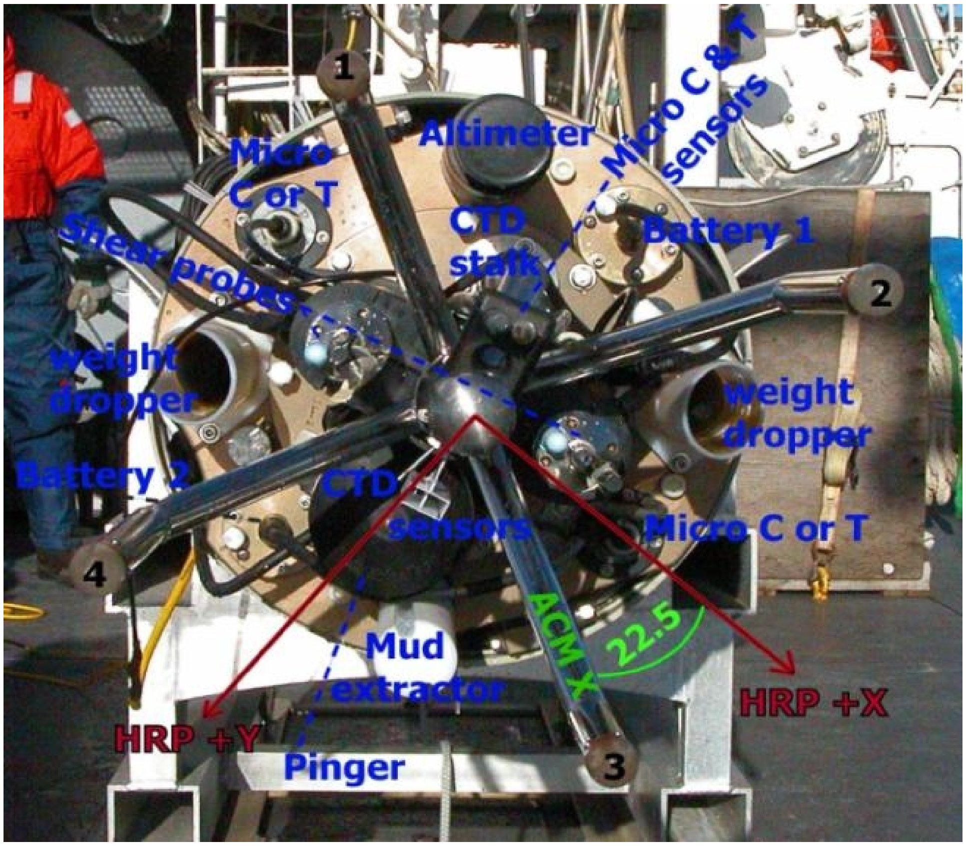
Seabird Instruments SBE 7 and SBE 8 sensors were selected and employed without modification. The pressure cases are mounted in the space between the pressure case and the skin, with the probes mounted on the CTD sting adjacent to the CTD sensors. The two analog outputs are passed through a four-pole butterworth filter before being sampled by the A/D at 200 Hz.

Orientation

The alignment of the sensors to each other is critical for successful analysis of the velocity and microstructure data. The HRP-II body was designed to rotate and oscillate along its long axis as it descends collecting data. The compass data is used to describe the rotations and later to convert velocity relative to the profiler (measured by the ACM) to earth referenced velocity. The data from the accelerometers quantifies the body motion during a profile, which must be removed from the relative velocity and compass signals. The EF sensor data describes larger scale motions, but must also employ compass and accelerometer data to adjust it for vehicle body motion.

In the HRP-II, X is defined as "up" when the chassis is horizontal. The photo in Figure 3 was taken from above (about 30° off X), and shows the chassis in the orientation used in bench testing. Compass North is aligned to X by how the electronics are mounted in the chassis. The accelerometers are rigidly mounted in pairs, with one of the two 90° from the other. One pair is bolted to the bottom end cap, and the other to the upper. The bolt hole positions ensure that both pairs have one sensor aligned with X. The ACM had to be installed at a known offset of 22.5° to HRP-II X because of space limitations on the end cap, and to keep the transducer head from interfering with the release weights and extractor. The collar supporting the EF sensors should not be secured rigidly to the body due to noise issues, so it floats. However, efforts were made to ensure that it remained oriented such that EF-1 was aligned with the instrument X. To summarize, during the test cruise, the following sensors were aligned with X: accelerometers 2 (top) and 4 (bottom), EF 1 and compass N. Figure 5.a. shows the sensor end of the HRP-II with the sensors labeled and the instrument X and Y axes added. Figure 5.b.shows the orientation of the EF sensors relative to the lower endcap.

a)



b)

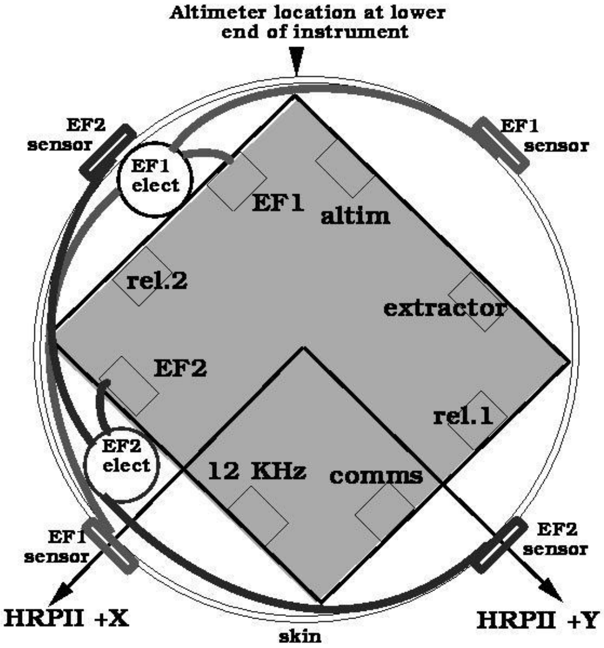


Figure 5: a) photo of the lower end with sensor labels, and axes added. b) schematic of the upper endcap (viewed from outside) with the EF sensor mounting details noted.

Body

The body of the HRP-II is the structure that carries and protects the sensors and electronics during operation. . The dimensions and materials were selected to minimize vibrational noise, and facilitate quiet data measurement. The body consists of five major parts: the electronics pressure case, the support and integration elements (exoskeleton, lifting bail and skin), the floatation, the battery packs and the releases, as shown in figure 6.

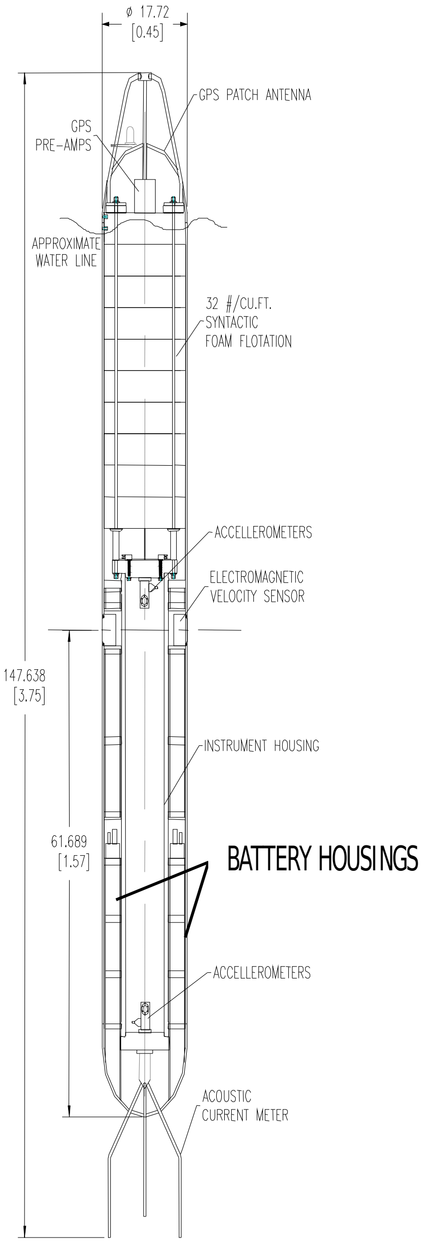


Figure 6: schematic of the HRP-II body

The pressure housing was made of 8” internal diameter, 1” wall 7075-T6 aluminum tube, anodized to prevent corrosion. The endcaps were fabricated of the same material. A schematic of the instrument is shown in figure 7, showing dimensions of the vehicle, along with the major structural elements.

The skin was fabricated from two cylinders of polypropylene. By minimizing the number of seams the frictional effects on body motion were decreased. The amount of syntactic foam attached at the top controls the rates of vehicle descent and ascent. The desired nominal descent rate is 0.6m/s. The power is supplied to the controller and sensors from two battery packs mounted between the pressure housing and the skin. Each pack can supply adequate power for operations independently. The solenoids that function to release the descent weights are also housed under the skin, but outside the pressure case.

Inside the pressure case, a chassis supports the computer, power control boards, and filters, as well as the electronics for the CTD, MAVS, compass, EF, altimeter and 12 KHz pinger. Electrical noise interference was minimized by physical separation and internal partitions separating the components. Figure 7 shows the chassis layout with some of the electronics installed.

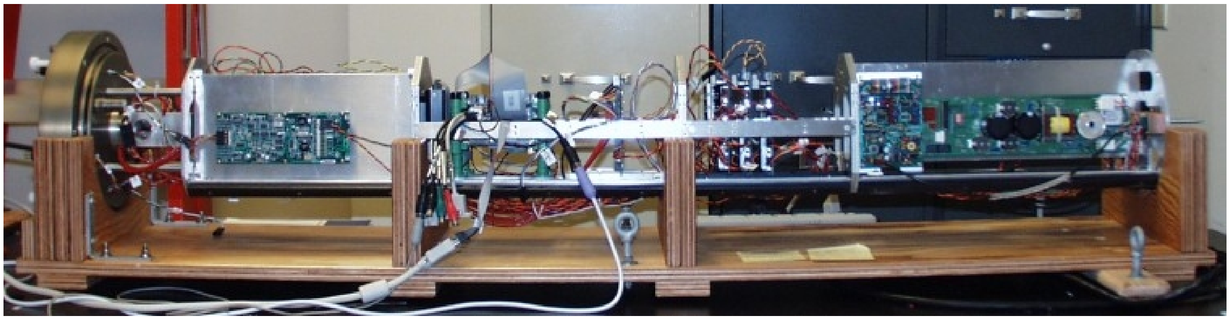


Figure 7: Picture of the lower endcap (left) and chassis that supports and isolates the electronics.

The CTD and MAVS electronics are installed nearest the sensors mounted on the bottom endcap (at left of figure 7) because minimizing the distance between the sensors and the electronics is critical obtaining for high quality data. The computer, A/D filter cards and power control cards occupy the middle of the chassis, and the compass, EF, altimeter and pinger electronics are near the top (right of figure7). The connection to the upper endcap during assembly is made using two blind-mate connectors that aren’t visible at the right of the picture.

Operational Overview-

While the HRP-II electronics are on the bench for testing, a monitor, keyboard and mouse can be directly connected to the PC104 computer. This configuration allows exercise and testing of the logger software, sensors, and power control operation. Modifications of the logger program can be easily be made and tested in this way.

When the HRP-II is fully assembled, communications outside the pressure case are via an ethernet connection. X-server software called VNC running on both the HRP-II and remote computers allows the PC104's desktop to be displayed at the remote machine instead of a monitor. The details of initiating communication with the assembled HRP-II are presented in Appendix G.

The interface with the dive control software is through a graphical user interface (GUI) that allows the user to operate the logger by clicking buttons on the screen. No knowledge of arcane command syntax is required- configuration and testing in addition to setting up and controlling profiles is accomplished by the click of a button. The main option window gives several function choices that should be done from top to bottom. Secondary menus appear and ask for additional inputs based on which button started them. The interface will be documented more fully in another report.

The sequence of events associated with each dive is:

- check mechanical systems (release weights, mud extractor) are ready for deployment
- check sensor configuration hasn't changed
- disconnect ship's power and dummy the connectors
- verify the battery voltage is adequate
- enter dive control parameters
- start the dive (with software)
- verify operation while still on deck
- disconnect communications cable and connect dummy plug
- deploy HRP-II
- track vehicle with echo sounder
- find vehicle after it surfaces
- recover vehicle
- reconnect communications cable
- offload data files
- reconnect power from the ship
- assess data quality to see whether any sensors need repair
- prepare mechanical systems for next dive
- replace any sensors shown to be bad in the previous dive

The handling of the HRP-II is almost exactly as it was for the original profiler. The key elements are a rolling cart on which the HRP-II is secured while on deck, and a hydraulic lifting rig that pivots to move the lift point beyond the ship's stern, so the HRP-II can be deployed and recovered without damage due to collisions with the ship.

Test cruise:

During the autumn of 2003, tests of the fully assembled HRP-II were conducted at the WHOI dock. These tests indicated a number of issues that were addressed prior to going to sea. The dock tests also allowed us to verify that the sensor alignments and channel connectivity were as expected.

The HRP-II was supposed to go to sea in November, but foul weather forced the postponement until January. We chose to work in the area around Hudson Canyon, instead of Georges Bank due to anticipated worse weather to the east. The cruise took place on January 10 –14, 2004, aboard the R/V Endeavor, number 388. The HRP group shared with A.Lavery and P.Wiebe's team, who worked on acoustic methods of differentiating scattering due to biology and that due to microstructure mixing. HRP-II operations took place during daylight hours, while the other work occurred overnight. The HRP team consisted of the following people: Kurt Polzin (Chief Scientist), Ellyn Montgomery, Ray Schmitt, John Toole, Ed Hobart, Bob Petitt, Fred Thwaites, Dave Wellwood, and David Steube.

Once at the work site, six successful profiles with the HRP-II were obtained. The early profiles were terminated well above the bottom, but as confidence in the system was gained, near bottom releases were sought. Software modifications made prior to dive 2 created a situation where the controller hung in an unanticipated way, so no data was collected. However, the mechanical back-up release mechanisms worked, and the profiler surfaced at the expected time. The profiler got to a maximum pressure of 1583db, and got to within 17 meters of the bottom on the last profile, despite the altimeter not working well. The list below provides additional detail about each dive, and figure 8 shows a map of dive positions with bathymetry contours indicating the character of the bottom.

dive #	date m/d/y	time (GMT)	Latitude d.deg	Longitude d.deg	H2O depth	End Pres.	Dive Pmax	How Ended	Comments
1	1/11/04	15:12:19	39.547	-72.095	260	160	160	Pressure	Good dive!
2	1/11/04	19:08:00	39.102	-71.934	2250	1100	-	-	computer hung
3	1/12/04	19:26:15	39.410	-72.250	270	100	100	Pressure	verify OK again
4	1/12/04	21:07:55	39.468	-72.224	1000	800	706	Time	1 wt. off early
5	1/13/04	09:09:00	39.659	-71.436	1650	1610	1583	Shear Pin	best CTD data
6	1/13/04	11:49:25	39.670	-71.437	1590	1580	1531	Time	27 m off bottom
7	1/13/04	15:54:32	39.803	-71.383	860	835	855	Pressure	17 m off bottom

The operational features of the HRP-II worked well, despite very cold operating conditions. It was gratifying that none of the components froze up as HRP-II sat on deck overnight at -6°F. Data from most of the sensors looked reasonable, though there were issues with the conductivity sensor on the CTD and the altimeter that must be resolved prior to further work at sea. By using the system, a number of handling/operations problems were discovered that need work as well. The “needs attention” list generated after the cruise is presented in Appendix H.

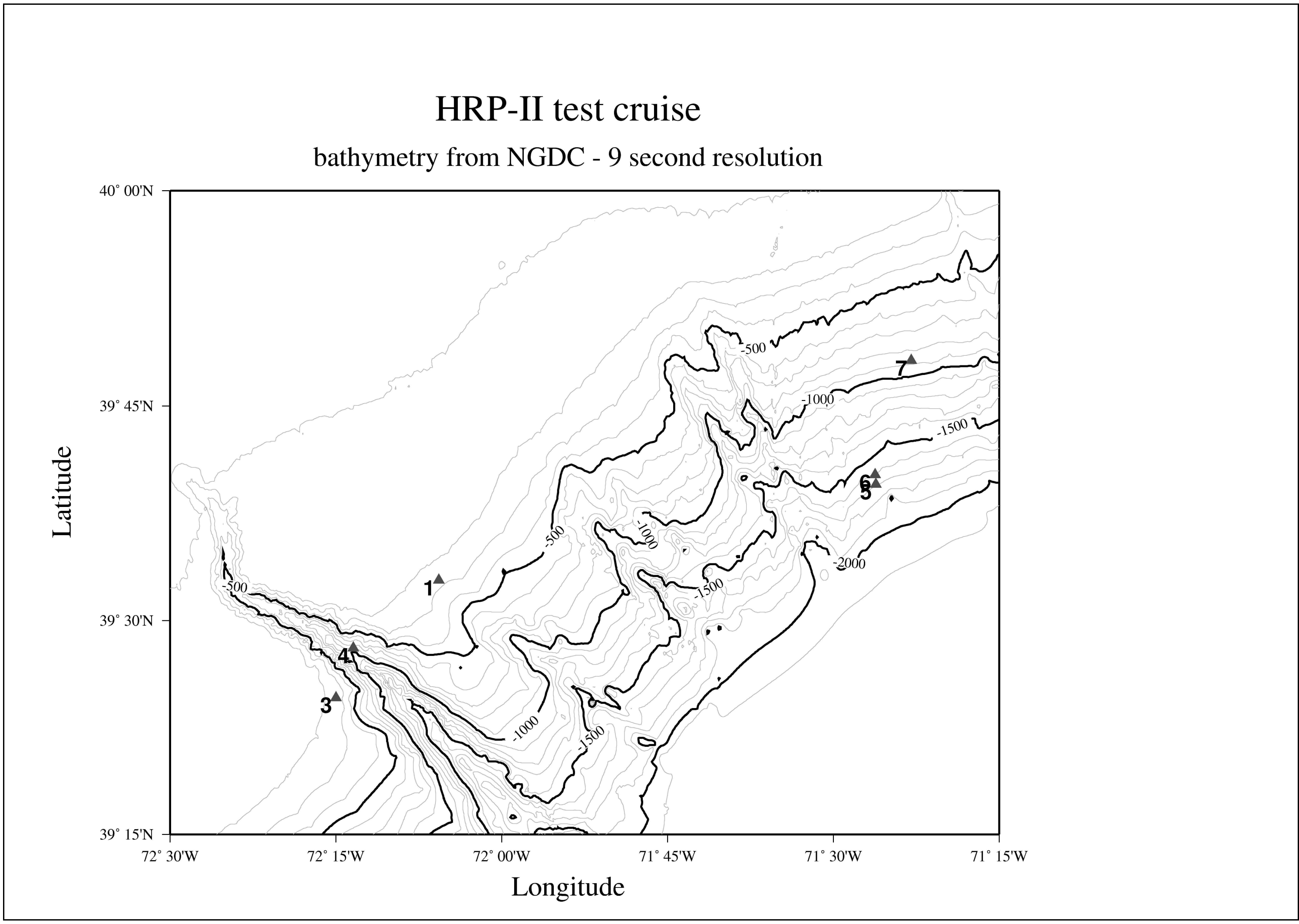


Figure 8: Map of the research area with dive positions indicated.

All in all, the cruise was a good validation of the operational status of HRP-II. For an initial use at sea, it performed extremely well. Working with a free vehicle in deep water is always a bit scary, so it was particularly nice to have it return to the surface more or less at the expected time every time it was deployed.

Data Processing

The methods for working with the data from the HRP-II are under development. The software primarily uses Matlab, and existing Fortran 77 code for the microstructure and EF data analysis. Scripts to unpack all the data formats and make quality control plots exist. Routines to compute absolute ocean velocity, which requires integration of data from the ACM, compass, EF sensors, accelerometers, and GPS positions are being developed. Implementation of a GUI to manage the data processing tasks is planned, but getting the analysis software completed takes precedence.

Future Work

Proposals for use of the HRP-II have been submitted, and hopefully one or more will be funded. These proposals include support for engineers to solve the problems discovered on the test cruise, so the HRP-II is expected to commence science operations with no known issues. We anticipate the HRP-II will prove itself as a robust vehicle for acquisition of data in support of research on deep ocean mixing.

Appendix A: Engineering Support

Engineers involved in HRP-II development and areas of impact.

Ken Doherty + Terry Hammar + Megan Carrol	Mechanical Gurus: responsible for body design, materials selection, battery specification, mechanical systems, EF collar, assembly. Designed and fabricated chassis.
Ed Hobart	PC/software Guru: selected, configured, formatted CPU and add-ons. Developed logger software, connectivity protocols & GUI interface.
Ellyn Montgomery	Project manager. Worked on WD/PC board software, internal communications protocol, integration, component and system testing.
Bob Petitt	Electronics Guru: responsible for CTD design and fabrication, design and assembly of WD/Power control boards and filter boards, electronics integration and testing.
Robin Singer	Developed CTD controller software.
Fred Thwaites + Craig Marquette	Designed and built custom ACM transducer sting and the transducer elements, ACM testing.

Appendix B: Att_tab.asc

This file is read by the logger program to determine the instrument configuration at startup. The columns are: a text abbreviation of the sensor name; which board the power comes from,; the switch(s) it’s connected to; output type (s=serial, a=A/D); the port or channel catching the data; and if serial, the baud rate required.

```
snsr   brd   switch   comm    port      baud
CTD     1       78      s       7       38400
ACM     2       6       s       4       38400
GPS     1       6       s       1       9600
ALT     3       7       s       9       9600
CMP     3       8       s       3       19200
AC1     3       12      a       1
AC2     3       12      a       2
AC3     3       34      a       3
AC4     3       34      a       4
EF1     2       12      a       5
EF2     2       12      a       6
MC      3       56      a       7
MT      3       56      a       8
SX      2       34      a       9
SY      2       34      a       10
PNG     2       5
RL1     1       1
RL2     1       2
EXT     1       3
PC104   1       4

** for switches, if it's two characters, it's a + & - voltage
that needs to be supplied simultaneously, each character
represents the channels to power on.  Command like 2nw34 powers
up board 2, channels 3 & 4 together to turn on the shear
probes.
```

Appendix C: RS485 language syntax

Any WD/PC board in a given backplane can be designated as the Watchdog by assigning it the address ‘1’. This board will be responsible for monitoring operation of the vehicle and taking appropriate action in case of failure. The logger application should terminate a dive, but the watchdog will initiate termination, if any of a number of additional criteria are met. The card that is the watchdog also has to have the releases, mud extractor and PC104 stack connected to it, since specialized commands are used to operate these items.

The communication protocol between the PC/104 logging computer and a chassis of up to 16 watchdog/power-control boards is half duplex, over a bussed RS485 channel. All communication is initiated by the logger application run on the PC104 computer and all WD/PC boards listen by default. An individual board listening on the bus can be queried for data by recognizing its unique address and responding with a defined length reply. The responding board then returns to listen mode thus freeing the channel for another query. The command protocol developed for the HRP is called ‘Rottweiler’ and is detailed below.
All commands must be preceeded by a #, have a board address, and be terminated by a <cr>. Replies from the W/PC boards are for the logger, so are preceeded by ‘L’.

Rottweiler Command Summary:

Write Command	Read Command	Read Response	Function
#Alwd<cr>	#Alrd<cr>	Lwd<cr>	Write/Read LED
#1ewpDDDD<cr>	#1erp<cr>	LewpDDDD<cr>	W/R dive end pressure
#1ewrDDD<cr>	#1err<cr>	LewrDDD<cr>	W/R dive end range
#1ewtDDD<cr>	#1ert<cr>	LewtDDD<cr>	W/R dive end time
#AnwX<cr>	#AnrX<cr>	Lnwc<cr>	W turn switch(s) on ++ R display power status
#AfwX<cr>	N/A	Lfwc<cr>	Turn switch(s) off ++
#1pwDDD<cr>	#1pr<cr>	LpwDDD<cr>	W/R current pressure
#1rwDD.D<cr>	#1rr<cr>	LrwDD.D<cr>	W/R current range
#AtwDDDD<cr>	#Atr<cr>	L1twDDDD<cr>	W/R System Time
N/A	#Ahr<cr>	LhwD<cr>	Read board Humidity

N/A	#Avr<cr>	LvwD<cr>	Read board Voltage
N/A	#Acr	LcwDDD<cr>	Read board temperature
N/A	#Agr	LgwDDD<cr>	Read board GFD
#1ww<cr>	#1wr<cr>	Lww<cr>	Fire weights
#1mw<cr>	#1mr<cr>	Lmw<cr>	Operate Mud extractor
N/A	#A?r	Help message	Display help summary
#AswD<cr>	#Asr<cr>	Lsw1<cr>	W/R Dive Status
N/A	#Axr<cr>	Lxwc<cr>	*** Error Condition

Key:
# = character that indicates a command follows
A = board address(hex), if recognized by all boards. The A is replaced by “1” if the command is specific to the WD.
X = power switch number
D = data character
d = data bit character(0 or1)
++ An ‘a’ replacing X (power switch number(s)) turns on/off all channels on the board
<cr> = 0Dh
*** Not yet implemented

Sample commands:
#1pw4567 : write pressure of 4567 to board 1 (the WD)
#bnw78 : turn on switches 7 & 8 simultaneously on board b
#bnr : read the status of PORTD on board b. CO indicates switches 7 & 8 are ON
#bfwa : turns off all switches on board b.
#2?r : displays a short command synopsis
#1tw0 : resets the WD seconds counter to 0
#1ww : fires the weights

Appendix D: Power Control Board assignments

Board = 1(watchdog), Address = 1, Output Voltage = +24VDC & +/-5VDC, Output power = N/A Power Module – BWR-5/700-D48

Channel	Sensor	Voltage	Current	Power
1 (J3-1)	Weight Release 1	24V	3A	75W
2 (J3- 4)	Weight Release 2	24V	3A	75W
3 (J7- 1)	Mud Extractor	24V	100mA	
4 (J7- 4)	Data Logging PC	24V	0.42A	10W
5 (J9 – 1)	Power Boards *			
6 (J9- 4)	GPS	+5VDC	35mA	0.18W
7 (J11-1)				
8 (J11-4)				
Total(+/-)				

* Hardwired on, PC is turned on at startup in software.

Board = 2, Address = 2, Output Voltage = +/- 12V, Output power = 10W
Power Module – BWR-12/415-D48A

Channel	Sensor	Voltage	Current	Power
1	E Field +	+12VDC		0.75W
2	E Field -	-12VDC		0.75W
3	Shear Probes +	+12VDC		0.1W
4	Shear Probes -	-12VDC		0.1W
5	CTD +	+12VDC	100mA	1.2W
6	CTD -	-12VDC	100mA	1.2W
7	Filter Board +	+12VDC	120mA	1.5W
8	Filter Boards -	-12VDC	120mA	1.5W
Total(+/-)				3.6W/3.55W

Board = 3, Address = 3, Output Voltage = +/- 15V, Output power = 10W
Power Module – BWR-15/330-D48A

Channel	Sensor	Voltage	Current	Power
1	Accel (top) (2) +	+ 15VDC	30mA	0.5W
2	Accel (top) (2) -	- 15VDC	30mA	0.5W
3	Accel (bottom) (2) +	+15VDC	30mA	0.5W
4	Accel (bottom) (2) -	- 15VDC	30mA	0.5W
5	Micro C / Micro T +	+15VDC		0.15W
6	Micro C / Micro T -	-15VDC		0.15W
7	Altimeter	+15VDC	100mA	1.5W
8	Compass	+15VDC		.1W
Total(+/-)				2.8W/1.2W

Board = 4, Address = 4, Output Voltage = +/- 12V, Output power = 10W
Power Module – BWR-12/415-D48A

Channel	Sensor	Voltage	Current	Power
1	Pinger	+ 12VDC		0.1W
2	MAVS ACM	+12VDC		2.0W
Total(+/-)				2.1/W

Serial Channels

Channel	Sensor	Baud		
Com 1	GPS	9600		
Com 2				
Com 3	Compass	19200		
Com 4	ACM	38400		
Com 5				
Com 6				
Com 7	CTD	38400		
Com 8				
Com 9	Altimeter	2400		
Com 10	485	9600		

A/D Channels

Channel	Sensor	Gain	Bandwidth	Cal Factor
1	Accelerometer 1	1	50Hz	23.5ug/ct
2	Accelerometer 2	1	50Hz	23.5ug/ct
3	Accelerometer 3	1	50Hz	23.5ug/ct
4	Accelerometer 4	1	50Hz	23.5ug/ct
5	Micro C	1	50Hz	305uV/ct
6	Micro T	1	50Hz	305uV/ct
7	Shear 1	1	50Hz	305uV/ct
8	Shear 2	1	50Hz	305uV/ct
9	E Field 1	1	50Hz	uV/m/ct
10	E Field 2	1	50Hz	uV/m/ct
11				
12				
13				
14				
15				
16				

Appendix E: HRP-II Sensors employed on EN388 test cruise

sensor	sample.rate	manufacturer
CTD	25Hz	(WHOI built, precision 24 bit)
pressure		Druck (model PDCR 1820-9082)
Thermomistor		Thermometrics (model, SP60DA202MA1) with stainless pressure housing
Conductivity		ceramic, internal-field, with embedded thermistors
Fast thermistors (2)		Thermometrics model P60DA202G
ACM	26.7Hz	MAVS-3 with special transducer sting
EF	200Hz	Sanford et al electronics wi WHOI collar
Accels	200Hz	Honeywell Q-flex 1400 (P/N 979-1400-011)
Compass	16Hz	PMI TCM-2
Shear probes	200Hz	Lueck design modified/fabricated at WHOI
Micro C & T	200Hz	Seabird
Altimeter	1Hz	Datasonics PSA 900
GPS	1Hz	Trimble, model Lassen SQ
Pinger		Edgetech BART special

Appendix F: HRP-II Sensor data formats.

On HRP-II each sensor logs its data to a separate file, so with 15 sensors configured, you'd expect 15 files in the directory for the dive, plus the four general descriptive files made each dive. The data file naming conventions used in HRP-II are described below.

Five sensor systems store their data as ascii data (described below), and the 10 sensors acquired by the A/D are binary files of type = float. The samples are stored sequentially in the order received. All the files start simultaneously, so the sampling rate or internal clocks must be used to synch up the various sources of data.

There is no header in any of the data files - one header file **hdren388d00#.txt** applies to all the data for the profile. A sample (**hdren388d005.txt**) is below.

```
SHIP: Endeavor
CRUISE NO: 388
CRUISE ID: en388td
DIVE NO: 5
EXPERIMENT: test cruise
LATITUDE: 39 40.60
LONGITUDE: 71 25.00
DECLINATION: 14.6
WATER DEPTH(m): 1650.000000

CTD Deck Pressure(db): 0.554
CTD Deck String:
0.575     7916533  186300994    5510391  204383323  201485096  270374140  4127    24402861
Deck Battery Voltage: 25.65
GPS ON/OFF PRES(db): 10
UP END PRES(db): 10
DOWN END PRES(db): 1610
END RANGE(m): 50.000000
DOWN MINUTES: 85
TOTAL MINUTES: 130
INITIAL DELAY: 3
OPERATOR: etm

PROFILE START Time: 4:03:56
Start Logging Time 4:7:11
Down Ending Time 5:30:53
Ending Pressure 0
Ending Range 0.700000
PROFILE ENDED DUE TO: User
```

The sensor configuration used on each dive is stored in **divcfgenn388d00#.txt**, providing a record of what was turned on and which settings were used:

```
dive no 5, down minutes 85, end press 1610, end range 50.0
serial ports
port state id baud board switch
1 ON   GPS 9600 1 6
3 ON   CMP 19200 3 8
4 ON   ACM 38400 4 2
7 ON   CTD 38400 1 78
9 ON   ALT 2400 3 7


a-to-d ports
port state id gain board switch
1 ON   AC1 1 3 12
2 ON   AC2 1 3 12
3 ON   AC3 1 3 34
4 ON   AC4 1 3 34
5 ON   MC 1 3 56 s/n 070113 tip 1
6 ON   MT 1 3 56 s/n 080114 tip 1
7 ON   SX 1 2 34 can 25 prb 68 prb_gain 0.0
8 ON   SY 1 2 34 can 21 prb 78 prb_gain 0.0
9 ON   EF1 1 2 12
10 ON   EF2 1 2 12
power info
PNG, 4, 1
RL1, 1, 1
RL2, 1, 2
EXT, 1, 3
PC104, 1, 4
```

In addition to the header and configuration files, there are two additional files related to the operational status of the instrument. All the RS485 traffic is stored in **drs485en388d00#.txt**, and the internal sensors (board temperature, humitity, voltage, ground status) are in **dvthgen388d00#.txt**.

ASCII formats

===

CTD data - named **dctden388d00#.s07** - sample rate : 20Hz

the contents of the data files, by column, is : nominal_processed_pressure, raw_pressure, raw_temperature, raw_conductivity, ??, fast_T_1, fast_T_2, ??,??, internal_time (picoseconds)- this is not relative to anything else, just lets one evaluate intra-sample drift.

```
0.492     7913573   6011964   5508329  203400340  198597452  181393661  2363   191606261
0.467     7912760   6011050   5508418  203384197  198576755  181403347  2363   191646269
0.518     7914411   6010068   5508628  203346280  198585155  181412646  2363   191686247
0.679     7919636  270652062   5508952  203283710  198626553  181429127  4411   191726256
0.633     7918138  270656725   5508488  203203141  198657206  181441419  4411   191766265
0.611     7917431  270657567   5508647  203126700  198663706  181448731  4411   191806273
0.613     7917485  535281924   5508738  203027208  198649603  181453162  8507   191846252
```

```
0.609     7917355  535283908   5509100  202936812  198635555  181462702  8507    191886259
0.562     7915851  535284591   5508956  202849177  198612191  181471394  8507    191926269
0.551     7915497  181613742   5508792  202770529  198578196  181485008   319    191966276
0.587     7916660  181619366   5509017  202688571  198539885  181492468   319    192006255
0.574     7916220  181624896   5509459  202585170  198495704  181498668   319    192046263
```

A conversion must be applied to this data to output P, T, C- the program to so this is under development.

MAVS data - named dacmen388d00#.s04 - sample rate : 26.7Hz

The columns contain time (milisecs) and raw travel times along the acoustic paths A-B B-C C-D D-A. The time is not relative to anything external, is used to evaluate intra-sample drift.

```
.168 E807 F30C EBD2 F120
.206 E7A7 F304 EC4A F160
.245 E7FF F334 EBFA F188
.283 E7B7 F2EC EC12 F148
.322 E7BF F2C4 EC3A F180
.360 E7EF F334 EC32 F120
.398 E78F F2C4 EC32 F108
.437 E7EF F2EC EC5A F210
.475 E7A7 F2BC EC3A F138
.513 E7F7 F30C EBFA F168
.552 E82F F2CC EC0A F158
.590 E81F F2C4 EC5A F168
.629 E7EF F2E4 EC82 F120
.667 E7C7 F2EC EC4A F180
.705 E7EF F2CC EC52 F118
.
```

Compass data - named dcmpen388d00#.s03 - sample rate : 16Hz

The compas 0 is aligned with ACM sting _. The data is compass heading, pitch, roll, and then the raw x, y, and z accellerations, so you can compute your own headings. The * indicateds the beginning of the checksum, and if there's an E for error, it follows thelast data and preceeds the *. Use cvt_tcm2.m to read this data.

```
$C47.8P-4.7R-12.5X41.67Y-51.12Z39.65*33
$C47.6P-4.4R-12.1X41.65Y-50.85Z39.89*35
$C47.7P-4.3R-11.7X41.59Y-50.63Z40.00*3E
$C47.7P-4.0R-11.3X41.49Y-50.39Z40.33*37
$C47.4P-3.9R-10.9X41.51Y-50.15Z40.63*33
$C47.5P-3.6R-10.5X41.39Y-49.91Z40.74*3D
$C47.5P-3.4R-10.1X41.25Y-49.69Z41.09*3A
$C47.3P-3.2R-9.6X41.26Y-49.43Z41.37*03
$C47.3P-2.9R-9.2X41.17Y-49.19Z41.60*02
$C47.5P-2.7R-8.7X40.98Y-48.96Z41.91*00
$C47.3P-2.5R-8.3X40.95Y-48.69Z42.32*07
$C47.3P-1.8R-7.6X40.80Y-48.43Z42.57*0C
$C47.8P-2.5R-7.3X40.59Y-48.17Z42.84*07
```

```
$C47.0P-1.4R-7.1X40.54Y-47.92Z43.15*09
```

Altimeter named dalten388d00#.s09 - sampled at 1Hz

The data is Temperature and Range from the bottom. This smple is garbage- when working correctly, it should show a monotonic decrease in range with fairly constant temperature.

```
T21.6 R77.7
T21.4 R137.3
T21.4 R192.9
T21.6 R208.2
T21.6 R228.0
T21.6 R219.8
T21.4 R204.9
T21.6 R210.2
T21.4 R225.8
```

GPS named dgpsen388d00#.s01

This data is only sampled prior to deployment and prior to recovery. It does not have to synch with any of the other data. This shows a segment with no satellite lock, and then with some good data showing that it was at 39.39.4286N, 71.26.1973W (the GGA string is the important one here)

```
$GPGGA,,,,,,0,05,,,,,,*63
$GPVTG,,,,,,,,,N*30
$GPGGA,,,,,,0,05,,,,,,*63
$GPVTG,,,,,,,,,N*30
$GPGGA,101310.00,3939.4286,N,07126.1973,W,1,05,1.28,-00008,M,-034,M,,*7B
$GPVTG,136.0,T,149.9,M,002.6,N,004.9,K,A*2B
$GPGGA,101311.00,3939.4275,N,07126.1984,W,1,05,1.28,-00007,M,-034,M,,*71
$GPVTG,147.2,T,161.1,M,003.4,N,006.2,K,A*27
$GPGGA,101312.00,3939.4270,N,07126.1988,W,1,05,1.28,-00007,M,-034,M,,*7B
$GPVTG,223.6,T,237.5,M,001.1,N,002.0,K,A*27
$GPGGA,101313.00,3939.4270,N,07126.1992,W,1,05,1.28,-00006,M,-034,M,,*70
$GPVTG,326.0,T,339.9,M,000.8,N,001.5,K,A*28
```

The get_imet.prl program should be adaptable to work with this data, but we got so few GPS records on the test cruise that we didn't make the necessary changes yet.

Binary data

==

A/D channels are sampled at 200 Hz and passed through a butterworth filter before storage. rd_adbin.m and rd_adbin_gui.m allow these files to be read into matlab for crunching. The file names are:

```
dac1en388d00#.a01   four accelerometers
dac2en388d00#.a02
dac3en388d00#.a03
dac4en388d00#.a04
dmcen388d00#.a05    Micro T & C
dmten388d00#.a06
dsxen388d00#.a07    Shear x & y
dsyen388d00#.a08
def1en388d00#.a09   EF 1 & 2
def2en388d00#.a10
```

Appendix G: External communications with HRP-II via the Ethernet connection

1) Connect the 5 pin -> Ethernet plug to the HRP. The RJ45 end should be connected to a netgear box or to a network, with the users computer also connected.
2) Given the HRP-II computer is ON, establish communications by either:
    a) using a java enabled browser, set the link to http://128.128.97.103:5800
    b) using VNC software, connect to 128.128.97.103 (password=hrp)

   The user's computer MAY need to use the same subnet address, and 128.128.97.98 is a good setting for the other computer.

   ++ If you need to log on, do so as Administrator, password=hrp. ++

Now you should be able to view the screen of the HRP-II monitor in a window on your computer. The mouse works, but response will be SLOW, due to having to maintain the windows information and translate all the clicks back and forth.

3) To communicate directly with the WD/ PC cards (RS485) use Hyperterm (under programs, accessories, communications). There should be a shortcut to Hyperterm on the desktop. The settings should be set up so you can just open wd.ht, but if you need to set it up, here's what you need:
    a) COM10
    b) 9600 baud, 8 data bits, no parity, 1 stop, no flow control
    c) under the settings tab, select : terminal keys, Ctl+H, AnsiW, VT100, 500, then under the ASCII setup button (receiving), choose "append ff to line end".

    Procomm will do RS485, but it will not do COM10, so you MUST use Hyperterm!!!!!
4) You can also use Hyperterm and Procomm together to view data, if you choose-
    a) In hyperterm, issue a command like #1nw78 to turn on the CTD
    b) In Procomm view the CTD output on comm7 at 38400 baud.
    c) In hyperterm turn off the CTD with #1fw78.
5) Use HRP2.exe to view or log data. (there should be a shortcut to hrp2 on the desktop) There will be other documentation to explain how to use hrp2.exe.
    a) Data logged by the viewer will be under \data\2003….. where the directory corresponds to the date created, and the file names are based on the time created.
    b) Data logged while running a dive is stored in \data\experiment\dive*.*.
6) Before FTPing files off the disk in HRP-II, you have to enable the server. Serv-U is the program, and there should be a U on the bottom taskbar, with a red line through it. Right mousing it allows it to be turned on or off. Only leave it on when transferring data.
7) Use WS-FTP95, or procomm to grab the files desired. The server account username is hrp, password is moejoe.

Appendix H: Items to be fixed on HRP-II

Logger Software

- verify interplay and consistent behavior of the watchdog and main controller (e.g., identical end of logging behavior regardless of how the dive is terminated - RTERM still has problems)
- pass dive parameters to watchdog asap and initiate watchdog ops before logging is started.
- initiate GPS logging on initial startup, (before the other sensors start, so it can aquire data before sinking)
- increase time between sequential fires of releases

Sensors

- improve the altimeter’s ability to find bottom or find another altimeter to use
- check output of 12 kHz pinger, improve shipboard signal reception (we didn't hear the pinger because it was set to output a different frequency internally- that's fixed, but it should still be checked)
- increase ping rate on up-profile to better facilitate tracking
- test GPS reception as a function of antenna angle
- improve mechanical strength of the CTD's conductivity cell and internal thermistors
- identify and fix the source of partial CTD data records
- validate the new CTD performance with detailed lab calibration and piggyback profiles with standard shipboard CTD system

Body

- consider moving 12 kHz pinger to top of body to improve signal reception
- revise GPS antenna mounting so that it is better protected
- make sure the battery pressure cases are clear of obstructions during removal (on test cruise they were blocked by the zinc anode and the 12 kHz mounting bracket)
- combine on-deck comms and shore-power cable to simplify swapping to lab-power and thus save internal battery power during time on deck
- reduce variety of bolt types and sizes to make at-sea maintenance simpler
- brighter paint job
- improve weight release doors (perhaps develop an overlapping door faired to the skin and hinged) to simplify deck operations
- add a pressure-case purge system to insure dry atmosphere inside the instrument after openings
- acquire a blank end cap to seal pressure vessel while electronics are being serviced
- one long (100+') ethernet cable with no couplers (they leak!)

Electronics

- add second capacitor to weight release solenoid circuit so that there

- is one cap per solenoid
- increase gain in the accelerometer channels and calibrate output from all 4

Batteries & Power Control

- explore ways to test remaining battery capacity (e.g. voltage measurement under various loads)
- add an "electric meter" on the battery packs that will accumulate output amps to better guide battery replacement decisions.
- explore use of rechargable batteries (cost, capacity,...)
- run HRP-II on bench under full load and measure current used. Give info to Steve L. so he can estimate how much to derate the BCX85 battery pack.

Data processing

- quantify microstructure noise levels based on test cruise data
- assess quality of the EM current meter data; derive test-cruise velocity profiles
- determine if the fast spin rate (one rev per ~15 m) is necessary for the EM current meter, and/or if errors contaminate derived velocity at rev period
- develop point-mass ocean velocity algorithm for HRP-II; apply and compare results to above (Former will require detailed estimates of body dimentions and mass)
- refine compass calibration; work out how to estimate direction based on raw magnetometer and tilt data
- devise a faster way to read the raw data files into the analysis computers (perhaps for now, just manually edit the serial data files to insure first and last data records are complete strings)
- create a data structure for both fine and micro files with links to (updated) reduction/analysis routines and final products