5. MARINE SEISMIC SYSTEM EXPERIMENT[1]

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ABSTRACT

The goal of the Marine Seismic System (MSS), as deployed on Leg 91, was to record long-term regional seismicity in the area of a subducting plate and to compare the results with conventional ocean bottom seismometers (OBSs). This chapter discusses the background of the MSS program and describes the equipment, equipment performance, its deployment, and recovery. The equipment suite was designed based on the successes and lessons learned on Legs 78B and 88. Primary components included a triaxial seismometer housed in a Borehole Instrumentation Package, which was connected to a recording unit referred to as the Bottom Processing Package. The mooring used to deploy, recover, and redeploy the system is also described. Final navigational positions of the various components are given in the event future researchers desire to reactivate the seismic station at Hole 595A.

In summary, regional seismicity was recorded and the MSS proved a much better recording instrument than conventional OBSs. The equipment operated as designed, with the exception of a connector failure. Mechanical handling and development procedures proved more that adequate.

BACKGROUND

Deep Sea Drilling Project (DSDP) Leg 91 was funded by the Defense Advanced Research Projects Agency (DARPA) for installing the Marine Seismic System (MSS). MSS is an ARPA project developing, installing, and operating a broadband, triaxial, ocean-bottom borehole seismometer station capable of discriminating between earthquakes and nuclear explosions. The Naval Ocean Research and Development Activity (NORDA) is directing the program for DARPA through government and contractor personnel. Global Marine Development, Inc. designed and built the reentry tools to place the seismic package in a borehole and developed procedures to lay out a mooring for subsequent retrieval and redeployment. The mooring was designed by the Navy Civil Engineering Laboratory. Site preparation and deployment was carried out in conjunction with DSDP using the *Glomar Challenger*. The downhole seismic instruments were designed and built by Teledyne Geotech, Inc.; Gould Defense Electronics Division, Inc., Glen Burnie, Maryland, designed and built the bottom processing package, which records 45 days of *in situ* seismic data.

A prototype MSS installed in Hole 395A during Leg 78B recorded approximately 30 hr. of shipboard data (Hyndman, Salisbury, et al., 1984). The installation in March 1981 proved the feasibility of the installation technique and showed improved signal-to-noise ratio over conventional ocean-bottom seismometers (OBS) deployed close to the drill site (Adair et al., 1984).

The installation performed on Leg 91 was to record 50 days of seismic data. Conventional OBSs were deployed concurrently with the MSS by the *Melville* operated by the Scripps Institution of Oceanography.

The next two sections describe the specialized equipment used on the MSS experiments. The first section describes the equipment as designed and lists capabilities and data formats. The second section describes how the equipment actually performed throughout deployment and recovery.

EQUIPMENT DESCRIPTIONS AND DATA FORMATS

Equipment Overview

The MSS as deployed consists of a borehole seismic package connected to a seafloor recording system that can be recovered, refurbished, and redeployed via a subsurface mooring. Both the seismic package and the recording package have shipboard consoles to check out the systems prior to deployment and to monitor instrument performance during deployment. A special reentry sub was built to place the seismic package gently into the reentry cone and hole. In addition, equipment was built to handle the cable, reduce heave motion, and monitor for cable entanglement. To aid in system recovery using ships other than the *Glomar Challenger*, a seafloor Acoustic Transponder Navigation (ATNAV) System was deployed. The MSS instrumentation on Leg 91 consists of the following functional subsets:

1. Borehole Instrumentation Package (BIP)
2. BIP Shipboard Test Console (STC)
3. Bottom Processing Package (BPP)

[1] Menard, H. W., Natland, J., Jordan, T. H., Orcutt, J. A., et al., *Init. Repts. DSDP*, 91: Washington (U.S. Govt. Printing Office).

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4. BPP Test Equipment Rack (TER)
5. BIP Subsea Deployment Equipment (Reentry Sub)
6. Installation Recovery and Reinstallation Mooring (IRR)
7. Deployment System Shipboard Handling Equipment

In addition to equipment descriptions, this section also provides BIP operational formats and BPP data tape formats.

BIP Functional Description

The primary function of the BIP is the acquisition of seismic data, which is accomplished by a set of three seismic sensors oriented in a mutually orthogonal configuration with one sensor vertical. An additional (fourth) sensor is provided in the vertical direction for redundancy. Additional sensors are available for monitoring acceleration, temperature, internal package pressure, and power supply outputs to aid in the BIP deployment, installation, and state-of-health (SOH) determinations. Microprocessor-controlled electronics provided for system control of data flow to, and command control from, the other functional units (STC, BPP, and TER) during the various phases of deployment, installation, and operation.

Figure 1 is a functional block diagram of the BIP. The three primary sensors (vertical and two horizontals, or Z, X, and Y; note there was no orienting device in the BIP, and the orientations of horizontal seismometers were unknown) drive a set of mid-period data filters that perform the desired waveshaping in a 0.01–1.0-Hz data band. These same sensors also drive, via a short-period switch, the three short-period (SP) filters that perform the desired waveshaping in the 0.1–20-Hz data band. Figures 2–4 show the short-period acceleration, velocity, and displacement responses, respectively. Figure 5 shows these same response functions for the mid-period data channels. As indicated, the short-period channels are approximately flat to acceleration from 1.0 to 10 Hz, and the mid-period channels are approximately flat to acceleration over the entire band. The short-period vertical backup channel (ZB) is identically shaped in short-period band, but is not utilized as a mid-period data sensor. The short-period switch serves as a calibration input switch allowing a calibration signal, discussed later, to be summed with the seismic data sensor output for diagnostic purposes. An additional function of this module, provided for future system expansion, is the ability to select either a primary or a secondary seismic sensor set under operator (command) control.

The seven wave-shaped seismic data channel outputs are input in parallel to a buffer-amplifier data transceiver unit (DTU) buffer and two mulitplexed input, gain-ranged digitizers (termed P channel and Q channel). The multiplexers, analog-to-digital converters and gain-range control modules, which are under microprocessor control, select and digitize the seismic data inputs and condition their amplitudes. The resulting outputs provide a 14-bit data word (inverted offset binary) and a two-bit gain code ($\times 1$, $\times 8$, $\times 32$, or $\times 128$), which result in sensitivities of 1.28×10^{-3}, 1.6×10^{-4}, 4×10^{-5}, and 1×10^{-5} V per count, respectively. The gain-range control modules also accept up to 16 (12 utilized) system voltage monitor inputs and output these as analog SOH functions, as described later. The DTU buffer is a unity-gain buffer amplifier that isolates the digital data system from the data transceiver unit.

A three-component accelerometer, signal-conditioning amplifier (charge amplifier), and positive and negative peak sample-and-hold circuitry sense accelerations during system deployment. The peak sample-and-hole circuits record only the maximum positive or negative peak occurring in each 20-ms window. This allows the detection, but not the reconstruction, of high-frequency acceleration peaks without an unduly high data conversion rate in the analog-to-digital system.

The six acceleration channels (Z+, Z−, X+, X−, Y+, and Y−) are input to the SOH multiplexer and the dual analog-to-digital converter (13 bits plus sign). Acceleration channel sensitivity is approximately 0.1 V/g from 5 to 100 Hz.

Four temperature sensors monitor temperatures at various points within the BIP. Two of these sensors measure temperature on circuit cards within the electronics stack, another is attached to the electronics bay frame in the seismometer section, and the fourth is attached to the electronics bay frame in the top of the BIP. Sensor outputs are preconditioned by the temperature amplifiers, then are input to the SOH multiplexer and dual SOH analog-to-digital converter.

A pressure transducer, which has a resolution of 0.01 1b./psi absolute, measures internal package pressure in the BIP. The device uses an internal amplifier for preconditioning the signal prior to input to the SOH multiplexer and 14-bit analog-to-digital converter.

As alluded to in previous paragraphs, 12 voltage monitors are provided for monitoring the BIP power supply input and outputs, as well as outputs from the several voltage regulators. These monitors are input via the gain-range controllers to the SOH analog-to-digital converter and digitized with 12-bit accuracy.

BIP command and control functions are divided among several functional modules within the system: format processor, control processor, interface logic, timing and data serializer, opto-isolated drivers, clock module (TCXO), and calibrator.

The format processor is a microprocessor-based (RCA 1802), data acquisition and formating controller. The format processor controls and fetches all digitized seismic, SOH, and status information; formats these data; and places these data on the format bus lines for ultimate transmission to the STC or BPP via the appropriate communication hardware.

The control processor is identical to the format processor except for the content of the erasable, programmable, read-only memory (EPROM) resident firmware. The primary functions of the control processor follow.

1. Monitor the downhole control communications for BIP commands.
2. Verify received commands through error checking.
3. Decode verified BIP commands and take appropriate action:

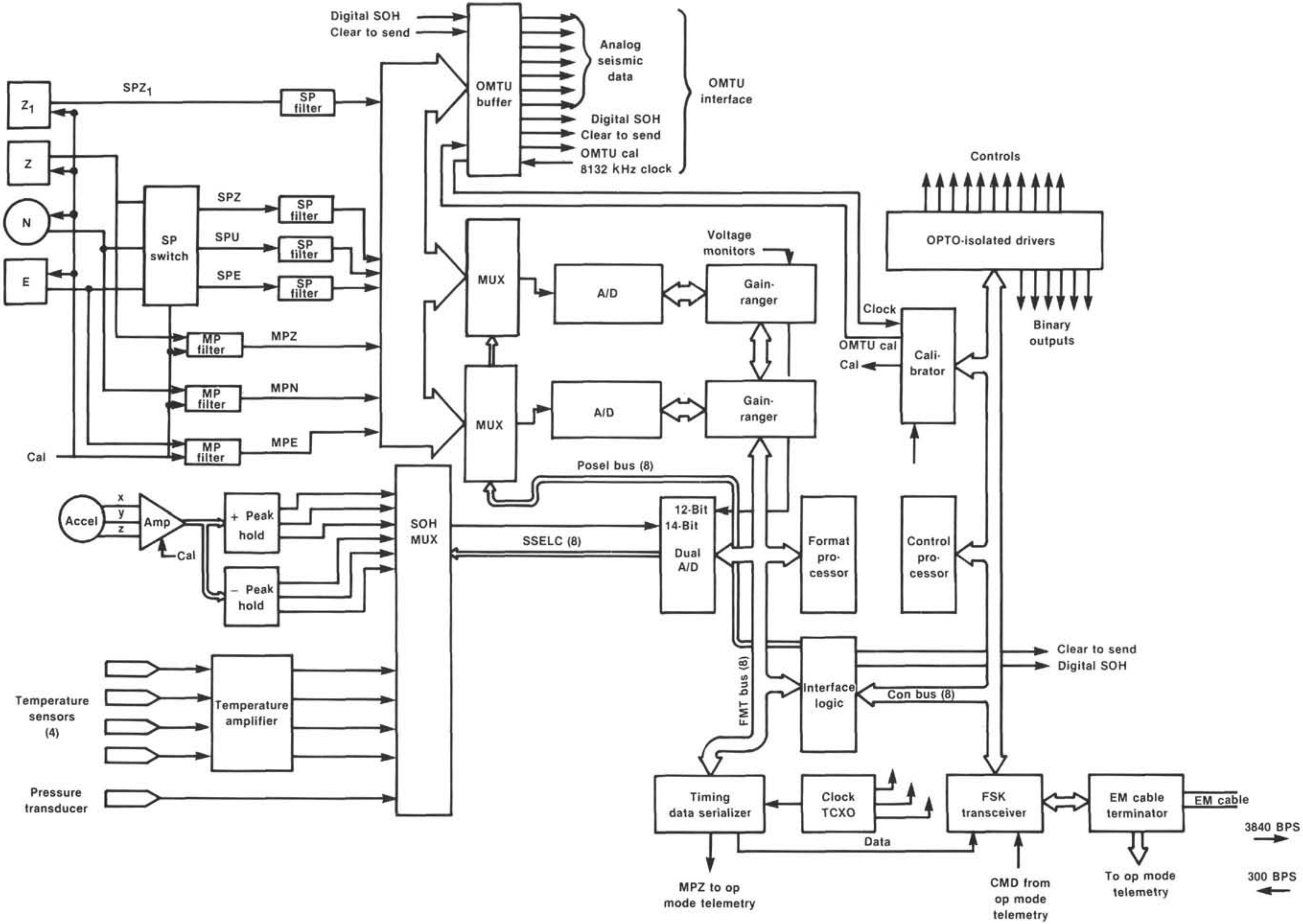


Figure 1. BIP functional block diagram.

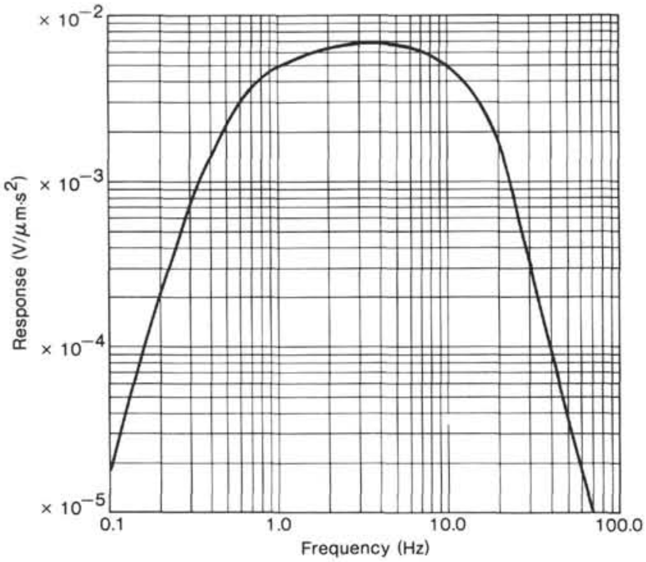


Figure 2. Short-period acceleration response.

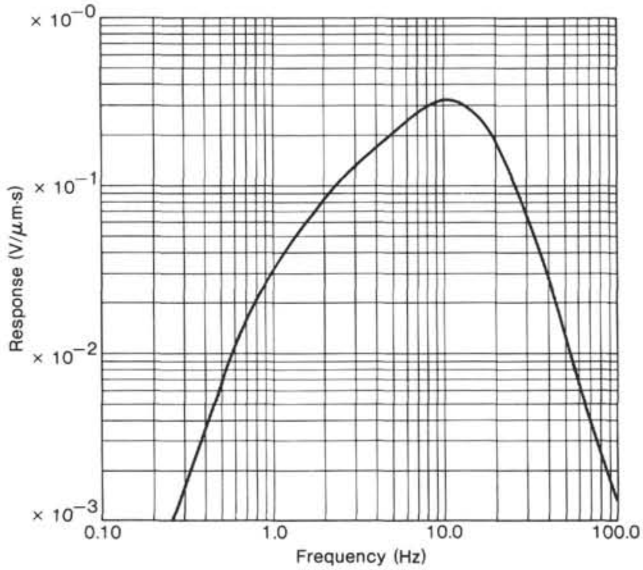


Figure 3. Short-period velocity response.

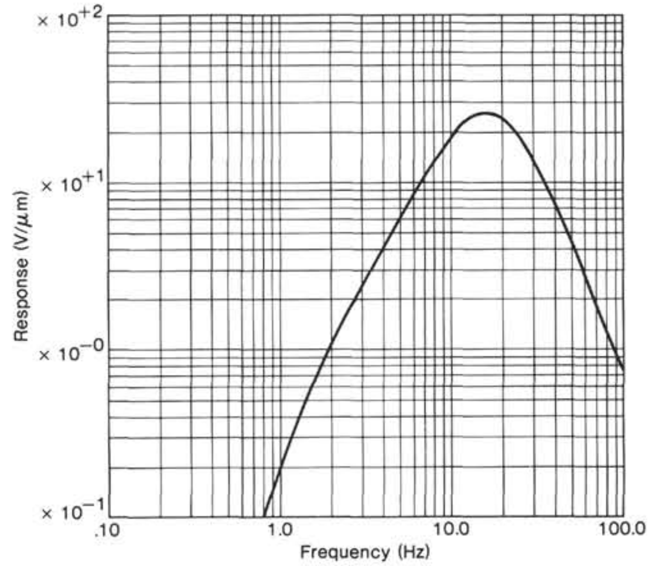


Figure 4. Short-period displacement response.

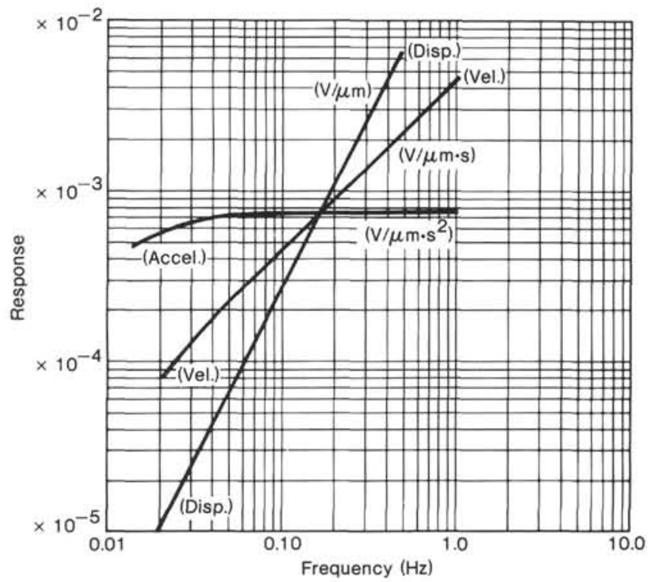


Figure 5. Mid-period response.

a. activate a BIP control signal,
b. Send a command to the format processor,
c. activate the BIP calibrator program,
d. run the BIP calibrator.

The interface logic module performs the following functions.

1. Provides a command interface between the command and format processors.
2. Provides a power-on reset delay.
3. Receives digitizer enable status from the format bus and generates appropriate digitizer control commands.
4. Provides a serial SOH input to the DTU via the buffer amplifier.

The timing and data serializer module generates a non-return-to-zero (NRZ) data stream, made up of data sent by the format processor.

In all operating modes requiring data transmissions to the STC, this NRZ data stream is input to the frequency shift key (FSK) transceiver for transmission via the electrical-mechanical (EM) cable terminator and EM cable to the STC. Several control clock frequencies related to data transmission are generated by this module from an input from the main clock. In operational mode (during and after deployment of the BPP) SOH data is transmitted via the DTU, and the interface logic module interfaces directly with the format bus as the source.

The opto-isolated driver module provides, via the control processor, digital control drivers and isolated switches. The digital drivers control calibration input switches for the various modules requiring periodic calibration inputs, as well as the frequency-select input lines to the calibrator module. The isolated switches provide the ability to turn off unneeded circuitry selectively. The isolated switches control the power to the analog-to-digital converters, the accelerometer-peak sample-and-hold amplifiers, and the pressure transducer, none of which are required after deployment of the BPP.

The temperature-controlled crystal oscillator (TCXO) clock module provides the master clock frequency (1.536 MHz) from which all other BIP clocks are derived. This TCXO also provides a bit clock to the time-and-date serializer of 3840 Hz in all shipboard recording modes and 2400 Hz in the operational mode.

The calibrator module is used to supply accurate sine wave or step voltages to the seismometer and signal processor inputs. The calibration frequencies and amplitudes are predetermined by system firmware (EPROM resident software) and are selectable in discrete steps under command control. The calibrator module also generates all data-sampling-rate clocks from a master clock input.

BIP power is derived from a dc supply in either the STC or the BPP, depending on the mode of operation. The dc power source supplies sufficient voltage to the coaxial cable to compensate for power losses in the cable and still have a dc level of between 100 and 110 V dc at the BIP. The coaxial EM cable is inductively and capacitively coupled to the BIP so that the dc power is input to the BIP power supplies, yet is isolated from the BIP signal-transmission electronics via the EM cable terminator. This power is input in parallel to a dc–dc converter supplying the necessary voltages for the DTU, plus a dc–dc converter supplying the necessary voltages for the remainder of the BIP. These voltages are then conditioned again by additional regulators to provide isolation and, thus, reduce the possibility of a single-component failure causing catastrophic failure of the entire BIP.

The DTU serves as the data telemetry and communications interface between the seismic instrumentation in the BIP and the Data Acquisition and Recording System (DARS) on the BPP in the operational mode. The primary functions of the DTU are listed.

1. Analog-to-digital conversion of seven channels of seismic data,
2. FSK modulation and transmission of seven channels of seismic data,
3. Receipt of commands from the DARS and transfer to BIP control processor,
4. Receipt of a BIP digital status and SOH data from the BIP format processor and transmission to the DARS.

The seven channels of seismic data are digitized using a delta-modulated encoding technique. The four short-period channels are sampled and digitized at a rate of 10,240 bits/s. The three mid-period channels are sampled and digitized at a rate of 1024 bits/s.

Once digitized, the seven channels of data are FSK encoded for transmission over the coaxial cable. Table 1 gives FSK frequency allocations. Commands to the BIP from the DARS and status from the BIP to the DARS are accomplished via an asynchronous, bidirectional, full-duplex communication link. Commands are transmitted to the BIP at 300 bits/s, with F_0 (space) at 2600 Hz, and F_1 (mark) at 3100 Hz. BIP status is transmitted to the DARS at 300 bits/s, with $F_0$0 (space) at 26,000 Hz and F_1 (mark) at 33,680 Hz.

Table 1. FSK frequency allocations.

Channel	Data rate (bits/s)	Frequency (Hz) (F_0 Hz [space])	(F_1 Hz [mark])
MP-Z	1024	8000	9024
MP-N	1024	12024	13048
MP-E	1024	16048	17072
SP-Z	10240	45000	55240
SP-Z (back-up)	10240	107480	117720
SP-N	10240	142720	152960
SP-E	10240	179880	190120

Figure 6 shows the physical dimensions and weight of the BIP. The BIP electronics and sensors are contained in a 20-ft.-long × 8-in. outer diameter pressure vessel. A cable isolator (the upper 13 ft.) is designed to lock the mechanical EM cable termination rigidly into the uncased borehole, while providing a slacking mechanism to decouple the EM cable mechanically from the sensor/electronics package. The EM cable electrical conductors, relatively flexible with respect to the overall EM cable construction and the large mass of the sensor/electronic package, pass through the center of the isolator and transfer very little of the vibrations that may be seen by the EM cable after system deployment. The lower 1.5 ft. of the mechanical package provides a slotted-key way to lock the BIP into the carriage assembly during deployment.

BIP Data Formats

The system allows a number of data formats to suit the operation being performed (Fig. 7).

Deployment mode (FMT 1), as shown in Figure 7, is used for BIP operations from initial "hook up" until "touchdown" at the bottom of the borehole. Key features of this format are

1. Short-period vertical (SPZ) data at 40 cps;
2. Peak acceleration (X+, Y+, Z+, X−, Y−, and Z−) at 20 cps;
3. SOH data;
4. Three-component, short-period seismic data at 40 samples/s;
5. Three-component, mid-period (north, east, and vertical) seismic data at 4 samples/s;
6. Long-period seismic data (when available) at 1 cps.

STC Functional Description

The shipboard test console (STC) is primarily an assemblage of off-the-shelf commercial data recorders, a data decoder, a timer, and a microprocessor-based controller. The console is mounted in standard relay racks in an 8- × 12-ft. air-conditioned, humidity-controlled, equipment van. Figure 8 is a block diagram of the STC equipment.

An uninterruptible power supply (UPS) supplies 115-V ac for all STC equipment and 100–110 V dc via redundant dc, power supplies, to the BIP via a data filter, which inductively and capacitively couples the dc power and signal, respectively, to a single coaxial EM cable.

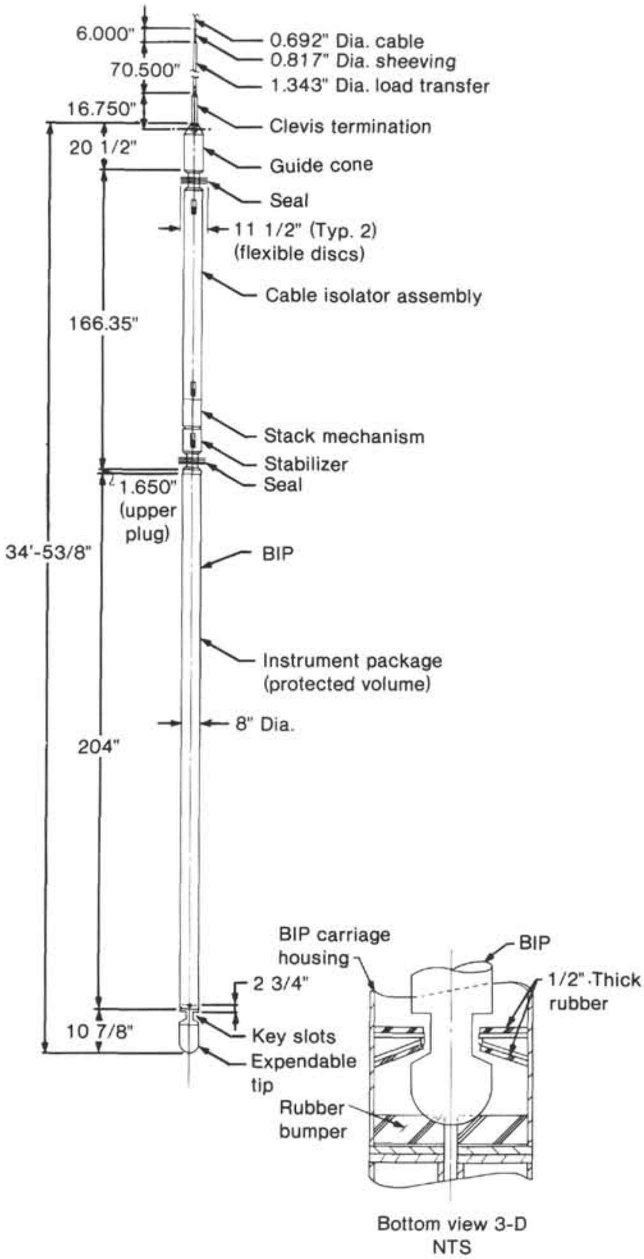


Figure 6. BIP mechanical configuration.

The BIP FSK data signal (26 kHz mark and 33.68 kHz space frequency) is ac-coupled through this same interface to the FSK receiver, where it is converted to a pulse-code-modulated (PCM) digital data stream. The PCM data is then directly recorded on one track of one (operator selectable) bit stream recorder (Ampex Model PR-2230). This same stream is also input to the data decommutator (Conic D-PAD-III), decommutated and output as SOH data on the cathode ray tube (CRT). It is then applied to an internal 12-bit digital-to-analog converter and output as analog (± 10 V full scale) data or, as in the case of digital SOH and gain-ranged seismic data, output as 16-bit parallel digital data to the Data Degain Range/Status Display Controller. This device then displays the digital SOH data on a 4 × 14-bit light-emitting diode (LED) array display panel and, under microprocessor control degain, ranges up to three operator-selectable seismic data channels, converts them to analog, and outputs them for real-time display. All available data (up to eight accelerometer and SOH channels and three seismic data channels) are available at a data-patch panel for input to any of eight available strip-chart channels for real-time display. All data decommutator outputs can be selected by the operator to suit the existing operating mode.

A time-code generator–translator (Datum Model 9300-7158), in synchronization with a Universal Standard Time reference, outputs a time code (IRIG B; inter-range instrumentation group format B), which is recorded on one track of the bit stream recorder for data timing. This same timer outputs a selectable serial time code available for data timing on the strip-chart records, and a parallel digital time word is used to synchronize commands initiated by the operator via the command-control processor.

The command-control processor is an Intel Microcomputer assembly that allows, under firmware control, operator-initiated control of various BIP functions. These commands are transmitted to the BIP via an FSK downhole link, operating over the same coaxial cable, at 300 baud (2600 Hz and 3100 Hz tones). Available command functions include:

1. BIP format control
2. selected BIP power controls
3. seismic sensor calibrations
   -amplitude
   -type (sine, step)
   -frequency (if sine wave)
   -duration
4. processor calibrations
   -(same functions as seismic sensor)

Commands are initiated by the operator via a keyboard/printer (Texas Instruments Model 743). A terminal switch allows this printer to be connected to either the command-control processor for BIP command inputs or to the Conic data decommutator for hard-copy dumps of BIP SOH data or implementation of program changes.

The 2-bit stream recorders are used in alternating modes with one machine "on line" and the second in a "standby" mode. Data and time are recorded on even- and odd-numbered channels (tracks), respectively. The tape record heads can be selectively activated and deactivated, thus allowing utilization of the 14 available tracks in seven passes, recording approximately 12 hr. of 3840-Hz BIP data and IRIG time on each pass (15/16 in./s).

Tape playback can be performed "off line" by selecting a data channel output on one tape-reproduce head to be input to the Conic decommutator and the corresponding time track to be input to the timer operating in the translate mode. The data decommutator and other STC equipment then manipulates and outputs data as previously described, now using tape as input rather than the BIP.

FMT 1

0	1	2	3	4	5	6	7	8	9	10	11
SYNC	PATT	SP-Z	X+	Y+	Z+	SOH	SOH	SP-Z	X–	Y–	Z–

	6	7
0		MSTAT
1	P1	
2		
3	T1	
4	T2	
5	T3	
6	T4	
7	Vin	
8	V1	SUBF1
9	V2	SUBFO
10	V3	STAT1
11	V4	ARTIM
12	V5	FMT
13	V6	SZERO
14	V7	VREF
15	V8	VCAL
16	V9	PCAL
17	V10	QCAL
18	V11	Vs
19	HS	VMUX

VS = Selected Vx monitored thru 14 bit a/d.
VMUX = 16-s cycle of Vin-V15.

16 bits/word	12 words/frame	20 frames/subfr	
3840 bits/s	240 words/s	20 frames/s	1 Subfr/s

Figure 7. MSS PCM format—deployment mode.

BPP Functional Description

The BPP interfaces electrically and mechanically with the EM cable from the BIP, acquires six channels of seismic data and one channel of hydroacoustic data, and records continuously all or a portion of the data over a 45-day period. In addition, the BPP provides the mechanical structure to support the deployment and retrieval of the equipment.

The BPP consists of the following major assemblies:

1. Sphere and sled assemblies;
2. DARS;
3. Two silver-zinc battery packs;
4. Hydroacoustic assembly.

Three aluminum spheres are mounted on an all-aluminum platform structure, which provides the means of terminating the EM coaxial cable and the riser line of the mooring and retrieval hardware (Fig. 9). The total BPP assembly weighs 4536 kg (air weight); the estimated water weight of the assembly is 2000 kg. BPP outside dimensions are 254.0 × 248.9 × 223.5 cm (L × W × H). The sled is fabricated from 6061,T6 aluminum. Three spheres (7078 aluminum) house the DARS and the two battery packs. The inside diameter of a sphere is 92.7 cm on the vertical axis and 85.1 cm on the horizontal axis. The wall thickness of spheres is 5.08 cm. Each sphere weighs approximately 487.6 kg (air weight).

The EM cable consists of a single coaxial conductor (RG-8), with torque balancing, caged-armor, exterior-strength members. Figure 10 provides an overview of the EM cable construction and its electrical-mechanical characteristics.

The DARS consists of three major assemblies: Data Input Assembly (DIA), Data Storage Controller (DSC),

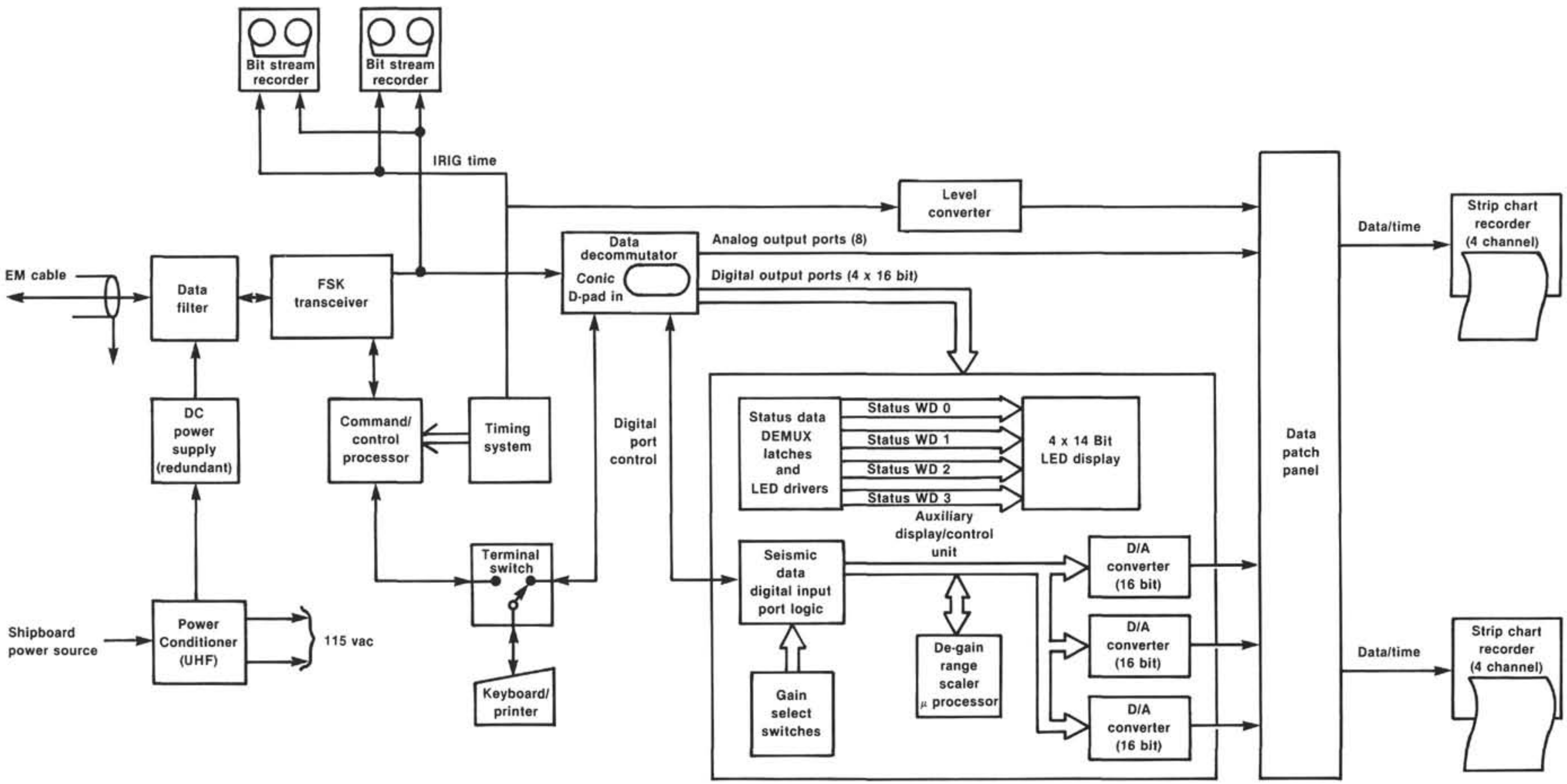


Figure 8. Shipboard test console block diagram.

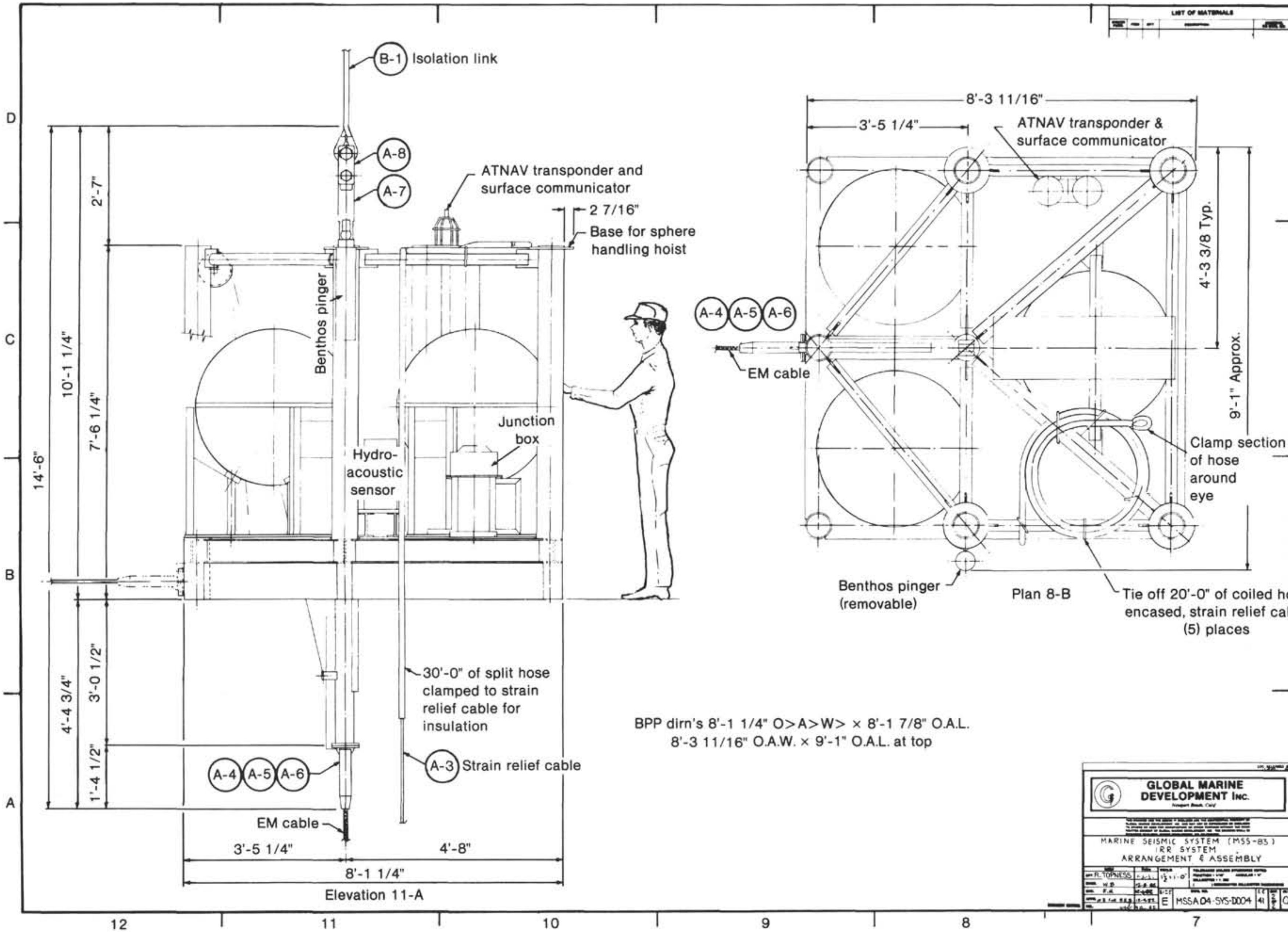
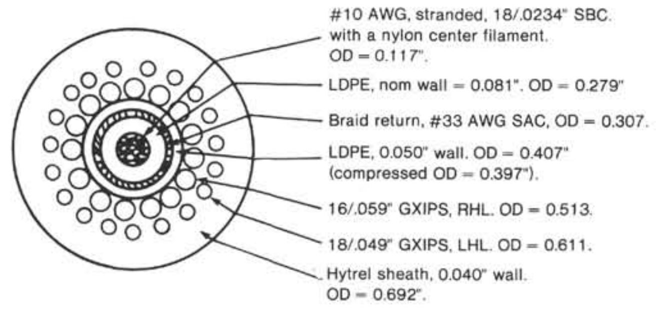


Figure 9. MSS bottom processing package.

The BIP EM cable is a submarine tow cable consisting of (10) #10 AWG coax with an overall double-caged armor and hytrel jacket.



Characteristics

Electrical:	Nom conductor dc resistance @ 20°C:	@ 10 AWG:	1.08 ohms/K ft.
		Coax return braid:	1.40 ohms/k ft.
	Voltage rating:		2,500 Volts rms
	Characteristic impedance:		40 ohms (ref)
	Attenuation at 500 KC:		1.4 dB/K ft.
Mechanical:	Filled shield:		Templube blkng compound.
	Break strength:		21,000#
	Weight in air:		462 #/KFT
	Weight in water (SG = 1.027)		295 #/KFT
	Torque balanced design		

Figure 10. MSS EM cable cross section.

and Data Storage Assembly (DSA). Figure 11 and Table 2 provide a functional overview of the DARS and its interfaces.

The DIA provides a communications interface between the BIP and the DSC. The following specific functions are performed by the DIA:

1. FSK demodulation. An FSK demodulator is provided for each of the seven data channels from the BIP, and an FSK modem is provided for the BIP command/status channel.

2. Finite impulse response (FIR) filters. Two multichannel FIR filters are implemented to decimate, bandpass limit, and convert the serial bit stream output of the delta modulators into 24-bit, 2's-complement integers. The mid-period FIR filter outputs 4 samples/s for each of the three mid-period data channels. The short-period FIR filter outputs 40 samples/s for each of the three short-period data channels and the hydroacoustic channel (the hydroacoustic data output is a 16-bit, 2's-complement integer). Note that only one of the two short-period vertical seismic channels is acquired and processed by the DIA. The selection as to which short-period vertical channel is to be processed is made prior to deployment and is hardwired into the system.

3. DARS SOH monitor. An 8-bit analog-to-digital converter and a 32-channel analog multiplexer acquire and monitor the system's SOH. The following SOH inputs are monitored: three leak detectors (one per sphere), two orthogonal tilt sensors, one pressure transducer, eight voltage monitors, and two analog-to-digital converter status monitors.

4. BIP command and status. Single- and full-frequency calibration commands are transmitted to the BIP. BIP SOH status is transmitted to the DIA via separate FSK communication channels.

5. Real time clock (RTC). The system clock is derived from a stress-temperature-cut crystal, which has a stability of better than 1 part in 10^9 at an operating temperature of 1.5°C. All system timing pulses are derived from the same crystal, which has a fundamental frequency of 6.5536 MHz. Time synchronization to universal coordinated time (UTC) is accomplished at the time of deployment, and the RTC maintains a 1-Hz time pulse synchronous to UTC to a nominal ± 20 ms over the 45-day operating period.

6. SOH communications. The DIA interfaces with an EG&G Sealink Model 321 responder and communicates the DARS SOH to the surface ship during the deployment of the BPP. The responder operates at a carrier frequency of 10.0 kHz. A 12- or 24-bit status message is transmitted once every 120 s at a rate of 1 bit/s.

The final function of the DIA is to acquire and buffer seismic, hydroacoustic, and SOH status data 1 s at a time and to transfer this buffer to the DSC.

The DSC's primary functions are to acquire the 1-s buffers from the DIA, to reformat and buffer the data prior to recording, and provide the control/interface with the DSC. The DSA contains two 64 kbytes Random Access Memory (RAM) boards. This 128 kbytes of buffer memory stores the 1-s data buffers from the DIA prior to recording. The buffer minimizes the power dissipation of the DSA. The DSC also reformats the data prior to storage in the buffer memory. The following formats are used:

1. 485 bytes/s. All data channels are buffered and recorded, 269 s of data are buffered prior to recording, the first 22 days of data are recorded in this format.

2. 245 bytes/s. The two short-period horizontal data channels are deleted from the buffer and recording, 533 s of data are buffered prior to recording, 8 days of data are recorded in this format.

3. 165 bytes/s. In addition to the two short-period horizontal channels, the hydroacoustic channel is also deleted from the buffer, 791 s of data are buffered prior to recording, 15 days of data are recorded in this format.

The DSC also performs the command and control functions with the DSA. The DSC provides the means to address, power-up, and transfer data with any one of the 20 tape drives in the DSA.

The DSA consists of two controller/formaters, and 20 3M model HCD-75 tape drives. The following is a summary of the DSA characteristics:

1. The tape drives utilize a 182.88 m, 0.635 cm formated cartridge.

2. Each cartridge consists of 16 tracks, 4096 blocks or 67.1 million bytes of user space.

3. Two controller/formaters are completely redundant and are capable of addressing any one of the 20 tape drives.

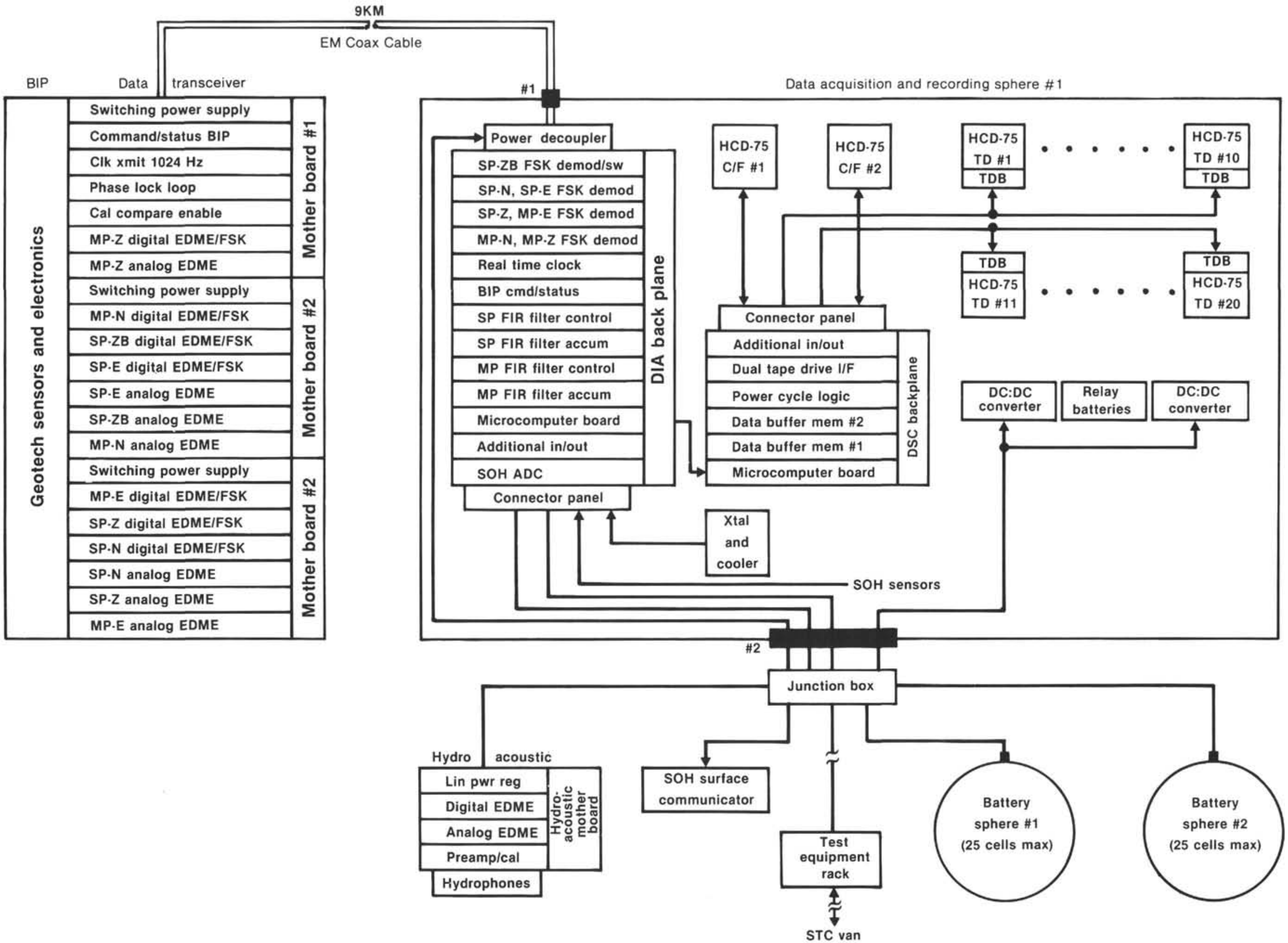


Figure 11. MSS data acquisition and recording system.

Table 2. Data acquisition and recording system characteristics.

Data storage controller (DCS) buffers (2 buffers)	
	128K Bytes total, 64K Bytes per buffer
	Stores 4–8 min. worth of data and takes 8 s to dump onto tape
Seismic data	
	MP - Z,N,E (4 S/S) 24 bits, 45 days
	SP - N,E (40 S/S) 24 bits, 22.5 days
	SP - Z/ZB (40 S/S) 24 bits, 45 days (Z or ZB)
Hydro-acoustic data	
	40 S/S, 16 bits, 30 days
State-of-health	
	BIP (channel number, samples, 16 Bits)
	DARS (leak, tilt, temperature, pressure, humidity, voltage)
	Batteries (leak)
Real time clock	
	Julian format DDD HH MM SS
	WWV sync at deployment 1HZ
	Redundant crystals
Data storage subsystem	
	HCD-75 controller formater
HCD-75 tape drives (20 ea.)	
	Digital format 67 million bytes/cartridge
	Power consumption 9.0 watts idle, 13.5 watts write + surges
Power subsystem	
	171.25 Watts continuous with no power cycling
	DC-DC converts 70% efficient (goal)
Surface communicator	
	EG&G Sealink responder model 321
	Acoustic coded messages (10 KHz, 20 ms)
	Self-contained batteries
Mechanical	
	OBS spheres (3)
	Sled
	Total air weight BPP 8500 lb.
	Total water weight BPP 3500 lb.

4. 1024-byte transfer at 17.5 kbytes/s (approximately 58.5 ms per block transfer).

5. Typical write time is 8 s (128 kbytes).

6. Typical hours of data per cartridge are 38.2, 75.7, or 112.3.

The system's primary power is provided by two silver-zinc batteries, Yardney part number 16950. Each battery is made up of 25 PML 2500 cells, connected in series. Each battery has a minimum capacity of 2500 amp · hr. at a nominal voltage under load of 38.75 V. The two batteries are connected in parallel, resulting in a total minimum capacity of 5000 amp · hr. The approximate dimensions of a battery are 63.65 cm × 63.65 cm^2 × 54.61 cm high. The approximate weight of the battery is 470.7 kg.

BPP Data Formats

This section defines the characteristics and formats of the MSS files stored on a 3M HCD-75 tape drive cartridge.

Storage characteristics. The 3M DC600HC data cartridge used as the storage medium in the MSS HCD-75 tape drives is organized into 16 tracks, with 4096 1-kybte blocks per track (1k = 1024 bytes). This gives each cartridge a total of 65,536 1k blocks or 67.1 Mbytes of storage capacity. The MSS data are written onto tape in variable length files, with the length of each file being determined by the amount of storage memory or data buffer memory (DBM) in the DSC available each time a file is built (with the maximum file length equal to 128-1k blocks). Each file contains a 416-byte "file header" composed of system status information, followed by "one-second data buffer" in a packed format.

The total number of seconds on 1-s data buffers contained in any given file depends upon the amount of DBM available (after allowing for the 416-byte file header) and the size of the 1-s data buffers being recorded. Figure 12 illustrates the MSS file structure built in the DBM to be written on tape.

Shipboard recording mode. The purpose of the shipboard recording mode is to record data prior to BPP deployment. The data format of the 1-s data buffer used is 525 bytes in length with the data buffer header at the beginning, followed by all four short-period (SP) channels of data (SP-Z, SP-ZB, SP-X, and SP-Y), and three mid-period (MP) channels of data (MP-Z, MP-X, MP-Y) being recorded each second. The hydroacoustic data is replaced by SP-ZB (backup) data in this format, and requires 40 additional bytes of storage memory (hydroacoustic is 16 bits/sample vs. 24 bits/sample for SP-ZB).

All SP channels are sampled 40 times/s and are recorded in a 24-bit signed (2's complement) format (i.e., the most significant bit is the sign bit followed by 23 data bits). All 40 samples of each SP channel are grouped in 120 contiguous bytes, with Sample 1 appearing first in the SP channel's data grouping and Sample 40 last.

All MP channels are sampled four times/s and are also recorded in the same signed format described for the SP data. Each of the four samples of all three MP channels are recorded together in 12 contiguous bytes, instead of being grouped by channel, as done with the SP data.

Deployment recording mode. During the deployment recording mode, data are recorded on 20 DC-600 cartridges in four different formats: 9-byte, 485-byte, 245-byte, and 165-byte format.

The 9-byte format occurs for the first 14,517 s (4 hr., 2 min.) of the deployment recording mode, and will be the only content of the first file recorded on Tape Drive 1. The 9 bytes recorded each second are actually the data buffer header, which is recorded this way to provide an accumulation of SOH data during the physical deployment of the BPP.

The 485-byte format is the first real data format recorded and commences with the second file recorded on Tape Drive 1. This data format will be recorded for 22.5 days after the 9-byte format and includes the data buffer header, three channels of SP data (SP-Z, SP-X, and SP-Y), three channels of MP data (MP-Z, MP-X, and MP-Y), and one channel of hydroacoustic data. (See Table 3 for the breakdown of number of MSS files per data format.)

The 245-byte format is the next data format recorded and differs from the 485-byte format in that the last two SP channel data groups in the buffer structure, SP-X and SP-Y, are excluded. This data format will be re-

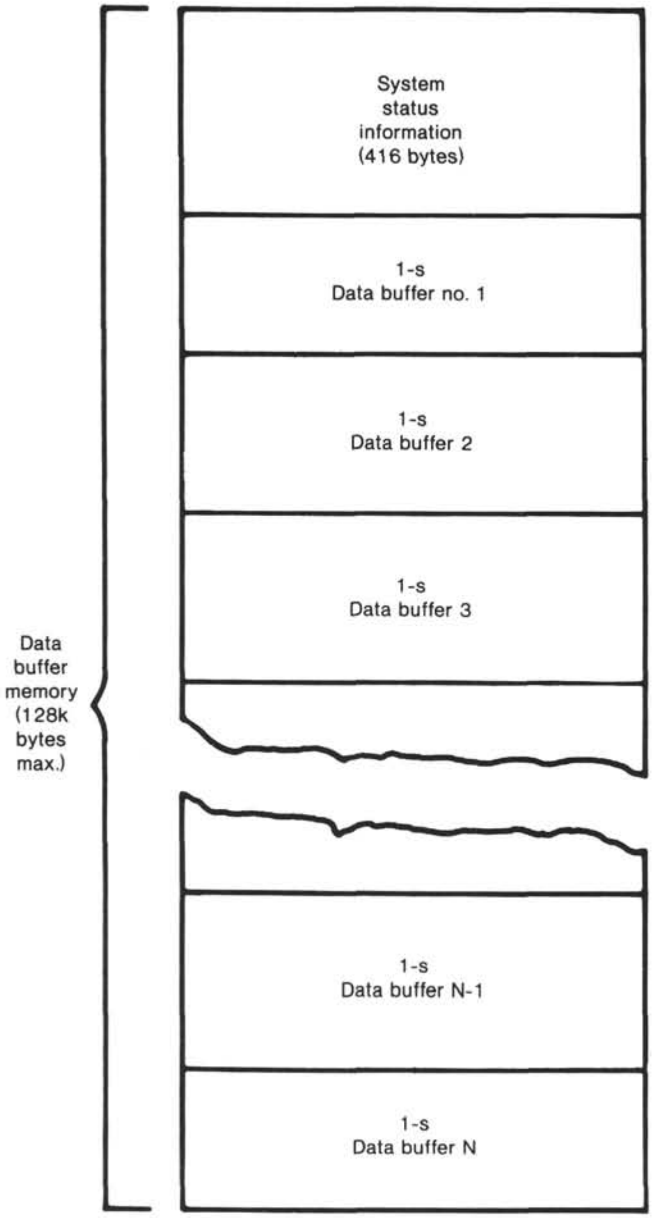


Figure 12. MSS file structure. The data acquisition controller provides a 485/245/165 byte buffer once a second; therefore, under ideal conditions, 269/533/791 s (respectively) of data can be buffered in the 128K of DBM and then written on tape. During shipboard recording mode, a 525-byte "one second data buffer" is recorded with a DBM of 31 kbytes maximum. This structure will allow 59 s of data per file.

corded for 7.5 days after the 485-byte format and includes the data buffer header, one channel of SP data (SP-Z), three channels of MP data (MP-Z, MP-X, and MP-Y), and one channel of hydroacoustic data.

The 165-byte format is the last data format recorded and is another reduction of data storage from the 245-byte format, with the 40 samples of hydroacoustic data being excluded. These data will be recorded for the last 16.3 days of the deployment recording mode and includes the data buffer header, one channel of SP data (SP-Z), and three channels of MP data (MP-Z, MP-X, and MP-Y).

Table 3. MSS files time schedule.

Format	Duration	No. MSS files	Start TD[a] and track/block	End TD and track/block
9 byte	4 hr., 2 min.	1	TD 1,0000H	TD 1,007FH
485 byte	22.5 days	7226	TD 1,0080H	TD 15,147FH
245 byte	7.5 days	1216	TD 15,2480H	TD 17,857FH
165 byte	16.3 days	1777	TD 17,8580H	TD 20,FF7FH

Note: All times, numbered MSS files, and locations are based upon the assumption that no bad blocks are encountered on any tapes, all hardware functions during the deployment recording mode, and no other exceptional circumstances are encountered. The BPP will properly handle bad blocks encountered on cartridges.
[a] Tape drive.

TER Functional Description

The purpose of the Test Equipment Rack (TER) is to provide the means of interfacing with the DARS to test, troubleshoot, and verify the performance of the system prior to deployment. In addition, the TER provides the means of directly interfacing with the BIP over the EM cable, recording data acquired by the DARS, and monitoring the system SOH during deployment.

The TER consists of the following assemblies: (1) SOH communications receiver, (2) shipboard recording unit, (3) microprocessor control unit, (4) test interface unit, (5) strip chart recorder, (6) data input assembly, (7) power supply. Figure 13 provides an overview of the interfaces and functions performed by the TER. As can be seen from this figure, the central assemblies of the TER are the test interface unit and the microprocessor control unit.

The test interface unit's primary function is to provide the means of interfacing the various peripheral units, as well as the BPP, with the microprocessor control unit. The test interface unit, along with its associated cables, is capable of interfacing with the DARS either through the junction box on the BPP, or directly when the DARS is removed from the sphere. The test interface unit also provides the interface between the SOH communications receiver and the microprocessor control unit, so that during the deployment of the BPP the system status transmitted by the SOH responder is received by the SOH communications receiver, digitized by the test interface unit, processed by the microprocessor control unit, and displayed on the control unit terminal. The DIA, which is identical to the unit in the DARS, is also interfaced with the microprocessor control unit through the test interface unit. The system time synchronization with WWVH is also performed by the test interface unit.

The microprocessor control unit performs the following functions: (1) emulates the DSC Unit in the DARS, which provides the means to perform the shipboard recording function; (2) processes and displays the system SOH during deployment; (3) post-processes data recorded on tapes; these processes include a Fast Fourier Transform algorithm, and a single-channel analog display; (4) displays a single channel of data in real time.

The shipboard recording unit consists of two HCD-75 tape drives and one HCD-75 controller/formater, identical to the units used in the DARS. The primary pur-

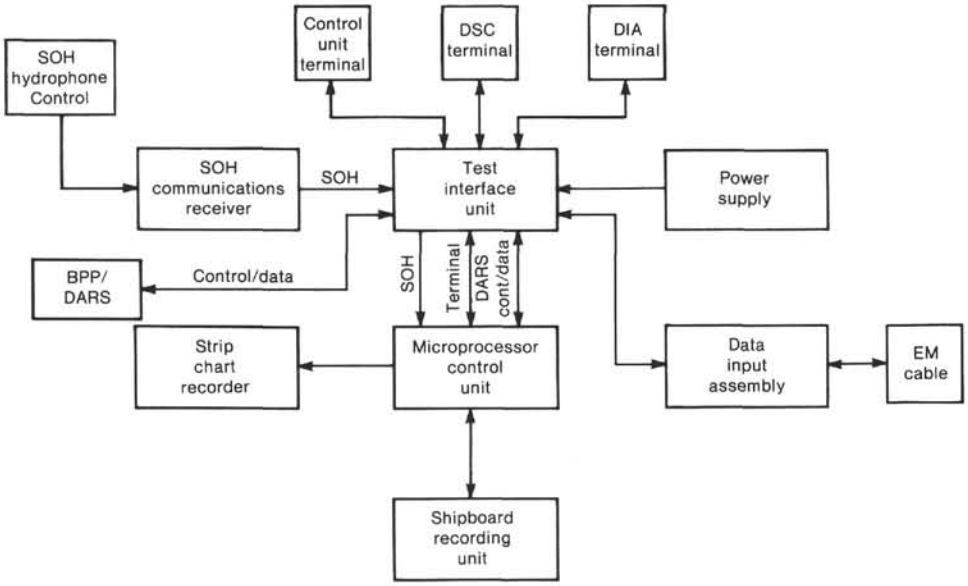


Figure 13. Test equipment rack block diagram.

pose of the unit is to perform the real-time recording of data when the BIP is installed in the borehole and the BPP is still on board the ship.

The unit is also used to process previously recorded data to determine the performance of the system.

The DIA is an exact duplicate of the unit used in the DARS, with the exception that the SOH/ADC board has been removed. The DIA is used to interface the TER to the BIP prior to deployment to verify the performance of the system.

The power supply provides power to the DIA or the DARS in the BPP in place of the batteries during the shipboard checkout of the system.

The TER, BPP, and STC van are used in three modes of operation: BIP deployment/installation, dual recording, and operational. Figure 14 illustrates the interfaces required for each of these modes.

During BIP deployment and installation, the TER and the STC van are connected to the EM cable. The STC van and the TER perform the following functions: (1) provide power to BIP by the TER; (2) command and control of BIP functions by the STC van; (3) acquire BIP status and data during deployment and installation by the STC van; (4) verify BIP sensors and electronics after installation (calibrations) through the STC van.

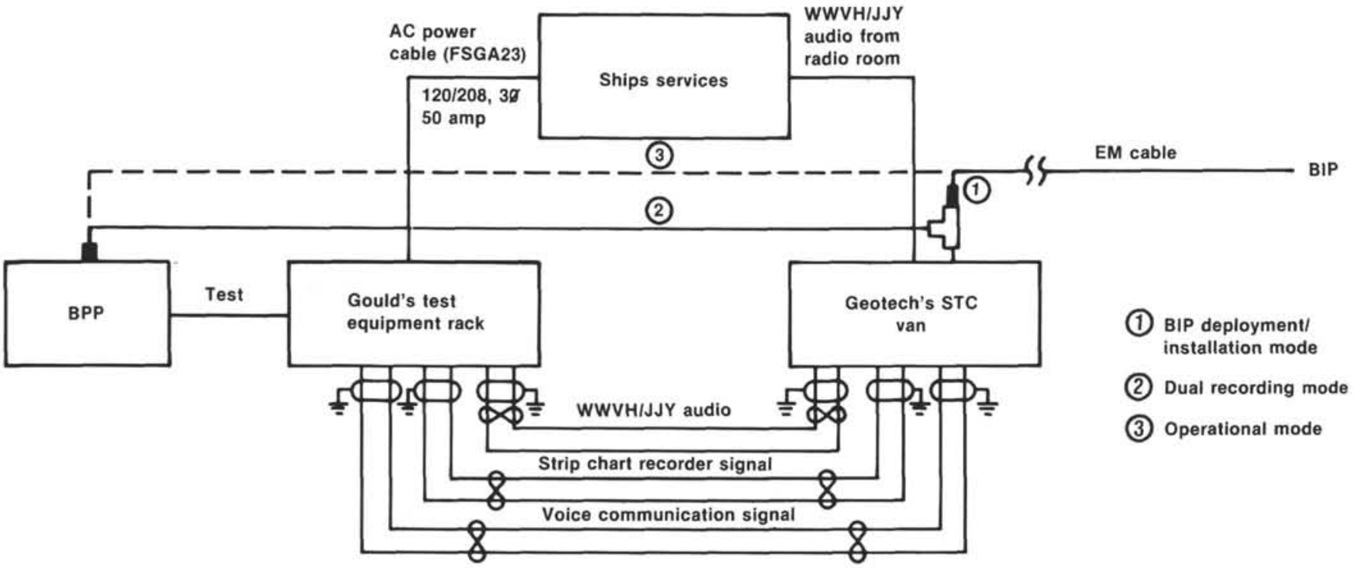
In the dual-recording mode, as data are recorded aboard ship, the BPP is interfaced to the EM cable as well as the STC van. The TER is connected to the BPP to acquire the data from the DARS. The following functions are being performed in the dual-recording mode. (1) Power is provided by the TER. (2) Command and control of the BIP is performed by the STC van. (3) BIP status and SOH are acquired by both the TER and the STC van. (4) Seven channels of seismic data are acquired and recorded by both the TER and the STC van. (5) Calibrations are initiated by the STC van.

In the operational mode, the BPP is connected directly to the EM cable; the STC van is no longer connected. The TER is initially connected to the BPP to initialize the DARS and to synchronize and set the system time. The TER is then disconnected and the BPP is deployed. The following functions are performed by the BPP and TER. (1) System power is provided by the batteries. (2) System status during deployment is monitored by the TER via the acoustic link (terminates in 18 hr.). (3) Tape drives are initialized and data are recorded. (4) Periodic calibrations are performed and recorded over the 45-day mission. (5) After all tape drives have been filled, the system automatically shuts off.

Reentry Sub Carriage and Assembly

The BIP is deployed into the reentry cone/borehole with a special subsea reentry assembly attached to the bottom end of the drill string. The reentry assembly is made up of a stinger, carriage, carriage housing, and control sub (Fig. 15). The assembly is 73 ft. long and weighs 15,000 lb. The BIP is shock-mounted within the carriage, which is initially off center in the housing. The carriage can be shifted by salt-water hydraulic pressure to the center line. The stinger is used to direct the reentry assembly into the reentry cone when it lands on the 24-in. throat ring. The control sub is utilized to land the sonar reentry tool and to seal the packer valve, which establishes flow to the saltwater hydraulic release cylinders.

The reentry assembly is assembled on the rig floor. The BIP is then loaded into the carriage and locked. The reentry assembly is connected to the drill string using a drill collar and four bumper subs and is lowered to near the seabed. During lowering, the EM cable, which is alongside the drill string, is unspooled with carefully controlled tension levels. The sonar reentry tool is deployed through the drill string to provide acoustic sensing for the reentry-cone positioning stab. The sonar tool is then recovered and a hydraulic packer is lowered down to the control sub. Pressurized saltwater from the ship's cement pumps actuates the hydraulic cylinders, shears the release pins, and centers the carriage aligned with



Cable definitions: (from Geotech's STC van to Gould's test equipment rack)

QTY	Description	
1	– RG58C/U coax cable	Ship, Geotech, Gould
3	– #20 AWG twisted pair shielded	Interface cabling

Cable lengths

- Require test equipment rack in cargo hold and on deck in lab area within 25′ of STC van
- Require BPP in cargo hold and on deck within 50′ of test equipment rack

Figure 14. DARS shipboard interface requirements.

the borehole. The BIP is lowered to the bottom of the borehole by paying out the EM cable. With the BIP resting in the borehole, the drill string/reentry assembly is raised and twisted to allow the EM cable to separate from the reentry assembly via the cable slot, which runs the length of the reentry assembly. Once the EM cable is freed from the reentry assembly, the drill string is recovered.

Installation, Recovery, and Reinstallation Mooring

The installation, recovery and reinstallation mooring (IRR) system is a unique deep-water mooring system designed by the Naval Civil Engineering Laboratory for recovering the BPP. The deployed configuation is depicted in Figure 16. The IRR system assures structural integrity through use of conservative safety factors, isolates the BPP from tensions and vibrations of the mooring line, and provides high probability of successful recovery through built-in procedural redundancies.

The IRR system is attached to the BPP through a Miller Swivel and a stainless steel insulation connector. The initial portion of the 1500 ft. of 1-1/8-in. diameter wire cable lies on the seabed and is used to isolate line tensions from the BPP.

The wire cable, in turn, is connected to the spliced end of the 1-3/4-in. riser braided line that is 21,500 ft. long. At the upper end is a tapered splice to 7/8-in. braided line. Adjacent to this splice are four dual buoys plus one flasher, each attached at 50-ft. intervals, which make up the "A" crown buoy. Attached to this is a grapnel line, 10,000 ft. long, ending up with five dual buoys plus one flasher, which make up the "B" crown buoy. The interconnection between the grapnel leg and the anchor leg is provided by an ATNAV dual-release transponder.

General deployment procedures are as follows. After most of the EM cable is payed out, it is temporarily stopped off. The free end is then attached to the BPP. The BPP, with IRR riser leg attached, is lowered over the side with the ship's crane, followed by subsequent load transfer to the riser line EM winch. The BPP is then deployed to the seabed while moving the *Challenger* downstream. Continuing to move downstream, first the "A" buoy and then the "B" buoy are launched on the surface while paying out the line. Then the anchor leg is attached and the line is payed out on the surface until the ship is approximately 45,000 ft. downstream of the BPP. When the ship is positioned to tension the anchor line to 500–1000-lb. level, the anchor is free-fall dropped to the seabed pulling the "A" and "B" buoys to depth. Final depths of the "A" and "B" buoys depend on current and actual line length but should be near 3000 ft. for "A" buoy and 4000 ft for "B" buoy.

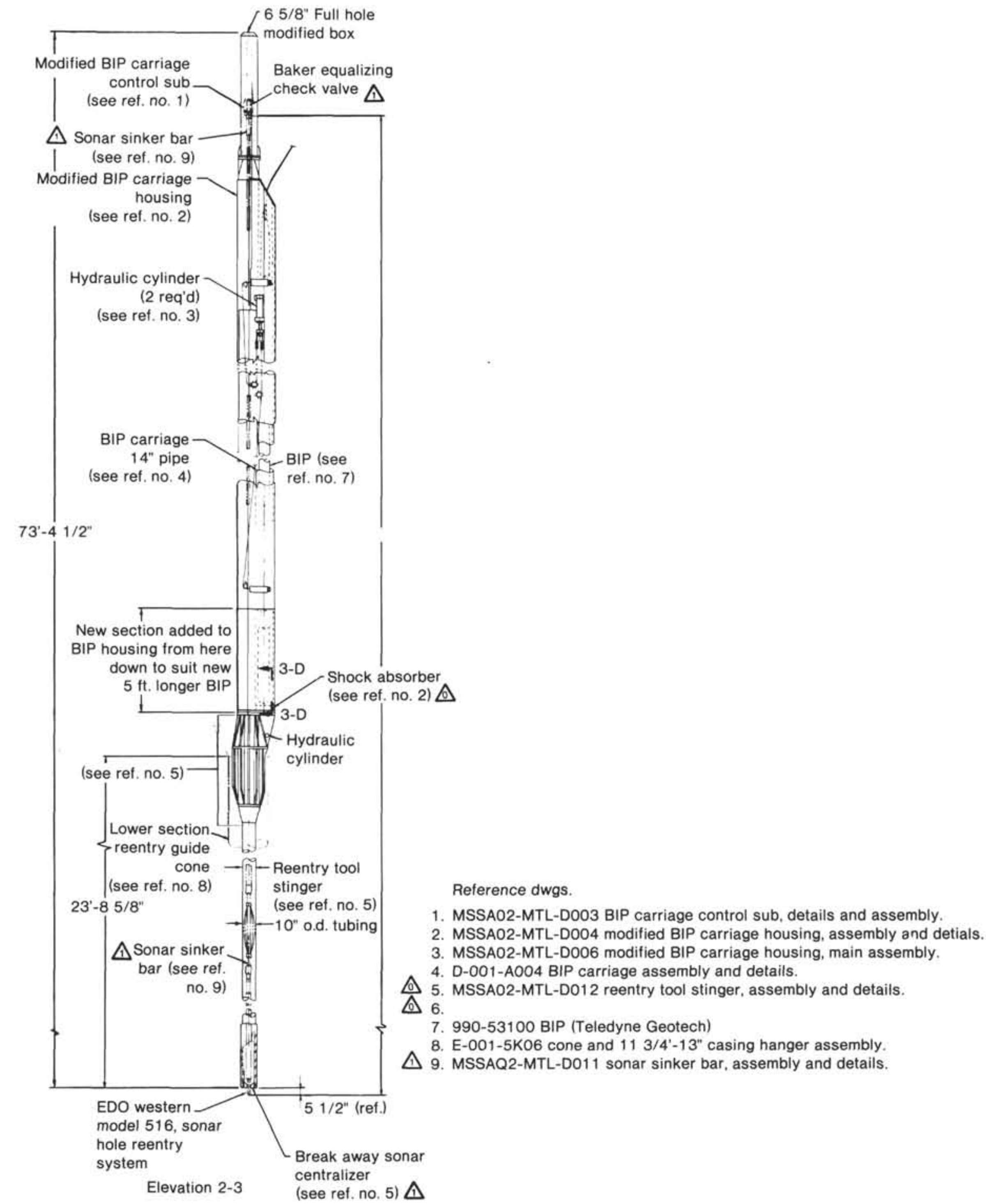


Figure 15. Configuration I reentry assembly.

SHIPBOARD HANDLING EQUIPMENT

The basic equipment on the *Glomar Challenger* to deploy the MSS equipment is a Pengo winch, an A-frame, an associated heave compensator, and the control console (Fig. 17). This equipment is located on the port side main deck area aft of the moonpool.

The Pengo winch has a diesel-powered, two bull gear plus reel hydraulic-drive arrangement. Load capability is 15,000 lb. continuous and 20,000 lb. maximum. The storage reel capability is about 35,000 ft. of 9/16-in. EM cable. maximum take-in/pay-out speed is approximately 200 ft./min. Control is exercised by regulating the pressure and stroke of three independent hydraulic motors. The Pengo winch weighs, with cable on reel, about 38,000 lb.

The A-frame, a cantilevered 26-ft. structure, is supported by pins mounted on the casing rack, the derrick

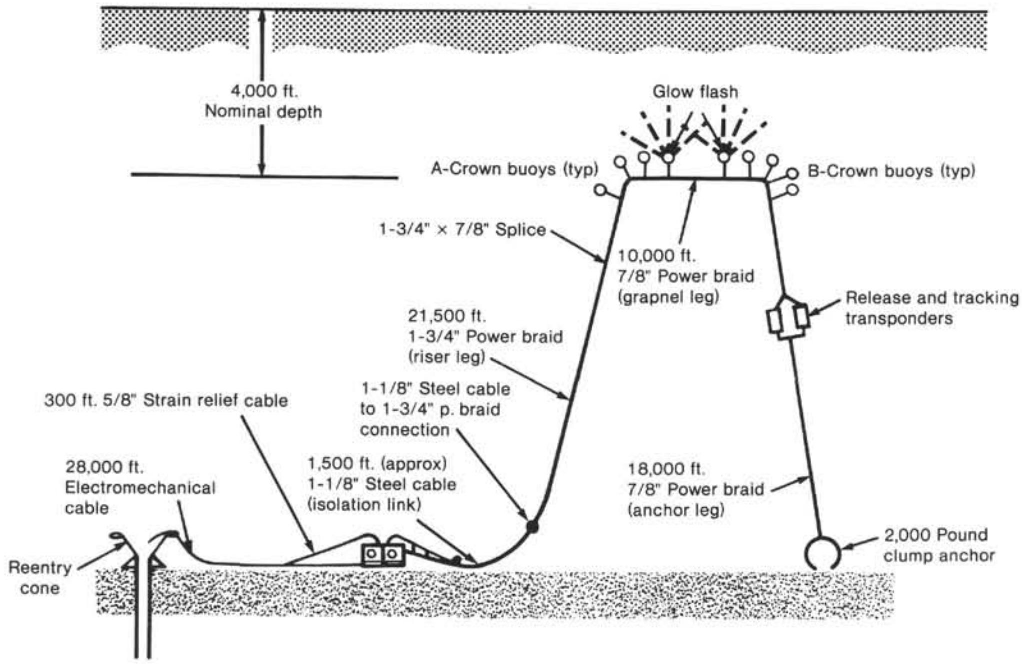


Figure 16. Installation, recovery, and reinstallation structure.

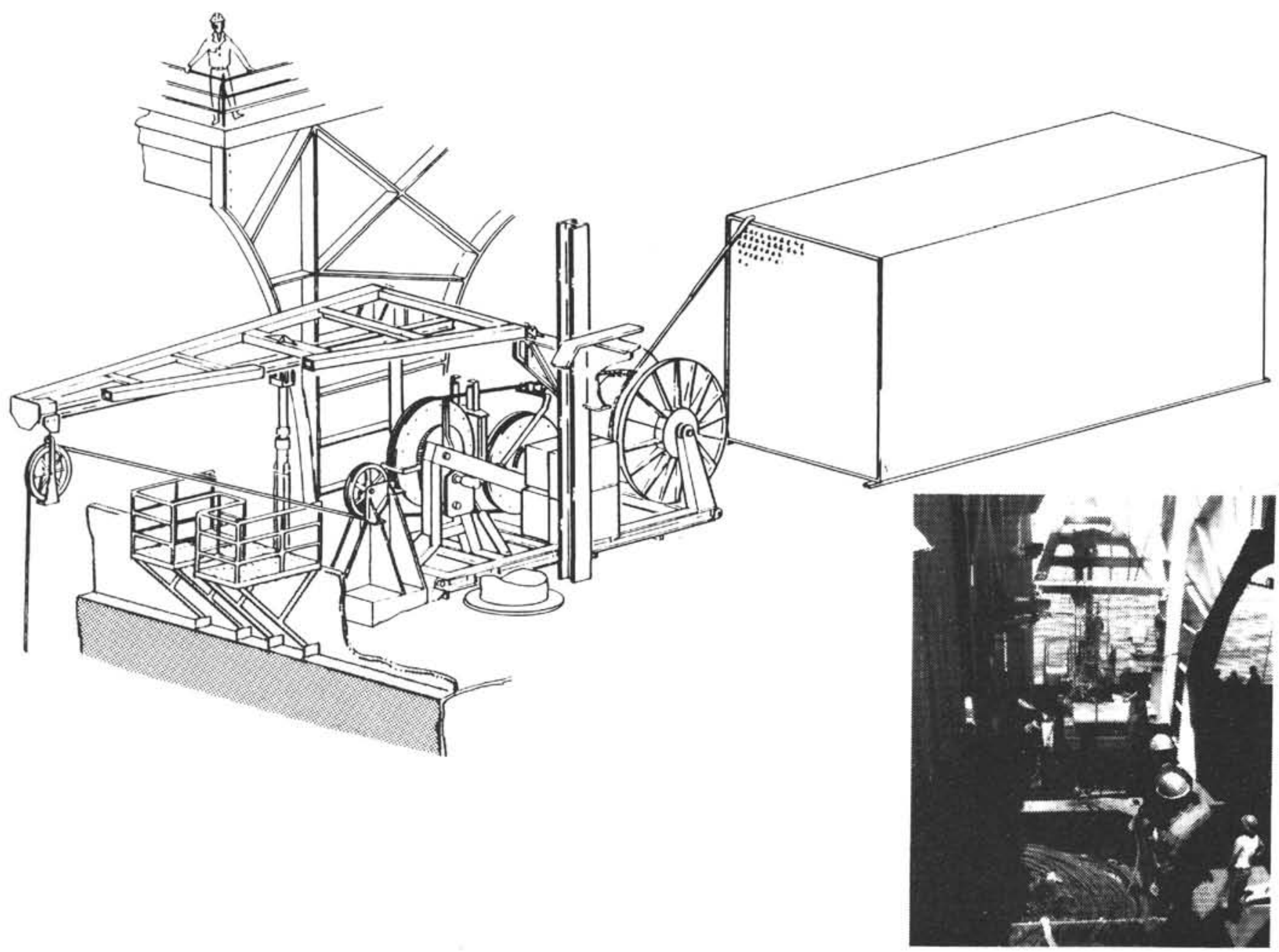


Figure 17. Traction winch reeved to deploy power braid.

sub-base structures, and the heave compensator. The A-frame has been tested to 20,000 lb. but is designed for 25,000 lb. The A-frame is equipped with a rack-and-gear pinion to mechanically position the A-frame sheave inboard when under load.

The heave compensator is a refurbished guideline tensioner rated at about 50,000 lb. Piston stroke and diameter are 7.5 ft. and 7 in., respectively. Interconnected with the heave compensator cylinder are two 11-gallon accumulators, which can be valved in or out to vary the effective spring constant. The heave-compensation subsystem is driven by four nitrogen bottles at an operating pressure of 1700 psi.

The control console consists of a series of performance data instruments and control functions. A pressure regulator, pressure relief valve, and auxiliary valves are utilized to control the heave-compensator system. A Martin-Decker hydraulic load-cell gauge plus a Strainsert strain-gauge readout measures cable tension. The Strainsert readout can also be connected to a dual strip-chart recorder. Two independent cable pay-out meters are installed. At the control station, special direct communications circuitry to the STC van, Gould van, bridge, and drawworks operator are installed.

A below-moonpool TV system can be installed in the event of cable entanglement. Four sets of five buoys each are provided for emergency release of the EM cable.

The EM cable and IRR line are both fed through the Pengo winch, through the Strainsert idler sheave, and over the A-frame sheave. Two sheaves, one for the EM cable and one for the IRR line, are carried. Both sheaves attach to the A-frame trolley through the Martin-Decker transducer.

EQUIPMENT DEPLOYMENT, RECOVERY, AND OPERATION

The MSS deployment was a significant engineering achievement. Problems were encountered during each step of the deployment, as can be expected in any R&D effort; however, each problem was quickly evaluated and overcome. The BIP was placed gently in the hole with the specially designed reentry sub. Five days of real-time seismic data were recorded aboard *Challenger*, including two shot lines for orientation and comparison with OBSs deployed near the reentry cone. The shipboard data include 60 earthquakes. The BPP was smoothly deployed, and its acoustic SOH sensor indicated normal conditions as it was lowered to the bottom. The first tape recorders turned on as programmed and recorded the first hours of the package's 45-day capability. The installation and recovery mooring, over nine miles long, payed out as planned and was submerged to the predetermined depth as its anchor reached bottom. In all, 10 days were required to prepare Hole 595B, and 12 days were used in deploying the MSS.

Forty-three days after deployment the *Melville* recovered the BPP. BIP calibration was checked and approximately 7 more hours of real-time data were recorded. The EM cable was then attached to an anchor and the mooring was redeployed. Unfortunately, a cable failure on one of the two BPP battery spheres started a chain of events that resulted in a loss of power to the recording sphere after only 44 hr. of its 45-day mission. Thus, only 3 of the 20 tape recorders in the BPP contained recorded data.

The specific deployment and recovery events, including problems and their solutions, are explained in more detail in the sections on the BIP, STC, BPP, and IRR. A complete table of events in chronological order is available in the introductory chapter, this volume.

A navigational layout of the entire MSS system after deployment in February 1983 is given in Figure 18, as well as a list of latitudes and longitudes of the major components. Figure 19 is the post-recovery layout as the mooring was deployed in March 1983.

The mooring was laid in the direction of the prevailing current. Figure 20 summarizes the currents for the period from 28 January 1983 to 11 February 1983 to a maximum depth of 1000 m. Currents generally flowed toward the northwest with an average speed of 20 cm/s at 100 m and fell off rapidly with depth to less than 5 cm/s. Currents were measured with a Neil Brown direct-reading current meter (DRCM) rated to 1000 m. Measurements were taken aboard the support ship *Melville*.

BIP and STC Instrument Performance

Predeployment checkout of the BIP and STC, BIP deployment, and the system performance after deployment were sufficient to allow the mission to be largely successful.

BIP Deployment

During initial BIP deployment, the installation proceeded smoothly, with only a minor fit problem related to the cable isolator pawls and the BIP housing. Installing the BIP into the housing was completed smoothly. As the pipe string makeup and BIP deployment were carried out, data glitches and eventual total data loss occurred with the BIP at approximately 700 ft. beneath the surface. Upon system retrieval it was determined that cable damage had occurred during preparatory cable termination, allowing seawater to penetrate the cable jacket and electrically short-circuit the EM cable. The damage occurred in a tightly coiled area of the cable, which made it necessary to accommodate the planned mechanical elongation and retraction of the BIP between the electrical and mechanical cable termination points. Because of doubt as to being able to provide the required cable flexibility successfully without again causing cable damage, and since the fit and function of the cable isolator within the BIP housing assembly was questionable, it was decided that eliminating the cable-isolator slacking mechanism and removing the isolator-hole locking pawls would resolve the fit question and lessen the possibility of redamaging the EM cable. The necessary corrective actions were taken, the cable reterminated, and reinstallation of the BIP was commenced. The reinstallation was successful, and the BIP lowering to the bottom of the borehole was relatively trouble-free.

Only one system operational flaw was detected during this operational phase. The accelerometer channels within the BIP, which monitor shock loads during ship-

MSS component locations

Hole 595B	23 – 49.34S (good) 165 – 31.61W
Point "A" (16 kHz beacon)	23 – 49.35S 165 – 31.85W
Point "B"	23 – 49.39S 165 – 31.54W
Point "Z"	23 – 48.83S (good) 165 – 32.23W
13.5 kHz beacon (not shown)	23 – 48.30S 165 – 33.03W
Point "Y"	23 – 48.81S (good) 165 – 32.35W
BPP	23 – 48.08S 165 – 33.27W
A-crown buoy	23 – 46.00S (est) 165 – 35.22W
B-crown buoy	23 – 45.00 (est) 165 – 36.55W
Anchor drop point	23 – 42.40S (est) 165 – 39.90W
ATNAV transponders	
.X-1	23 – 49.38S 165 – 31.61W
.X-2	23 – 48.60S (est) 165 – 34.95W
.X-3	23 – 46.58S (est)
Dual release	See B-crown buoy
.BPP X-ponder	See BPP

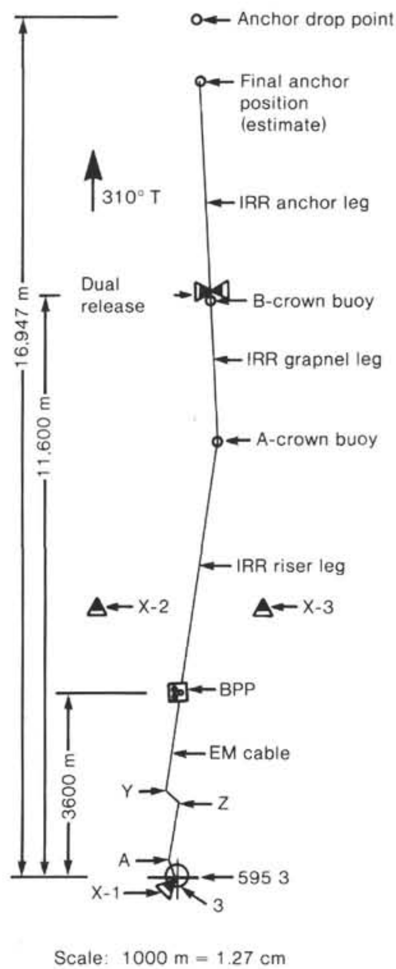


Figure 18. MSS navigational layout, 12 February 1983.

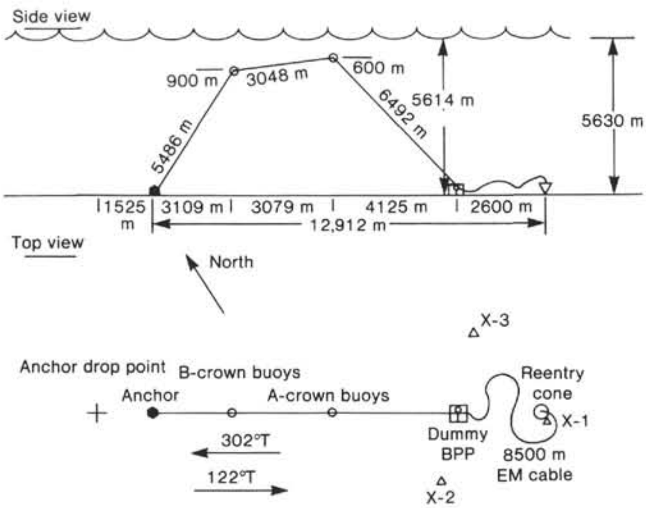
board handling and deployment, registered a maximum 1 G on board ship and at reentry. These loads, though possibly correct, seem low based upon observed handling and previous reentry data.

BIP Downhole Performance

Once installed in the borehole, BIP performance was measured using sensor channel calibrations and preliminary data analysis. Results of the sensor calibrations are shown in Figures 21 through 26. As indicated by these figures, the SPZ, SPZB, and SPY sensor channels responded as predicted. Response rolloff is slight at the high frequencies, but measurement of these same calibrations through the DARS indicates a near-perfect match to the calculated norms. It is suspected that playback instrumentation within the STC is responsible for this response deviation.

The SPX data channel deviated greatly from the calibration norm and exhibited background noise approximately 12 db greater than the other SP channels. The instrument did, however, respond to large signals (refraction study explosions and large earthquakes) during initial recording periods, but degraded toward the end of the shipboard recording period. We suspect sensor internal failure or physical damage to be the cause of the poor data quality and improper calibration response associated with this instrument channel.

The MP data channel responses deviated quite drastically from the calibration norm, due to the failure of either the sensor transfer function or the sensor calibration function to behave as theoretically predicted at the lower data frequencies (less than 0.5 Hz). This conclusion is supported by the apparent lack of channel response to large earthquakes from which large amounts of energy should be emitted in the MP frequency band. The MPN data channel exhibited additional deviations from the theoretical norms, again implying an electrical or mechanical failure internal to the X data sensor.



Component locations	Latitude (S)	Longitude (W)
Reentry cone	23° 49.34'	165° 31.61'
Dummy BBP	23° 48.57'	165° 32.87'
A-crown buoys	23° 47.38'	165° 34.92'
B-crown buoys	23° 46.5'	165° 36.43'
Anchor location	23° 45.6'	165° 37.98'
Anchor drop point	23° 45.15'	165° 38.73'
Transponder X-1	23° 49.38'	165° 31.61'
X-2 (recovered)	23° 48.46'	165° 35.21'
X-3	23° 46.53'	165° 33.03'

Figure 19. MSS navigational layout, March 1983.

All other functions, with the exception of a data transceiver unit failure (described later), were verified to be within specified and predicted parameters.

During BPP recovery aboard the *Melville* the operation of the BIP was checked via the EM cable. System lock-up instructions were completed with no hesitation, proving that the communication link had not deteriorated since installation. Operational tests were performed and indicated normal voltages and operation. A full set of frequency response data were taken for all seismic sensors. The three (Z, X, Y) mid-period sensors were calibrated at frequencies from 0.03125 to 1.00 Hz inclusively and had not changed since installation. The four short-period sensors (Z, ZB, X, Y) were tested from 0.125 to 16.00 Hz and were within operational limits set during deployment.

At the request of the chief scientists on board the *Melville*, several hours of data were recorded to compare noise generated by the *Melville* and *Glomar Challenger*. This noise comparison includes almost 7 hr. of short-period seismic data, as well as 30 min. of mid-period data.

After BIP checks were complete the EM cable was reterminated. A blank fitting was installed to prevent water seepage down the cable and was attached to the dummy BPP (anchor). The IRR was then redeployed.

STC Performance

All STC functions were performed without undue difficulty. A real-time tape recorder maladjustment, caused by the apparent low sensitivity of the magnetic tape being used, caused some concern when first discovered. Subsequent readjustment corrected the problem, and all data have since been verified to be retrievable.

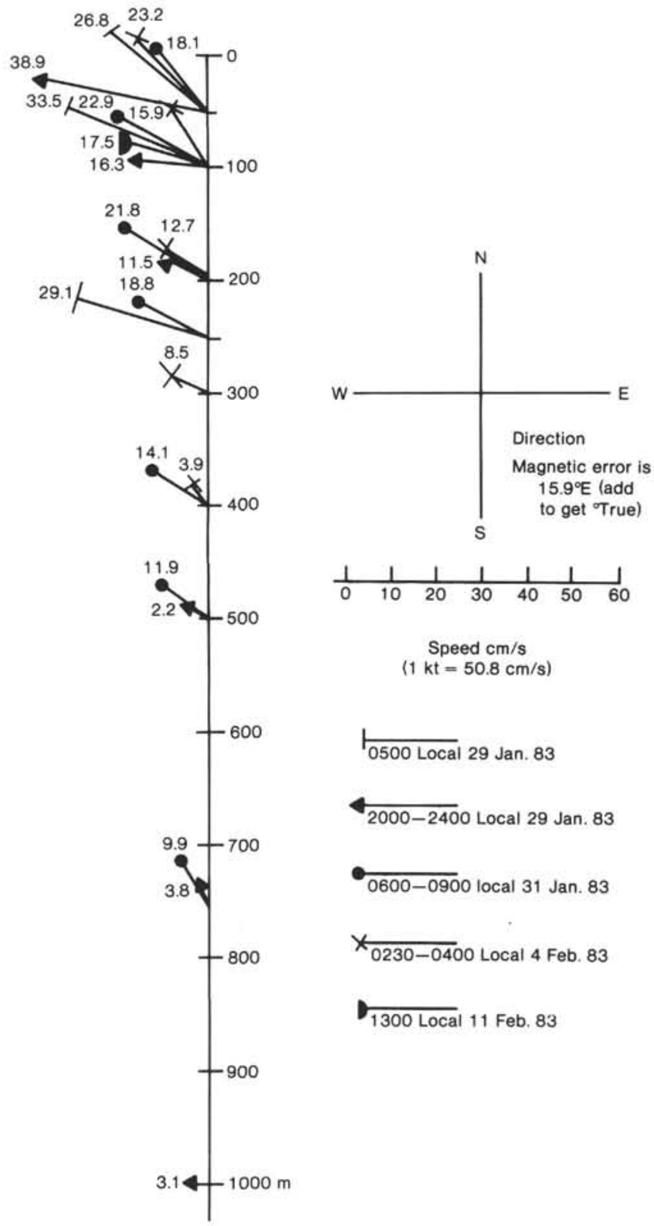


Figure 20. DRCM current measurements from *Melville*, February 1983.

Figure 27 is a correction curve for all temporal data recorded on either the strip chart records or the magnetic tape. Timing system errors were obtained via frequent comparisons of the RTC output with the National Bureau of Standards time broadcast on Station WWVH, Hawaii. The true time is derived from the algebraic sum of the indicated clock time and the appropriate time correction extrapolated from the correction curve.

Acquired Data

The shipboard recording period during deployment (seismic data only) commenced at approximately 1110Z on Julian date 037 and was concluded at 0957Z on Julian date 042. During this period, a total of approximately 113 hr. of real-time data was recorded. Recording time for the various aspects of the experiment follows.

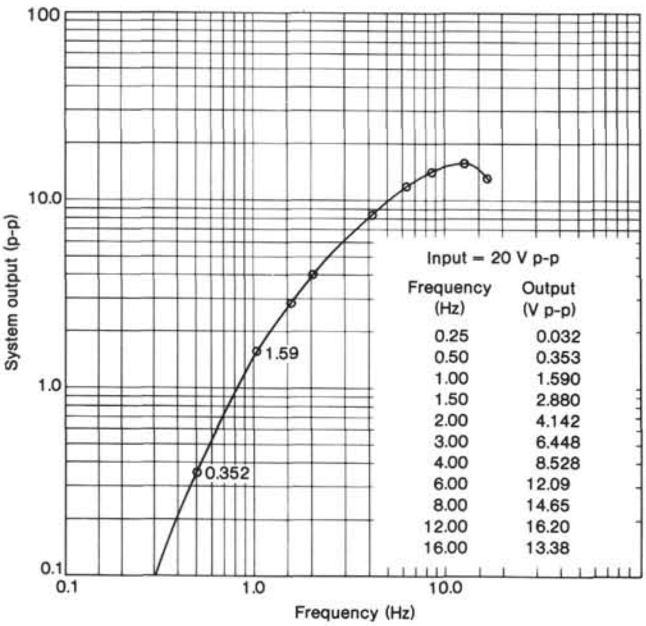


Figure 21. Short-period system calibration response norm.

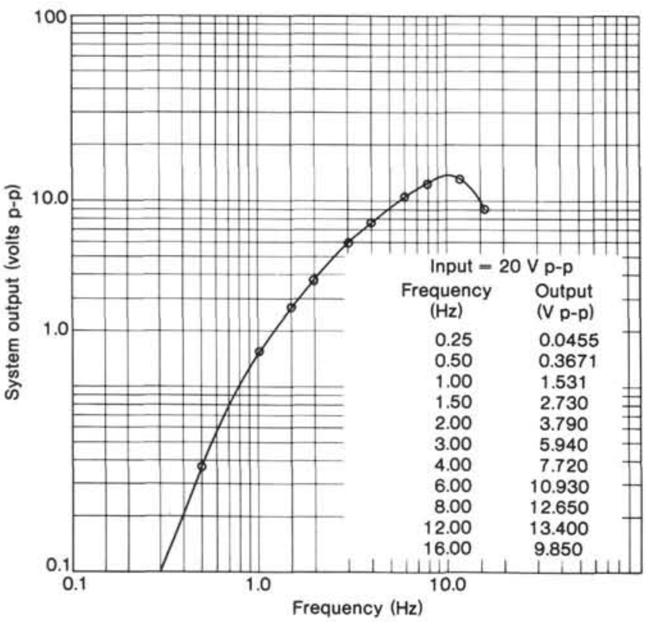


Figure 22. Short-period vertical calibration response.

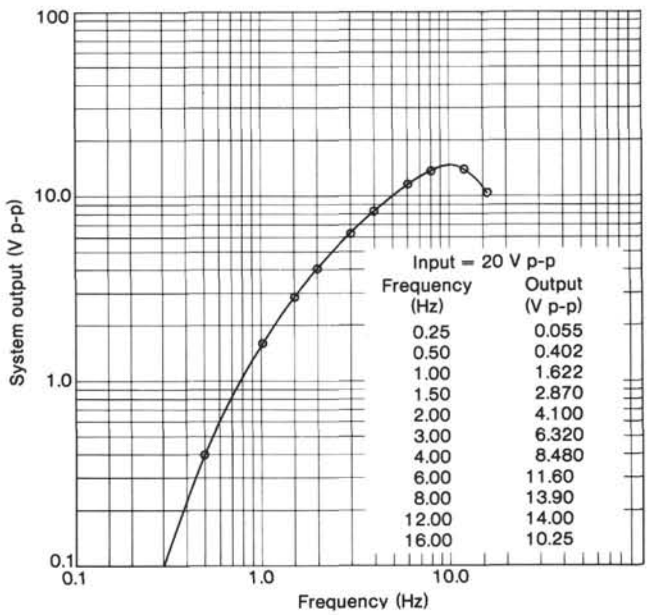


Figure 23. Short-period vertical (backup) calibration response.

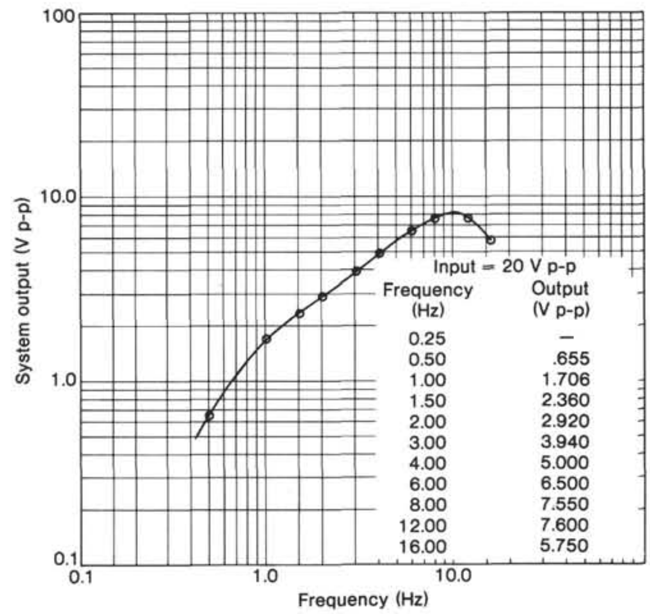


Figure 24. Short-period north calibration response.

Regional seismicity recording	63.5 hr.
Seismic refraction experiment recording	39.5 hr.
System setup, maintenance, and special testing	16.0 hr.

During the recovery the following data was recorded:

Regional seismicity recording	7.0 hr.

BPP Instrument Performance

All BPP functions were tested and evaluated prior to system deployment. The backup SP vertical seismic channel was selected for acquisition in the operational mode. A failure in bay 3 of the DTU in the BIP resulted in the loss of the MPZ data channel and the status/control communications between the package and the BPP. Approximately 84 hr. of data were recorded by the system during the 5-day shipboard recording period, which included approximately 25 hr. of the shot program and 59 hr. of regional seismicity recordings. Monitoring of the system SOH communications during the deployment indicated that the system was functioning properly all the way to the ocean floor. Unfortunately, a cable failure in one of the battery spheres resulted in a loss of power to the recording sphere only 44 hr. after deployment.

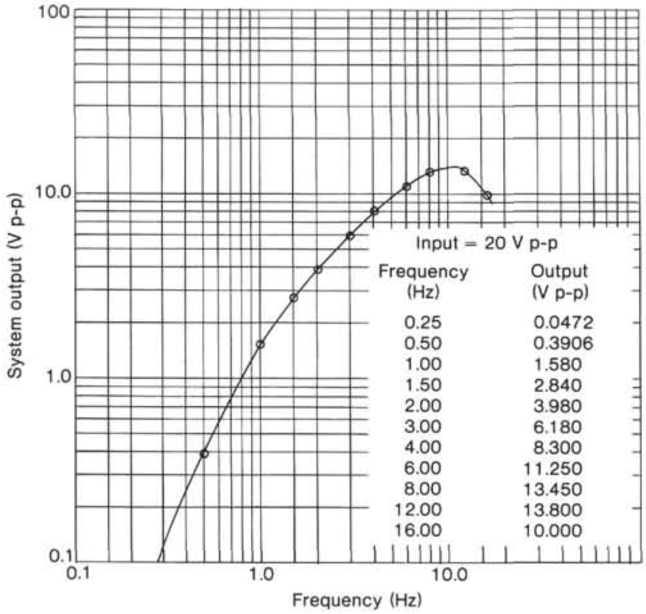


Figure 25. Short-period east calibration response.

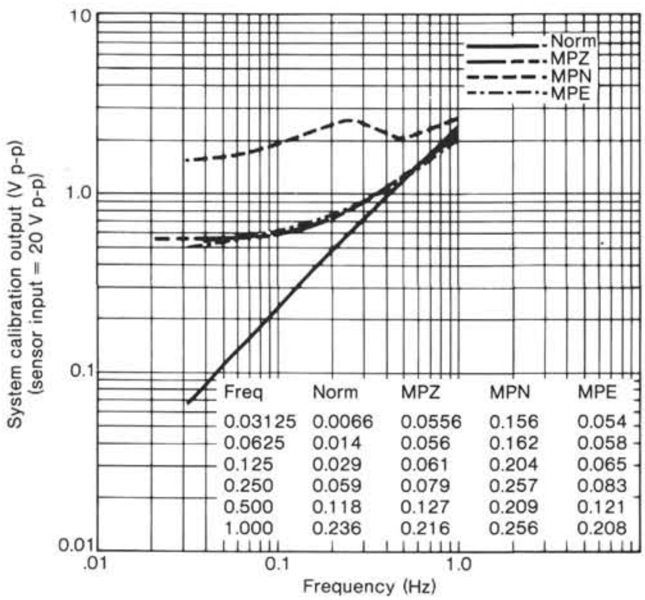


Figure 26. Mid-period channel calibration response (MSS, 1983).

BPP Deployment and Recovery

With the EM cable attached to the BPP, a predeployment checkout of the system was initiated. During this time, the system SOH was monitored; synchronization with WWVH was performed, and a full-frequency calibration was initiated. However, the BPP was unable to initiate communications with the BIP. By having the STC initiate a calibration, it was determined that the MPZ channel was also malfunctioning. Based on these symptoms, there was a failure in bay 3 of the DTU in the BIP.

Without the capability to communicate with the BIP, it was not possible to initiate calibration in the operational mode. As a fallback, a frequency response calibration, recorded and processed by the test equipment, was performed by the STC. Results were satisfactory.

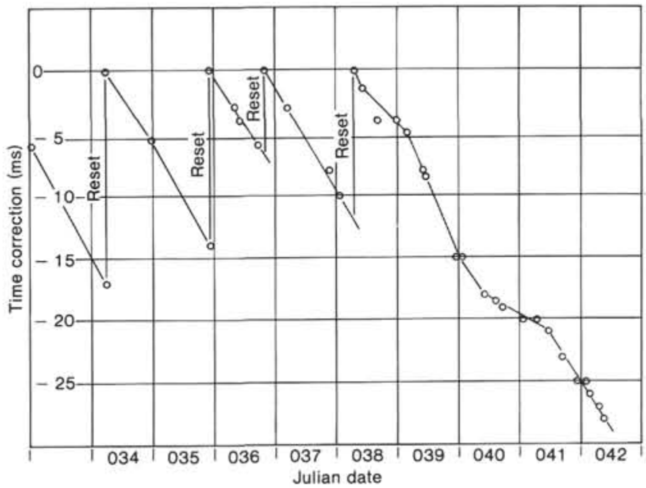


Figure 27. Time correction curve for timing system.

The system was prepared for deployment and the operational firmware was initialized. A system ground to the case of the SOH transponder was discovered and corrected.

System status, communicated to the ship via the SOH transponder, was monitored on board by the TER. The communication link was reliable to a depth of approximately 4000 ft., where the noise generated by the ship's thrusters and screws began to interfere with transmissions. To a depth of approximately 5000 ft., the status reported was normal. The system did report that the relative humidity in the electronics sphere had dropped to 20%, which was not considered critical. The system also reported that the crystal cooler power had been turned off, as planned; the recording format had changed, as planned; Tape Drive 1 was powered up and initialized; a single frequency calibration was initialized and aborted, as expected due to loss of BIP communications; Tape Drive 1 had failed after approximately 4 hr. of recording, cause unknown; and finally, Tape Drive 2 had been powered up, initialized, full-frequency calibration initiated and aborted, as expected. The final system status was received from a depth of approximately 14,000–15,000 ft. At this time the system reported that the relative humidity was 20%.

During BPP recovery 24 March 1983 by the *Melville*, it was discovered that a cable failure in battery vessel B started a chain of events that cut off power to the recording sphere after only 44 hr. into the 43-day mission. heavy corrosion was visible on the sled, especially in the vicinity of battery vessel B. Mud stains were visible at the pressure ring of vessel B. Battery A was discharged and battery B was fully charged. The DARS was tested and found to be fully operational.

Tests and Calibrations of the BPP

The following describes tests performed and results obtained prior to BPP deployment:

• Tape formating and verifications. This test consists of an automated exercise routine that preformats (writes to each block on the tape) and verifies (reads and checks contents of each block on the tape) all tape drives. This test verifies that the tape is okay and the hardware is working. While performing this test, two tape drives were found defective; they were replaced, and the new ones tested satisfactorily. Some difficulties were encountered in performing this test due to radio frequency interference from the ship's antenna and CW transmitter (500–600 W).

• Mini-mission exercise. This automated test simulates the entire sequence of the deployment and operation of the system in 1.3 hr., simulating the 45-day mission. The exercise verifies that the system, under firmware control, performs the following functions: communicating system SOH, turning off the crystal cooler after a 4 hr. period, activating and initializing the 20 tape drives in sequence, recording data, initializing both single- and full-frequency calibrations at the proper time, and switching the system power off after the last tape drive has completed recording.

The exercise was completed on 28 January. All results were satisfactory.

Calibrations. Three types of calibration tests were performed:

• Data input assembly. A known signal (provided by a 0.3 and 3.0 Hz low-distortion oscillator) is transmitted to the data input assembly and recorded. The recorded data are then processed using the Fast Fourier Transform algorithm resident in the TER microprocessor to verify both integrity and quality of the data. The results of this test are compared with the results for identical tests performed in the laboratory. The DIA calibration test was performed several times prior to deployment. The results of each test were satisfactory.

• Enhanced Delta Modulator Encoder (EDME). This calibration is performed by the DTU in the BIP. On command from the DARS, the analog inputs to the DTU are removed, and a 10-volt peak, 1.0-Hz square wave is applied to the seven inputs of the DTU for approximately 14 s. This test verifies DTU and DIA performance.

The EDME tests revealed that the SPZ channel was noisy. Investigation revealed that an interfering frequency of 45–55 kHz caused the noise. Since the noise could not be isolated, the SPZ backup channel was used in the operational mode. Calibrations were performed on BIPs on board, during deployment, and after entry in the borehole.

• Frequency response. This calibration is initiated in the BIP under the control of the STC. The following frequencies were used: 0.03125, 0.0625, 0.125, 0.25, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 12.0, and 16 Hz. Data are acquired for frequencies below 1.5 Hz for 10 min. and for frequencies above 1.0 Hz for 1 min. These data are postprocessed using the Fast Fourier Transform algorithm to determine and compare the frequency response of the individual data channels through the entire system.

The frequency response calibrations were performed on BIP 2 after entry into the borehole. Two sets of calibrations were performed. The test results were compared with the data acquired through the STC. The comparisons were almost identical, which indicated that no degradation of performance occurred through the system.

The following tests were performed after BPP recovery because a cable failed in the "B" battery sphere resulted in a loss of power to the DARS sphere after only 44 hr. of recording. Checks of the BPP after recovery showed the hydroacoustic assembly to be fully operational. The data buffer memory, located in the data storage assembly, was tested and found to be fully operational. The tape drive system was tested using the HCD-75 test firmware and found to be operational. A frequency calibration was performed with satisfactory results, which indicated that the system was still performing properly.

Acquired Data

Only 3 of the 20 tape cartridges were used during the mission. Tape 1 recorded for 5 hr., 13 min., 40 s. Tape 2 recorded for 38 hr., 10 min., 58 s. Tape 3 recorded for 53 min., 47 s. The total system operating time was 44 hr., 18 min., 25 s. The total amount of seismic data recorded was 40 hr., 16 min., 25 s. The first and last SOH information recorded on tape show no indication of system failure.

Mechanical Deployment and Retrieval Systems

This section describes the performance of the deployment and handling systems used to place the BIP in the reentry cone, launch and recover the BPP, and use of the IRR mooring. Data sheets for the BPP and BIP installation are included in the final section.

Description of the BIP Installation

The MSS 1983 BIP deployment followed the procedures established for the earlier MSS 1981 operation. The EM cable was keelhauled through the moonpool and up to the rig floor. The stinger was then lifted up to and supported off the rig floor. The reentry carriage housing-control sub was attached to the stinger with 10-7/8-in.-diameter, high-strength A490 bolts. All bolts were tightened and tack-welded. A trial fit with the special reentry tool assembly was performed. Using the special TV camera below the moonpool, we determined that a 5-in. extension should be added at the bottom as a drive shaft guard. The BIP was lowered into the carriage and shear release pins installed.

The BHA was then made up using 4 bumper subs, one 7-1/4-in. drill collar, two crossover subs, two 5-1/2-in, joints, and one 5-in pup joint. Total length of the BHA, including MSS reentry assembly, was 81.12 m. Approximate assembly time was 12 hr.

Initial deployment had reached approximately 700 ft. when the BIP failed. The reentry assembly was returned to the rig floor and the BIP removed.

In two days, the EM cable was reterminated and connected to BIP 2. The BIP was then loaded into the reentry assembly. Again, the BHA was made up. This operation took approximately 5 hr.

Deployment was then reinitiated at 1330Z on 2 February 1983 without major difficulties, except for repeated Pengo winch shutdowns. No unusual cable dynamics were experienced. Minimum cable tension at the BIP was maintained at greater than 500 lb. The typical lowering speed was about 30 ft./min. Reentry depth was achieved at 0830 on 5 February.

Several difficulties were experienced with the reentry tool assembly. The centralizer spring was modified to correct for a possible cable torquing. Reentry positioning was then quickly accomplished and a successful borehole reentry was made at 2125Z. The reentry stab depth was 5621.5 m. The reentry set-down depth on the cone was approximately 5629.5 m. No unusual forces or impact loads were noted. The reentry tool was recovered and the Baker equalizing valve pumped down. Successful hydraulically activated shear-pin release was achieved at about 2300 psi. Cable tension then increased about 500 lb. as planned. As the released BIP was lowered into the borehole, it stopped momentarily while pushing through the breakaway plug located at the bottom of the stinger. The bottom of the borehole was touched with approximately 5741 m of EM cable payed out instead of the expected 5754 m. The bottom tension at the BIP was then released to 500 lb. Total lowering time was about 12 hr. The ship was then offset upstream of the borehole by 200 ft. The drill string was then quickly raised one stand (30.5 m). During this time, the saltwater hydraulic pressure was increased to greater than 3000 psi. The exact time of gate release is uncertain. No unusual cable tensions or drill string loads occurred. The cement saltwater hydraulic system maintained pressure above 1000 psi for several minutes until the reentry sub was 54 ft. above the cone; then pressure was relieved. The ship was then moved 300 ft. farther upstream, at which position recovery of the drill string commenced. Approximately 700 ft. of excess cable had been payed out during the entire 500-ft. offset of the ship from the cone.

At 1512 on 6 February, the ship was moved 500 ft. in a westerly direction for an ATNAV beacon drop. Approximately 300 ft. of EM cable were deployed. The ship was then moved to the seismic hold station. An additional 5300 ft. of cable were laid out. By this time, approximately 25,000 ft. of EM cable had been deployed.

Surprisingly, the recovery of the reentry assembly showed the loss of the stinger. All ten 7/8-in., high-strength bolts had failed in tension. The probable cause was bending fatigue; however, overtorquing, material brittleness, or bolt shortness are possible contributing factors. The stinger is designed to fill the complete throat area of the cone and provide the maximum stiffness of section possible to compensate for the cable release slot. Several changes can be made to correct this problem on future installations.

Some important questions remain: When and where did the stinger separate? And is it still in the cone? Several theories have developed. One theory is that actual separation took place outside the cone during the recovery operation. This conclusion is based upon the following:

1. Eccessive fatigue damage to the bolts probably occurred during the post reentry and BIP lowering phase;

2. Moment loadings of the magnitude to break all 10 bolts would probably have kicked the housing out of the cone and/or severed the cable;

3. The gate release hydraulic pressure of 1000 psi set by a relief valve was maintained for several minutes after the first stand was recovered, implying that the stinger was still attached.

This theory thus holds that the stinger was raised out of the cone and subsequent oscillatory motions finally caused the already damaged bolts to fail. The stinger separated and broke the hydraulic gate tubing.

The other theory is that the stinger is still in the cone. This supposition is based on the argument that nothing could have broken it off after it safely left the cone.

Description of the BPP/IRR Installation

The BPP deployment began at 1635Z on February 1983 with the transfer of the BPP from the casing rack to the main deck port-side launch area. The EM cable was turned over to the deployment crew at 2400Z. Earlier in the day a majority of the remaining 2197 ft. of EM cable had been deployed and stopped off with cable clamps. Total EM cable length was estimated at 8300 m; estimated accuracy was 5%.

The 1-1/8-in.-diameter, lower riser-leg cable segment was set up on the EM winch and fed through the IRR sheave on the A-frame. It was then attached to the Miller swivel at the top of the BPP. Cable clamps on the EM cable were positioned about 10 m from the end. The EM cable termination was then connected to the swivel arm at the bottom of the BPP. The BPP was then picked up by the ship's crane and raised to a position where it could take up the tension of the deployed EM cable. The strain relief cable was then coiled and strapped to the BPP.

At 1320 the BPP plus attached EM cable were launched to the water surface level. The load was transferred from the crane to the 1-1/8-in. cable on the Pengo winch. The BPP was then lowered to a depth of 457 m, where the 1-3/4-in. braided line connection was fed through the winch. The BPP was then lowered an additional 152 to 610 m below sea level.

The ship was then turned broadside to the prevailing wind and current and slowly positioned toward the eventual site at speeds of 10–50 ft./min. on a general 310° course. The riser line was payed out at a rate of 80–120 ft./min. Line payout was monitored by two independent counters plus 1000-ft. markers on the braided line. The objective was to pay out line at a general 2:1 ratio to the distance the ship had moved. The lowering operation was interrupted numerous times by Pengo winch shutdowns. The line load tension was steadily reduced from 11,000 to 6500 lb. as the EM cable was laid on the seafloor and the buoy riser leg was payed out.

During the slowdown for the first check stop at 2248, a soft BPP landing was unexpectedly made. Depth of water was 5614 m. Indicated line payout at that time was in range from 4968 to 5273 m, indicating longer line segments or greater elongation than expected. A hold was made to verify BPP depth by use of ATNAV. After confirming bottom depth and position, the ship was moved farther downstream as the line continued to pay out.

Because of the weather, line tensions were generally as expected. No serious resonance areas were encountered. Wave and wind conditions were favorable with light winds and very little sea and swell. Exact weather conditions are available in the ship's log. Weather is a critical factor in deployment. Just as good weather allowed a successful development on DSDP Leg 91 with the reentry assembly, bad weather prevented similar success on Leg 88.

The IRR mooring system was installed after the BPP was lowered to the seafloor by payout of the riser leg (1-3/4-in.-diameter power braid; see Fig. 16).

With BPP on the seafloor at 2320 on 11 February, the remainder of the riser leg was payed out as the *Challenger* drifted with the seas in a direction of 310°. Since the riser leg possesses a slight positive buoyancy of 0.03 lb./ft. length, the measured line tension gradually decreased as the isolation link (1-1/8-in. diameter 6 × 37 wire rope) was laid down onto the seafloor by payout of the riser leg. Thereafter, a minimum tension of 200 lb. was maintained in the lines until the clump anchor was attached.

The A-frame sheave was cranked in during the last 2000 ft. of riser leg payout. This maneuver was to facilitate attachment of all buoys, glow flashers, and dual-release transponders to the grapnel leg (7/8-in.-diameter power braid). This operation was done from a specially built platform, outboard of the bulwark, under the A-frame.

The taper splice from the riser leg to the grapnel leg was slowly passed through the Pengo winch, idler sheave, and A-frame sheave. At 0330 on 12 February, four A-crown buoys and a glow flasher were easily snap-shackled to the running eye splices in the grapnel leg, after they passed over the A-frame sheave. This operation was accomplished without halting the ship drift and while maintaining 200-lb. line tension.

Ten thousand feet of grapnel leg was payed out, and at 0457 on 12 February, a glow flasher and five B-crown buoys were snap-shackled to the running eye splices toward the end of the grapnel leg. This was done with the same procedure and ease as at the A-crown buoy position.

The remaining length of grapnel leg was payed out until the marriage to the anchor leg (7/8-in.-diameter power braid) was just over the A-frame sheave. Ship drift was halted and the end of the grapnel leg was momentarily tied off to hold the line tension while the dual-release transponders were connected between the grapnel leg and the anchor leg. At 0554 on 12 February, the tie-off was released, the transponders were lowered into the water, and the anchor leg payout commenced with ship drift. Line tension was kept at 200 lb. during the payout of the anchor line.

When the end of the anchor line was near, ship drift was halted. The anchor line was momentarily tied off to a pad eye on the A-frame sheave to hold the line tension while the last 150 ft. of anchor leg were unreaved from the Pengo winch and all sheaves. The eye splice at the free end of the anchor leg was shackled to the clump anchor, which was at the open bulwark gate on the main deck. A separate rope was tied to the anchor line forward of the clump anchor. The other end of the rope was tied to a dynamometer, which was shackled to a pad eye on the main deck at 0830 on 12 February. The temporary tie off to the A-frame sheave pad eye was released, thus transferring the tension through the dynamometer. Controlled ship drift was continued. By 0858 on 12 February, the dynamometer indicated 1500 lb. of line tension. At that time the rope was cut, transferring the load to the clump anchor and thereby pulling the anchor into the water for its free fall to the seafloor.

Scientists on the *Melville* observed the submergence of the B-crown buoys approximately 50 min. after the anchor release. The group on the *Challenger* surveyed the site to confirm submergence of all lines and buoys and then took position over the B-crown buoys. The dual-release transponders were interrogated and determined to be submerged about 3000 ft. below the water level. Depending on line length used, the depth of the A-crown buoy was between 2000 and 900 ft. below the surface based on the B-crown buoy depth.

BPP/IRR Recovery and Redeployment

At about 0430 on 23 March 1983, the recovery operations were initiated with actuation of the ATNAV transponder release. This dual release, located downstream of the "B" buoys, provides separation from the upper anchor IRR leg, allowing the grapnel leg to float to the surface. The 5486-m anchor leg was left tethered subsurface to its anchor. Only one of the two parallel releases functioned. The *Melville* was positioned alongside of the "B" buoys and all (five dual buoys plus flashers) were recovered. The 3.2-cm power braid grapnel leg was then led through a sheave on the starboard U-frame to a special rope tugger positioned on the rope box. The 3048-m grapnel leg was easily brought aboard in about 2 hr. Typically, the line bearing angle was maintained between 15 and 45° relative to the ship's heading. The four dual buoys and one flasher of the "A" buoy were recovered.

The 4.45-cm power braid riser leg was taken directly to the IRR stern-mounted sheave and then separated from the grapnel leg. The power braid was led through the idler sheave to the winch with four wraps around the reel. While 1500 m of the upper riser leg was being brought in and tensioned, the *Melville* then powered upstream toward the BPP site (a distance of approximately 4000 m). With the *Melville* over the BPP, the riser leg tension was increased to approximately 2500 lb., at which time the isolation cable link should have been vertical. Approximately 300 m braid was then brought aboard, which raised the tension to about 7400 lb. At this stage the power braid was stretched about 6%.

No specific lift-off pullout was noted on the Martin-Decker gauge strainsert line tension recorder. The line was reeled in using the Pengo winch, with gradual increasing tension due to EM cable weight increase. The *Melville* moved upstream an additional 2800 m. At 1850, the connector to the 2.9-cm isolation cable link was brought aboard and led carefully through the winch. Line tension was approximately 12,000 lb. The wire cable was secured with a preformed cable clamp while the braid termination was cut. The wire cable was then dead-ended to the winch and wrapped around the reel. The system was secured at 2200, with a majority of cable load on the winch. Major cable oscillatory loads of ±4000 lb. were noted on the Martin-Decker gauge and strainsert recorder.

Starting at 0730 on the morning of 24 March 1983, the remainder of the isolation cable link was winched in. The BPP surfaced with an indicated load of 11,000 lb. The coiled strain relief cable was attached to the traveling winch cable and EM cable load transferred from the BPP. The BPP was then raised clear of the water and brought back over the ramp using the stern U-frame hydraulic system. The BPP was then lowered gently to the special sled resting on the ramp. The sled with the BPP was then pulled up to the deck where it was secured at 1150. Two air tuggers plus a capstan assisted in positioning the BPP.

The redeployment of the dummy BPP began early the morning of 25 March 1983, but was quickly terminated when it was discovered that the EM cable had been kinked near the surface. This failure occurred because of torque imposed by twisting of the strain relief cable. All day was spent in bringing aboard the EM cable and reheading the mechanical and electrical terminations. At 1900, redeployment was begun. Several hours were spent in launching the dummy BPP and in transferring the cable load to the dummy BPP. Two major problems encountered were the twisting of the loaded strain relief cable and the short payout length allowed by the trawling winch cable.

At 2240 the dummy BPP lowering commenced. Typical speed was 50 m/min. During this time, the *Melville* was unable to reposition near the old BPP site. As a consequence, the new dummy site is approximately 1500 m short of the intended site. Sitdown occurred at approximately 0040 on 26 March 1983.

Payout of the riser line continued until the transition to grapnel leg was reached. The line was shifted to the starboard U-frame sheave but ran directly off the reel. The four dual buoys and one flasher were reattached, and the 3048-m-grapnel line was deployed on the ocean surface. The *Melville* moved in a general 300°T direction, maintaining a typical load of 200 lb. At the end of the grapnel leg, the flasher and five dual buoys were attached. The new anchor leg was also connected but without an ATNAV release.

The 5486-m anchor line was swiftly payed out, allowing approximately 80 m/min. at times as the ship moved downstream toward the anchor launch position. When the end of the anchor line was reached, it was led directly to the 2300-lb. IRR anchor resting on the deck. The *Melville* maneuvered slowly downstream, tensioning the anchor line to approximately 1000 lb. This tension was maintained for about 2 hr., as all line slack was pulled out and the line curvature straightened. A quick recheck indicated an acceptable anchor release position, and the anchor was launched overside at 0801 with a probable 1000-lb. line pull. The *Melville* returned to the B-crown position where the five buoys were observed to completely submerge by 0915. A check of the A-frame buoy position also confirmed submergence.

Postanalysis indicates that the actual launch position was approximately 14,400 m from the BPP. This is allowing for an estimated 1500 m pull-in of the anchor during the free fall, plus the estimated anchor position at 12,900 m from the dummy BPP. Figure 19 depicts the approximate configuration of the IRR system and gives estimated latitude and longitude.

Although the IRR recovery and redeployment operational activities were satisfactory, several areas of concern should be addressed. This is particularly true if more severe weather or current conditions are likely.

Generally speaking, the *Melville* is an acceptable surface platform for such operations. Although it appears to have a fast roll condition, this constraint would be critical only in rather severe weather (above possibly Sea State 5 conditions).

The strain relief attachment to the EM cable is a serious problem area. Severe problems with EM cable torquing and kinking were encountered when cable load was taken up by the strain relief line. A torque balanced wire cable, plus swivels on both ends, is mandatory. The strain relief cable also must be contained within an enclosure on the BPP.

Improved surface navigation is required, particularly during the deployment phase. An improved procedure is required to coordinate cable pay-in/pay-out ship movement. For the anchor launch phase, an accurate ship position verification is required, particularly if a severe cross-current condition exists.

Further improvement in protection/isolation of the electronic cable length and cable tension equipment is necessary. The present sensing operation idler sheave strainsert transducer location is not adequate as a load monitor, although good analog cable tension data (above 2000 lb.) were recorded during the BIP recovery phase. An independent load measurement system is required. A strain gauged pin for the sheave attachment is recommended. The dual analog static/dynamic recorder should be compatible with either the Martin-Decker hydraulic or the strainsert pin.

In retrospect, deployment and/or redeployment of the BPP/IRR systems are definitely feasible and practical. The overall procedures as established are adequate, but must be tailored specifically in detail to each ship, master, and weather conditions. To avoid damage to sensitive instrumentation, more power-controlled tag lines should be used.

SUMMARY

The efforts on Leg 91 showed that a marine seismic system can be deployed. Equipment descriptions of the Borehole Instrumentation Package, Bottom Processing Package, and the installation mooring have been given. Equipment operating characteristics and their deployment scenarios have been presented. If, in the future, it is decided to deploy and MSS for operational use, the information given here will serve as a design benchmark from which to proceed.

ACKNOWLEDGMENTS

I would like to thank all of the engineers, managers, technicians, and scientists who contributed to the MSS program and this chapter.

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APPENDIX
Glossary of Acronyms

ARPA: Advanced Research Projects Agency
ATNAV: Acoustic Transponder Navigation System
BHA: Bottom Hole Assembly—drill bit collars and subs for adding weight and flexibility to drill string
BIP: Borehole Instrument Package
BPP: Bottom Processing Package—data recorders, etc., housed in 40-inch diameter pressure vessels
CRT: Cathode Ray Tube
DARS: Data Acquisition and Recording System—formats and records seismic and SOH data on digital tape
DBM: Data Buffer Memory
DHE: Deployment System Shipboard Handling Equipment
DRCM: Direct-Reading Current Meter (direction and speed)
DIA: Data Input Assembly—communication interface between BIP and DSC
DSA: Data Storage Assembly—20 HCD-75 tape recorders
DSC: Data Storage Controller—control interface and electronics for data storage (DSA)
DSDP: Deep-Sea Drilling Project
DTU: Data Transceiver Unit—data telemetry and communication unit in the BIP
EDME: Enhanced Delta Modulator Encoder—24-bit analog-to-digital converter used in the BIP DTU
EM: Electrical-Mechanical Cable—torque-balanced coaxial cable connecting BIP and BPP
EPROM: Erasable Programmable Read-Only Memory
FIR: Finite Impulse Response Filters—bandpass filters and converters bit stream to integers
FSK: Frequency Shift Key
IRIG: Inter-range Instrumentation Group
IRR: Installation Recovery and Reinstallation Mooring
LED: Light-Emitting Diode
MP: Mid-period (0.01–1.0 Hz filtered band)
MSS: Marine Seismic System
NORDA: Naval Ocean Research and Development Activity
NRZ: Nonreturn to zero
OBS: Ocean Bottom Seismometer
PCM: Pulse-Code-Modulated
RAM: Random Access Memory
RTC: Real Time Clock—6.5536 MHz crystal that provides system timing pulses
SOH: State-of-Health (voltage and temperature detection in BIP)
SP: Short-period (0.1–20 Hz filtered band)
STC: BIP Shipboard Test Console
TCXO: Temperature-Controlled Crystal Oscillator
TER: BPP Test Equipment Rack
UPS: Uninterruptible Power Supply—supplies 115-V ac and 100–110-V dc operating power to both shipboard and borehole electronics
UTC: Universal Coordinated Time
WWVH: National Bureau of Standards time transmitting station in Hawaii
ZB: Backup Vertical Seismometer