Workshop Report

Defining New Goals, Techniques, and Development/Support Mechanisms for Downhole Tools in the Integrated Ocean Drilling Program

Contents

1.0 Introduction

The Integrated Ocean Drilling Program (IODP) builds from the successes of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Program (ODP), yet it is a fundamentally more extensive and challenging endeavor. The IODP involves simultaneous use of riser, riserless, and mission-specific drilling platforms, and it explores environments and problems that could not be addressed previously. These characteristics influence virtually all facets of planning, funding, at-sea operations, and technical development. It is particularly important to examine the role of downhole tools (DHTs) in the IODP because they are critical to IODP science, because their development and use are the responsibility of numerous implementing organizations and third-party developers, and because technology advances are driving new measurement capabilities and scientific demands.

Fifty-one scientists, engineers and program managers met in Washington for two days in late May, 2004 to discuss DHTs. For the purposes of this workshop, we limited our definition of downhole tools to "instruments that are lowered into a borehole and are intended to collect samples, or make measurements of formation or fluid properties during a short period of time over a limited depth interval." We specifically avoided discussion of conventional and developmental wireline logging and logging-while-drilling technologies in the interests of time and to help focus our discussions.

The workshop participants were asked to concentrate on these questions.

1) What downhole measurements and sampling are essential to address fundamental goals described in the Initial Science Plan (ISP) for IODP?
2) What capabilities exist for use of these tools on the various IODP platforms, and what technologies are needed for future success?
3) How can IODP and its scientific and technical partners nurture development of new tools, and facilitate the transfer of technology from the development stage to become part of standard operations?

This was the first community-wide meeting to assess DHT development and use within the context of the new program. It begins a discussion among scientists, engineers, and administrators of how to strengthen our ability to use DHTs to address the scientific goals of IODP. We examined the state of the art in DHTs, and identified priorities for the next generation of tool developments. Just as importantly, we explored the process of tool development and proposed steps to strengthen our ability to develop and deploy downhole tools successfully.

2.0 Background and Motivation

The ODP community has realized a long series of notable achievements with respect to DHTs, including development of hydrogeologic testing instruments, a pressure core sampler, pore-fluid samplers, and tools for measurement of *in-situ* temperatures. These tools have been deployed in a broad range of environments, to address questions related to hydrogeology, hydrates, diagenesis, climate change, active margins, crustal evolution, and other topics. However, the road to success with these projects has been rough in some cases, and several important developments have proven less successful or been abandoned after expenditure of considerable funding and effort. Should DHT operation and development within IODP be fundamentally different from that practiced during DSDP and ODP? There is often misunderstanding within the scientific drilling community as to what is broadly possible, what developments have been attempted during ODP, and what deployments comprise "standard" drilling operations. The Downhole Measurements and Shipboard Measurements Panels of ODP have at various times reviewed earlier developments, made recommendations as to what tools are needed, and helped to develop guidelines for investigators wanting to create new tools for use at sea ("third-party" developments). However, there has never been a community-wide meeting to assess DHT development and use within the context of the new program.

DHTs are critical to achieving IODP science and there is growing momentum behind improving present tools and developing new ones. The Hydrogeology PPG Report stressed the importance of developing, improving, and maintaining tools, the importance of the routine collection of hydrogeologic data, and described a series of hydrogeological science problems where understanding hydrologic properties and *in-situ* pressures are critical [*Ge et al.*, 2002]. An industry-academic workshop cited the need to develop geotechnical tools for measurements in the shallow sedimentary section [*Flemings et al.*, 2000]. The geochemical community recommended to "Increase the Use, Development, and Quality of *In Situ* and Other Instrumentation" [*Murray et al.*, 2001; *Murray et al.*, 2002]. DHTs , and how to improve their capabilities and integration with other aspects of platform based measurements, is under discussion by both the Scientific Measurements Panel and Technical Advisory Panel within the iSAS/IODP Advisory Structure. Other communities are also working towards improved *in situ* sensors and instrumentation.

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3.0 Workshop Overview:

51 scientists, engineers and program managers met on May 24 and May 25, 2004 in Washington D.C. (Appendix A). During the first day, participants split into 3 working groups that reflected the three primary IODP research themes identified in the Initial Science Plan (ISP). Working groups focused on what measurements must by made with DHTs to achieve the goals of the ISP. Next, working groups identified current capabilities and existing gaps between these capabilities and critical measurements and sampling.

During the second day, we focused on the process of tool development. We examined case histories of tool development and identified successes and failures in the processes by which tools progress from "concept" to "implementation". We subsequently broke into two technical working groups focused on (a) measuring physical state and (b) sampling. Groups focused on identifying an appropriate development process to achieve DHT measurements. We closed the day by recognizing top technical needs and identifying approaches to improve the process to achieve those needs. The full agenda is in Appendix B.

4.0 The IODP Initial Science Plan and Downhole Tools (DHTs)

4.1a What DHT measurements are important to The Deep Biosphere and the Subseafloor Ocean theme of the ISP?

This working group prepared Table 1 to list DHT measurements that are critical to achieve the science goals of the ISP related to the deep biosphere and the subseafloor ocean. This research theme has 2 components (Deep Biosphere and Subseafloor Ocean) and 2 Initiatives (Hydrates and the Deep Biosphere), as defined in the Initial Science Plan. Specific comments related to desired measurements are listed after the table.

Table 1: Critical DHT measurements for study of the research theme 'Deep Biosphere and the Subseafloor Ocean.' Each category was ranked as critical (C), important (I) or not applicable (N/A).

Category	*Measurement Description*	*Deep Biosphere*	*Hydrates*	*Inorganic sub-seafloor ocean*
Fluid sampling	Incubation, spiking, preservation	C	I	N/A
Fluid Sampling	Recover samples at *in-situ* conditions from high temperature and pressure regimes	C	C	C
Fluid Sampling	Gas – exsolved (e.g. CH_4)	C	C	I
Fluid Sampling	Gas – dissolved (e.g. CH_4)	C	C	I

Fluid: *in-situ*	Microbial activity, Metabolites, activity rates, biomass, biodiversity, DNA/RNA, microscopy, kinetics?	C	C	N/A
Fluid: *in-situ*	Pressure	C	C	C
Fluid: *in-situ*	Temperature	C	C	C
Fluid: *in-situ*	P_h, Pe	C	I	I
Fluid: *in-situ*	Flow rates	C	C	C
Fluid: *in-situ*	Aqueous chemistry – for specific analytes	C	C	C
Fluid: *in-situ*	Gas chemistry	C	C	I
Formation properties	Porosity	C	C	C
Formation property	Permeability	I	C	C
Formation property	Shear Strength	-	C	I
Formation property	Resistivity	I	C	C
Formation Property	Magnetic	I	C	C
Formation property	Thermal Conductivity	C	C	C
Sampling: Formation In-situ	Sediment, rock sample return	C	C	I
Sampling: Formation	High return, high quality core recovery – “quality” specific to particular applications	C	C	C
Sampling: Formation	Geochemistry – in situ	I	I	I
Formation state	Stress (in-situ)	N/A	C	C in specific environment
Formation: *State*	Pressure (in-situ)	C	C	C
Formation: *State*	Temperature (in-situ)	C	C	C

Hydrates. DHTs are critical for achieving the ISP’s scientific goals related to gas hydrates and microbes. Quantifying the amount of methane in sediments is important and there have been major successes in this. However, it is now also critically important to measure properties and parameters that illuminate the processes governing gas hydrate occurrence.

Microbial community. The effects of occurrence, temperature, and time were the main themes covered in discussions related to microbes. How do time and temperature affect the microbial community? What is the linkage between lithology and microbial diagnensis? What are the groups of microbes? How is microbial disbribution correlated with millimeter scale lithologic changes? Are there microbe-specific bio molecules, lipids, and/or surfactants?

Discrete samples at in situ pressure and temperature. The ability to recover discrete samples at in situ pressure and temperature is required for geotechnical, geochemical, and microbial studies. Maintenance of in situ conditions will provide more pristine samples. Equipment such as the PCS and HYACE to recover samples while maintaining in situ temperatures are not yet functional. Developing the capability to maintain core at in-situ pressure and temperature would allow laboratory studies of fluid, gas, and sediment at in situ conditions without pressure/temperature cycling.

Discrete samples. At sites with low-core-recovery (especially in mixed lithology sequences, e.g. chert-chalk, clays-sands) it is highly desirable to have discrete *in situ* samples to fulfill a number of scientific objectives. Discrete samples can: 1) provide physical properties data (e.g. porosity, density, gamma-radiation) that can be used to "ground truth" interpretation of standard wireline logging data; 2) provide lithological information; 3) provide biostratigraphic information.

Increased quality sample return: Sample "quality" holds different meaning for different specific scientific objectives. Primary considerations are: recovery, preservation of chemistry and biology, and mechanical disturbance. Some tools exist to maximize recovery in hard rock (RCT). Tools also exist to assess chemical and biological sampling disturbance (e.g., tracer tests). In general, APC provides high recovery with little chemical/biological disturbance in soft sediments – but samples are allowed to expand in the core liner, making them of low quality for geotechnical testing. Sidewall coring (SWS) has the potential to provide chemically/biologically undisturbed samples in some cases. Recovery of chemically or biologically undisturbed samples in indurated sediments and hard rock remains a challenge.

Discrete fluid samples at in situ pressure and temperature. It is desirable to measure and collect discrete fluid samples at *in situ* P, T conditions. The collection of fluid samples negates the need to take whole core rounds for pore water sampling for palaeoclimate studies (e.g. δ18O in pore waters can be used to reconstruct δ18O of palaeo-seawater).

Lateral variations in physical properties. Lateral variations in physical properties is an important parameter that has hardly been investigated at single-hole DSDP and ODP sites. Obvious ways to obtain lateral variability include: multiple hole measurements at appropriate lateral separation, cross-hole, and deviated borehole measurements. The most useful techniques are seismic, electrical, and hydrological. Lateral scales ranging between a few m to several km should be possible.

Microbiology. A possible DHT approach is to perform an initial exploratory survey of microbial signals with a fluorescence logger and then collect samples from specific depths, taking precautions to avoid contamination and to maintain ambient temperature, pressure, and fluid/gas composition.

In-situ distribution of microbial types – Use laser- or LED-induced autofluorescence to map total microbial concentration (tryptophan signal) and methanogen concentration (F420 signal) as a function of depth, and relate maximum temperature (depth) for existence of mesophiles, thermophiles, and hyperthermophiles. A major goal would be to search for maximum temperature at which any microorganisms can survive. Several months after the initial drilling and logging, a follow-up log should be obtained, in order to look for growth of microbial mats on the borehole wall. Fluorescence logger exists but needs to be modified for high pressure.

In-situ distribution of biomolecules – Use laser- or LED-induced autofluorescence to map biomarkers of former microbial life: porphyrins and other degradation products of microbial decomposition. Fluorescence logger exists but needs to be modified for high pressure.

Chemistry. Chemical measurements encompass a wide-range of dissolved specifies, including inorganic ions (major cations and anions), the dissolved carbonate system (pH, alkalinity, and total CO_2), gases, and trace amounts of organic molecules (e.g., dissolved organic matter, biopolymers, and fluorescent compounds). There is an enormous variety of laboratory-based analytical methods that are capable of quantifying small sub-classes of these compounds at concentrations typical of those in sedimentary pore fluids. Adapting these techniques to high pressure and temperature borehole applications is possible, however selectivity, sensitivity, and specificity of the method will be significant analytical issues. In some cases creating an instrument that can fit down a borehole and be powered from batteries or a conducting wireline will be challenging. The effects of corrosive downhole chemical environments and fouling of sensors (especially optical) will present operational and reliability challenges. Because of these analytical and technical difficulties, we consider in situ chemical analysis to be technically difficult. The most promising methods for in situ analysis include those that have selectivity for a suite of compounds. Various scanning spectroscopy techniques (e.g., ultra-violet, vibrational, and fluorescence) with variable frequency sources (perhaps laser-based) and in situ mass spectrometry appear to be the most promising techniques. There is at least one commercial product coming onto the market that uses ultra-violet scanning spectroscopy (e.g., ISUS) for in situ measurements of dissolved bromide and bisulfide in ocean water. The biggest challenge for borehole mass spectrometry development is the construction of an inlet system suitable for the high-pressure difference that will exist across the inlet.

4.1b What DHT measurements are important to <u>Environmental Change, Process and Effects?</u>

Table 2: Critical DHT Measurements for study of the research theme 'Environmental Change, Process and Effects.'

Scientific Goal	Measurement
Millenial and longer scale records	Detecting mm-scale lithologic variability in-situ, from 0-200 mbsf
	Coring in difficult enfironments: Sand, carbonate, chert/shale
	Recover continuous records from extreme climate records at the millimeter scale
	Detect ash layers
Reconstructing Bottom Water temperatures	High spatial resolution of temperature in the shallow section

The Environmental Change, Process and Effects group focused on the need to collect records of environmental change with improved resolution. In addition, it was felt that DHTs might be used to acquire better high resolution temperature records that would allow reconstruction of the evolution of bottom water temperatures through time and also allow monitoring of marine permafrost on continental margins.

Detection of mm-scale lithological changes. In certain palaeoenvironmental settings extremely high-resolution marine sedimentary records may be preserved (e.g. varves, coral banding, millennial scale records). APC coring can cause disturbance in extremely soft sediments and conventional logging tools cannot be used in the uppermost part of the sedimentary section.

Detection of ash layers. Explosive volcanic events may have a significant short-term effect on global climate. High-resolution records of ash layers may be important for understanding rapid climate change. Ash layers are generally easily recognized in APC cores using the MST and visual core description. In the absence of core, FMS logs, in conjunction with other data, can be used to identify ash layers.

Reconstructing bottom water temperature. One method to help lengthen our understanding of environmental change on the ocean floor is through reconstructions of bottom water temperature. One method for doing this is to monitor the vertical distribution of temperature within boreholes over time. Perturbations to the background thermal regime can be used to reconstruct bottom water temperatures.

Marine Permafrost. In polar regions an important and sensitive indicator of climate change is the state of marine permafrost associated with continental shelves. Temperature measurements are an effective way to assess the health of permafrost. Equally important is monitoring the position of the phase change between water and ice at the top of the permafrost. The depth extent of permafrost may also be important to monitor.

4.1c What DHT measurements are important to Solid Earth Cycles and Geodynamics?

*Table 3: What DHT measurements are important to Solid Earth Cycles and Geodynamics (SECGD)? Material Properties/State/Fluxes. Each category was ranked Essential (E) or Would-be-nice/Important (I). "I" includes things that are essential but can be obtained in other ways than DHTs. **E1** are items that apply across all SECGD projects*

Justification	
1) Material State:	E1
Pore Pressure	
Temperature	E1
Stress tensor (σ_1, σ_2, σ_3, S_{Hmin}, S_{Hmax})	E
2) Fluid and Gas Chemistry	E
(both concentration and samples)	
3) Seismic structure	E1
velocity (compressional and shear)	
Velocity anisotropy	
Absorbtion (Q)	
Seismicity (active micro-eqrthquakes, hydrofracture experiments, passive micro-earthquakes)	I
4) Permeability	E
5) Porosity (heterogeneity, scale dependence)	
6) Compressibility (elastic properties)	E
7) Electrical Structure	I
8) Thermal Conductivity	I
8) Fluid Flux	I
9) Gas Flux	I
10) Heat Flux	I
11) Momentum Flux	I
12) Rheology	E1
shear, compressive strength	
Seismic waveform (frequency, amplitude)	E
13) Strain transients—tilt, strain tensor	I
14) Rock/Sediment samples (precisely located "special" cores—e.g. sidewall, cuttings, sampling, mechanically undisturbed samples	I
Rock Fabric—wall structure	I

In situ stresses: In situ stresses may be recovered from stress relief (overcoring), core recovery, borehole failure, and hydraulic fracturing methods. Stress relief methods are not applied in deep boreholes in hostile environments, but have the advantage that they yield the full stress tensor. Core recovery methods involve restressing an oriented core to ambient in situ conditions, with arrival at these conditions indexed by elevated acoustic emissions, or by marked changes in deformation modulus. Borehole breakouts may be used to define orientations of the minimum principal stress (Gough and Bell, 1970), and magnitude of the breakouts may be used to define the magnitude of components of borehole-normal stress or the differential stress (e.g., $Sh_{max} – Sh_{min}$).

Hydraulic fracturing is routinely used in deep environments to define minimum principal stress magnitude and orientation (e.g. Haimson, 1972). Extended leak-off tests are performed by isolating a short section of open hole with a drill string packer, then pumping into this interval until flow into the formation increases. With several cycles of active pumping and shut-in, the initial hydraulic fracture stress ($Co + \sigma_3$) and the least principal stress can be determined (extended leak-off test: XLOT). This is commonly done in industry and geothermal applications. HTPF (hydraulic testing of pre-exisiting fractures) testing may be used to determine the oriented state of stress on pre-existing fractures (Cornet, 1987). The zone is packed and inflated to breakdown, and the known fluid pressure and observed (borehole camera or impression packer) orientation of the fracture used to determine the stress normal to the pre-existing fracture. Stimulation of multiple variably inclined fractures enables the full stress tensor to be determined. Injection tests to steady-state may be used to measure fracture permeability with stress (Rutqvist, 1995).

Advanced downhole rheologic experiments: There is a need to go beyond standard geotechnical measurements as well. For many problems of interest to the IOPD community (fault mechanics, limits of the seismogenic zone, aseismic transients), there is a need to move beyond simple failure laws defined by only a few elastic parameters or static strength measurements. These problems require measurements of inelastic strength, determination of the strain rate dependence of strength, and flow properties of candidate materials. Ideally, these measurements would be made in-situ, in soft sediments, indurated sediments, and hard rock, to augment detailed laboratory experiments on core. New experiments will be developed for which existing downhole technology is yet to be identified, though it may encompass adaptations of dilatometers, borehole jacks, packers, and fluid pressure perturbation capabilities.

4.2 What are the current DHT capabilities?

Working groups identified current capabilities and existing gaps between these capabilities and critical measurements and sampling. Comments follow Table 4.

Table 4: DHT measurements that are important to the ISP, current methods to achieve the measurements, and the status of these measurements. All of the measurements are deemed important to the ISP. 'Difficulty' is a qualitative measure of how difficult it will be to make the measurement. A minor improvement of an existing tool would be 'low' whereas a new tool with new technology would be 'high.'

Category	***Measurement Description***	***Method***	***Difficulty***	***IODP Status***	***Quality/ Success Rate***
Fluid sampling	Incubation, Spiking, preservation	Manifold sampling system	High	In development (3rd Party)	?
	From soft	WSTP	Low	Standard	low

	sediments				
	From soft sediments	Fissler (IWS)	Moderate	3rd Party	Low
	From soft sediments	Bat-probe	High?	Commercial?	?
	From Soft Sediments	PCS	Low	ODP	Good
	From indurated sediments	RFT	High	Commercial. Does not fit in Joides Resolution drill pipe	high in permeable formations
	From permeable sediments	Pack-off and let flow or pump	can't pump out	ODP	High
	From fractured rock	RFT WSTP	Low	3rd Party—easily contaminated.	Low unless in permeable formation
	Gas – exsolved & dissolved	PCS	Low	Exists.	Moderate
		RFT	Low	Commercial	Variable
		HYACE	Low	Exists	Unknown
Rock sampling	High return, high quality core – "quality" specific to particular applications	RCT	Moderate - diameter -operator	3rd Party	Good
		SWS	High - diameter		Variable
		GEL coring			?
	Sediment, rock sample return at *in situ* conditions	PCS	moderate	3rd Party? on hold	variable, soft seds only
State	Pressure in soft sediments	A. DVTP-P	Low	A. IODP	Highly variable
		B. Piezoprobe	Low	B. 3rd party	Good
		C. MDT	Low	C. 3rd party	Good in permeable sediment

	Pressure in rock & indurated sediments	Wireline Packer	High	3rd Party (industry)	Fair/ Low
		Drill String Packer	Low	3rd Party. Do-able but non routine	Good/High
		MDT (Modular Dynamics Tester)	Low	Standard in industry, available if pipe diameter is large. May be limit in rock induration and permeability to get result	Good/High
	Stress	Drillstring Packer, (Extended leak-off test)	Routine in industry, not done in ODP, should be do-able	ODP plus 3rd party gauges	High
		LAST & LAST-II	difficult	Developed >10 years ago, deployed once or twice	low
		Industry (Fugro) tools: stressmeters?	Should be investigated	commercial	
		Geoprops probe	Unsucc. 3rd party	Dormant/dead	
	Temperature in soft sediments	DVTP	Low	Routine	Excellent
		APCT	Low	Existing and under development?	High
	Temperature in rock	DVTP Spiess Logging Probe Wireline logging tool	Low	Routine/ can only be deployed in borehole.	Limited to temperature of borehole, which may not be equilibrated to formation
	Microbial activity in	Fluorescence PCR devices	High	Non-existent	?

Material Property	fluids				
	PH, pE	Probes	Low	Non-existent	?
	In-situ aqueous chemistry – for specific analytes	Probes Raman scatter Optrodes	High	In development for *seafloor* applications	?/?
	In situ gas chemistry	GC's Mass Specs	High	In development for *seafloor* applications	?
	Fluid and Gas Chemistry	PCS	Low	A. ODP	High for soft sediments
		other pressurized samplers	Low	B. 3rd party	?
		MDT	high	commercial	high
		IWS	high	ODP, not ready	Low
		Pack-off and let flow or pump	low	ODP	Done in overpressured settings; can't pump out
		VSP, other	Low	Exists	High/variable
		Vane Shear	Low	3rd Party	High/variable
		Penetrometer	Low	3rd Party	Moderate
	Rheology/ geotechnical properties	Cone Penetrometer		commercial	Good
		Piezoprobe		commercial	Good
		Seimic shear wave measurement		commercial (Routine logging measurement)	Poor data in low velocity sediments/Hi g
		Undisturbed whole core		exists	APC samples cause disturbance
		Borehole jacks/dilatometers		non-ODP; routine in geotechnical use	
		Sacks-Everdon strainmeter.		An observatory element, has been deployed in ODP	
	Hydrologic properties	DVTP-P	Low	Existing	variable
		piezoprobe	Low	3rd Party	variable
		packer expts	Low	existing	Variable

	-pumps -realtime P			(need better pumps, real time p data) Variable
	RFT	Low	commercial	
Electrical, magnetic	DLL, DIL	High	In development (3rd Party)	
Thermal conductivity	Probe	High	Existing	Variable, soft sed. Only
Seismic Velocity and Attenuation	Broadband Borehole seismometers	Low	3rd party	Good
	3-comp VLF seismometers	Low	3rd party	Good
	Multi-node strings	Low	3rd party	?
	Mems and fiber sensors	High	requires emerging technology	?

Fluid Sampling: Many of the scientific problems posed in the ISP are critically dependant on fluid (gas) chemistry. While there are some available tools, none adequately provide pristine samples of the formation fluids. Most samples of pore fluids have been extracted from solid samples recovered in the cores. However the properties of these samples change during core recovery. Some tools exist to sample *in-situ*, but need improvements. All of the tools listed below compromise the samples.

At present there are essentially no techniques to make meaningful chemical measurements of most key components within the formation. The uncertainty in the data provided by the existing tools and approach compromises the interpretation of the data, and thus hinders scientific progress. New tools need to be developed. It is critical to be able to make measurements of the pore fluid within the formation, both within the bore hole, and in samples that are recovered in a pristine state from within hard and soft rocks.

The existing tools that need improvements include:

WSTP – The water sampling pressure corer has existed, in various forms, since DSDP. However, this tool is known to fracture the formation and drilling fluid contaminates the sample in most cases.
Fissler (IWS)- The Fissler Intersitial Water Sampler was a modification of the WSTP, with a superior shape and sampling design. However, this development was never completed and it would be worthwhile to pursue it.
PCS *(Pressure Core Sampler)* - This tool was originally developed during DSDP (under the name Pressure Core Barrel). However, it was not until Leg 164 that it

recovered pressurized cores routinely. This device has generally been used solely to determine the amount of gas contained in the sediments, and not used as a pore fluid sampling tool.

***HYACE** (HYACINTH-project)* - The HYACE, developed by a European consortium, was first used successfully on leg 204. The HYACE tool was designed to measure *in-situ* core properties on samples collected under pressure and to transfer these samples to other pressurized containers for other measurement. It is still in the development stage and is not primarily for pore water sampling.

Bat-probe - The group was not very aware of this DHT. However we understand it to be a commercially available sampler.

MDT-RFT- These tools were originally designed by Schlumberger but are also available through other wireline logging companies. They both measure in situ pressure and hydraulic conductivity and can be used to take fluid samples. They do not fit within the borehole diameter of the drill pipe on the Joides Resolution.

Rock Sampling. Solid sample return at in situ conditions:

***PCS (Pressure core sampler)**:* - This tool was originally developed during DSDP (under the name Pressure Core Barrel). However, it was not until Leg 164 that it did recover pressurized cores routinely.

***HYACE (HYACINTH-project)**:* - The HYACE, developed by a European consortium was first used successfully on leg 204. The HYACE tool has been designed to allow in situ core properties to be measured on samples collected under pressure and ultimately to be transferred to other pressurized containers for other measurement. It is still in its developmental stage.

State:

Temperature, Pressure, Conductivity. The TPC tool, which is under development, measures temperature, pressure and conductivity changes within the headspace of an APC core during core recovery. Historical shipboard observations of cold core temperatures, frozen pore water, and catwalk core temperature measurements of gas-rich cores suggest that gas expansion cools the core during its ascent to the surface. The TPC is designed to measurement these temperature changes during core recovery. It is a completely autonomous downhole tool that is contained completely within the interior of the APC piston sub-assembly. The major components of the TPC include the sensors (P, T, and C), a signal conditioning board, a 32-bit 16 MHz computer with 48 Mbyte RAM, and 2 double "D" lithium batteries. This tool has been run on ODP Legs 195 for engineering tests, and on Legs 201 and 204 for scientific measurements. The goal is to use the T, P, and C data to provide constraints on the relative gas content of continental margin sediments and to learn more about the effects of coring on sediments.

Pressure. DVTP-P – After several deployments in ODP, it is still in development stage and has been moderately successful. Its wide diameter requires significant time to interpret in-situ pressure. It runs on a separate run on the coring line and its range of operations is limited to the upper range of XCB coring. An absolute pressure sensor was added to the DVTP tool to measure in situ formation pressure with DVTP-P. More deployments in different sediment types are needed to gain more experience and allow a full assessment of the tool's capabilities and limitations.

Pressure. Piezoprobe – Deployed routinely by Fugro. Was run successfully on ODP Leg 204. Available commercially and a similar tool is now under development as a 3rd party tool. The Piezoprobe, a Fugro-developed pore pressure probe, was deployed twice during ODP Leg 204, and one successful measurement was made. The tool is currently being optimized through a NSF-funded proposal.

*Pressure***.** Modular Formation Dynamics Tester (MDT)-- Commercial and fully operational wireline deployed tool. Makes several pressure measurements in a single run. It requires the use of large diameter pipe (6"5/8). It was run successfully on the JOIDES Resolution during the JNOC gas hydrate experiment.

*Pressure***.** Packer measurements: Extrapolation to in situ pore pressure can be made through isolation with drill string or wireline packers. Primary issues include the effects of drilling perturbations on fluid pressures. Previous tests in ODP have generally not been run long enough to confidently extrapolate to in situ pressures.

Temperature: In low permeability and soft sediments, penetrometer tools, if equipped with a thermister, (e.g. the DVTP-P, Piezopropbe, cone penetrometer) can be used to measure formation temperature and pressure. Temperature measurement is a fairly routine technique. The DVTP is a routine tool used since ODP Leg 164; it has been consistently reliable at provided good quality temperature data. It runs on a coring line. Its range of operation is limited to moderately hard sediments, in the upper range of the XCB coring.

Temperature. APCT (formerly known as Adara). The existing APCT has been very successful and reliable for temperature measurements in soft sediments. The thermistor is located in the APC cutting shoe, and its operation range limited to soft sediments. The old tool electronics are currently being updated by a German-funded project. At the same time, a sub is being developed (A. Fisher, UCSC) which will host a second set of electronics and which will potentially allow determination of in-situ temperature gradient. Requires frequent and careful calibrations to guarantee high quality absolute temperature data. This is important for consistency of data between legs and instruments.

Temperature. The DVTP is routinely run in semi-consolidated sediments and has a proven record of providing reliable temperature data. Both the APCT and DVTP instruments require frequent and careful calibrations to guarantee high quality absolute temperature data. This is important for consistency of data between legs and instruments.

Temperature. Borehole temperature logging. No technique exists for measuring in-situ temperatures within hard formations that cannot be penetrated. Downhole tools can be used to log borehole temperatures shortly after drilling operations, with established methods for extrapolating to estimate formation temperatures. In addition, holes can be revisited long after drilling by wireline reentry for logging of temperatures after dissipation of any drilling disturbances. Among the existing tools available for logging borehole temperatures are the following:

1. DVTP and APCT tools, while normally used in penetration mode in sediments, can also be deployed to log open-hole borehole temperatures.
2. LDEO Borehole Research Group operates a memory temperature-logging tool that can be added to the bottom of a wireline logging string.
3. The MPL Control Vehicle wireline reentry system includes a logging sonde that can continuously log borehole temperatures on wireline reentry.
4. In the 1990’s, NSF supported acquisition of a dewared, memory, temperature logging tool that can be run on the coring ling to log temperatures in hot holes. It has been used successfully in ODP to log borehole temperatures up to 318°C, and, although still a third-party tool, it remains available for IODP use.

Temperature: Install a high precision thermistor string in a borehole and logging temperatures as a function of time. One potential shortcoming of this technique is that data loggers limit the number of thermistors on the string, and thus limiting the spatial density of measurements. One way to overcome this obstacle would be to log the borehole through a borehole seal.

Comment: Hi-temperature (>150 to 300 C) issues are critical for some applications. Most existing tools are not capable to temperatures above ~125 C.

Comment: Many of the temperature and pressure tools listed above generate a transient disturbance of the parameter to be measured. The extrapolation of the decay in temperature or pressure to undisturbed formation state needs further standardization to allow comparison of data sets.

Stress: LAST tool: The LAST tool was developed in ODP to measure lateral stress in soft sediments. It was deployed with limited success and its development abandoned.

Microbial activity: A suite of downhole instruments need to be developed to measure microbial activity in situ (i.e. at the bit).

Gas concentrations. The PCS is a proven tool to estimate the in situ concentration of subsurface gasses. It has been successfully used on legs 164, 201, and 204. However the sampling is time and effort intensive. Approximately 60 PCS samples of methane concentration exist to date including Blake Ridge, Hydrate Ridge, and the Peru margin). The major shortcoming of the PCS is the inability to keep samples at in situ temperature. The best way forward is to start using PCS routinely and measure gas concentrations in different geological environments and depths. Also, the logging of PCS before and during degassing would provide valuable information on the distribution of gas phases and properties of sediment.

pH, pE, and in situ aqueous geochemistry: Electrodes need to be developed/modified to penetrate the formation at or ahead of the bit. The measurements can be transmitted via cable in real time, allowing drilling strategy to be adapted. The electrodes could be designed at the bit or in a probe-type of instrument inserted ahead of the bit. Analytes of interest (mainly for deep biosphere objectives) include Fe, H2S, pH, and pE. This is critical for some analytes (pH, pE) because they change during sample retrieval and cannot be measured shipboard.

Gas Chemistry, in situ: A suite of downhole tools will require development – including GC and Mass Spec. These tools are being developed for seafloor applications, but do not currently exist for use in boreholes.

Material Properties:

Rheology. Borehole (Menard, 1957) and self-boring dilatometers (Hughes and Wroth, 1970) are routinely used in soils, and borehole jacks (Goodman, 1976) in rocks, in shallow terrestrial environments. All measure deformation of borehole walls displaced by a pressure applied through a packer or opposing platens. If stressed to failure, dilatometers will measure cohesive and frictional characteristics of soils.

uCPT are routinely applied in soils at shallow depths to measure end-bearing, sleeve friction, and drivage-induced excess pore pressures – these data define magnitudes of undrained cohesion and frictional resistance.

Piezoprobes may be used in a similar manner if outfitted with a load cell behind the penetrometer tip. Field vane shear apparatus are used to measure in situ cohesive strengths in soft clays.

Mechanical: A suite of elastic and geotechnical properties can be measured in the borehole. Acoustic properties can be measured through a vertical seismic profile. Shear strength can be directly measured with a vane shear, and other geotechnical properties can be measured with a penetrometer. In most cases, elastic/acoustic properties can also be measured using existing logging while drilling (LWD) and/or wireline logging tools.

The Cone Penetrometer Tool (CPT). The CPT is a commercial tool, providing good quality data. It is a passive tool, limited to soft sediments and needs some adaptation for latching problems.

Hydraulic Conductivity. Piezoprobe and DVTP-P (inferred)*:* Hydraulic conductivity can be determined from dissipation records (pressure vs. time) of penetrometer devices in soft sediments. The method relies on matching the observed pressure dissipation with predictions from theoretical models. Permeability can be derived from the hydraulic conductivity if the formation stiffness is known. The utility of this technique is limited to formations in which the probes can penetrate without cracking (soft to moderately stiff sediments). Penetrometers (e.g. piezocones/piezoprobes) are used to determine hydraulic properties. Dissipation of excess pore pressures around penetrometers are used to determine transport properties. Pressure dissipation recovers hydraulic diffusivity (consolidation coefficient) and if coupled with independently measured compressibility enables permeability to be determined.

Permeability. Packer Test. Measured by steady state injection tests in rock and sediment. Injection within a packed-off zone enable steady flow rates to be linked to observed pressure drop via injection geometry and permeability. Shipboard packer tests for determination of permeability using drillstring packers have been conducted successfully (but are not routine) within ODP in stable formations and within the bottom of casing in unstable formations. Currently, downhole pressure gauges are 3rd party. For improved hydrologic testing, better resolution shipboard pressure gauges and pump control have been recommended. Feasibility of wireline packers should be investigated, because of the saving in deployment time over drillstring packers. Primary issues in packer tests are the limited scale of measurement, especially within low permeability formations.

Compressibility: Packer Test: Single-well tests cannot provide storage parameters, so cross-hole tests are necessary (e.g., instrumenting and sealing one or more borehole, and pumping at a nearby borehole). Cross-hole tests are currently planned for early IODP operations, but have not yet been conducted.

Electromagnetics: These measurements, in general, can already be obtained via standard (or available) logging tools.

Thermal Conductivity: Tools to measure downhole thermal conductivity do not currently exist. A probe-type tool could be used in soft sediments, but this requires development.

Fluxes:
Flow Rates: Fluid flow rates can be measured “directly” using mechanical, thermal, or chemical flowmeters. For high flow rates, 3rd party borehole flowmeter tools exist. For low-flow environments (e.g., mm’s to cm’s yr^{-1}), a collector-type of flowmeter using a chemical or thermal tracer would need to be developed. This type of tool would amplify formation flow rate through a measurement device by reducing the area of flow from the formation to the measuring point, as is done in “benthic barrel” instruments used at the seafloor. The use of such tools is possible in packed open-hole intervals or screened, cased intervals. Flow rate in many formations can also be calculated using independent measurements of fluid pressure and permeability (both discussed above).

Borehole Seismology
Performing vertical seismic profiles (VSPs), walkaway and offset VSPs, and crosswell seismic experiments will be desirable in many IODP operations in crust and sediment sections. Such studies require a wireline-deployed single seismometer or array of seismometers. Crosswell experiments will require a wireline-deployed seismic source.

Single component, short period seismometers such as the WST (well seismic tool) are established for routine ODP operations. 3-component clamped seismometers, including very low frequency (VLF: 5-100 Hz) instruments are available as commercial 3rd party tools, as are broadband borehole instruments. High-resolution recording of active source experiments will require deployment of arrays of sensors along the borehole, which has been rarely done in ODP. Quality of VSPs is expected to increase in IODP versus ODP through use of appropriate tools for lithologies and depths of a drillsite, cumulative experience, and standardized procedures.

Emerging promising technologies that have not yet been adapted for scientific ocean drilling include MEMS (micro-electronic machined sensor??) and fiber-optic acceleration or displacement sensors, now being used in industry downhole applications. Both of these technologies offer potential advantages in high-temperature applications, low power requirements, cost, and physical sensor size.

5.0 Overview: Present and Future Processes of Tool Development

We address the process of how to achieve the DHT measurements. We begin with a discussion of the historical process of tool development in ODP through a limited number of case studies.

5.1 Past Process of Tool Development

Tool development has been pursued in two manners. First, some tools are developed and maintained by the primary contractors. These ‘Standard’ DHTs are available on all ODP scientific legs. Second, ODP some DHTs have been developed outside the framework of its primary contractors. These “third-party” tools are developed by individual investigators. A successful “third party” tool may evolve to be an ODP “standard” tool that is supported/maintained by the operator.

In the U.S., third party tool development support has often come from the ODP division of NSF Ocean Sciences. Alternatively, tool development has been pursued by the primary contractors under the direction of the Science Advisory panel structure. There are also examples where tool modifications have been supported by other U.S. government agencies. Finally, there are examples of independent tool developments pursued in the international arena that have ultimately been assimilated into ODP.

5.2 Future Structure of Tool Support

At present, within the United States, tool development largely follows the legacy approach described above. There are a number of 3rd party tool developments that are proceeding in addition to tools that continue to be developed and refined by the operators. However, we are at the onset of the IODP and it is appropriate to consider the form of the future DHT Program.

1) What are the responsibilities of individual scientists in generating these tools? What are the responsibilities of the operator(s)? What is the role of the central management organization (IODP-MI)?
2) How will input from the science community be translated into the development and support of specific tools?

3) What is the role the operator should play in tool development/maintenance? How can we create an environment where tools are well maintained?
4) How do we create an environment where individual champions can be encouraged to develop needed tools? How should these tools make the transition from experimental to mainstream, operational status?
5) Role of NSF ODP in tool development

5.3 Brainstorming How to Achieve Tool Development

One large obstacle in obtaining new downhole tools (DHTs) is constructing a streamlined, timely, and cost-efficient methodology for taking the idea for a specific sample or measurement and developing and implementing the tool that can meet the scientific objectives. We propose a simple, straw-man system with five steps: (1) development of the scientific idea; (2) develop a proposal to build the DHT; (3) engineer and construct the DHT; (4) test tool; and (5) routinely use DHT for reliable measurements. A further breakdown of each step was suggested to provide an informal mechanism for taking a measurement idea through reliable and routine deployment.

(1) Development of the Scientific Measurement Idea

The first phase for tool development is to establish the measurement or sample that is necessary. This will require a champion scientist to take a measurement of interest to the greater ocean drilling community and goals of the ISP and start pushing it forward. The next step is to assemble a small working group of scientists, engineers, and operators to assess the feasibility of designing the tool. This is a critical step before moving forward to a full proposal but will require seed-funding. It was suggested seed money could be provided by USSSP. This seed money would allow for the working group to assemble for a mini-workshop and to allow for detailed definition of the tool for a full proposal. This definition would include the engineer and scientist working to develop tool drawings that not only define the key technology and design specifications but also how the tool will integrate with existing drilling infrastructure.

(2) Develop a Proposal to Build the DHT

After the working team has assembled and formulated a plan for tool development that includes detailed diagrams and insights on the implementation with operations, specific drilling legs, and the ISP, the champion must lead the charge on developing a fundable research proposal. Funding might fall into two separate categories: (a) NSF funding and (b) IMI funding.

(a) NSF funding would be pursed for tool development that involved modest funds for development (a few $100k or less). The champion would take the lead for developing the full proposal with close contact between engineers and operators. Key inputs for the proposal include necessity of the tool to the goals of specific drilling and larger goals of the ISP, technical specifications for the tool including design specifications, and how its deployment fits into the operations. One other suggestion was that tool ideas be run through the appropriate IODP panel (e.g., SciMP).

(b) IMI funding would include a multiple stage procedure that needs to be defined. One possible pathway is for the team or team leader to notify the appropriate IODP panel (e.g., SciMP, TAP), which would be followed by a presentation of the tool and its capability within the program to the IODP panel. If the panel deemed the concept valuable and feasible, the panel would then suggest to IMI that the tool would be a value to the program and that an RFP should be issued. The IMI would then issue the RFP and the tool would be developed by the winning awardee. One concern with this path forward is separation from the idea originator (the working group and team leader) and the developer. Without open communication, the scientific goals may be compromised in the full tool development.

Discussion also focused on the time-frame for soliciting outside funding for assisting in tool development. It was decided that outside agencies (e.g., DOE, MMS) should be contacted early in the proposal stage to see if additional funds are available.

(3) Engineer and Construct the Tool
With successful funding through NSF or IMI funds, tool development would be initiated. The design and development of the tool must proceed with constant communication between scientists, engineers, and operators. Communication between the science party and the engineer will promote the development of an efficient tool that will take the desired scientific measurements. Interaction with operators or operators experienced with ODP/IODP drilling operations will allow for streamlined development that can be integrated with the operational procedures and techniques of the IODP drillships and MSPs. Development should proceed with prototype stages in mind so progress of tool development can be assessed and tested during development. This suggestion is intended to prevent excess time being lost in development.

(4) Test Tool at Multiple Levels
The testing of new tools during development and prior to deployment on a scientific drilling leg is necessary for creating tools that are reliable and going to be considered as routine within the IODP. It is recommended that a formal protocol for pre-cruise testing of all new tools be established. This protocol should allow for demonstration that the tool produces reliable and reproducible results and that the tool will be compatible with operations. The protocol would include, but not be limited to, (a) testing on land-based holes and test facilities, (b) testing on ocean trials in existing holes, and (c) testing on IODP engineering legs that are designed for tool development. A secondary part of tool testing is calibrating it with other tools that make similar measurements such that tool performance can be compared.

(5) Routinely use DHT for Reliable Measurements
The final stage in tool development is routine and reliable use within the IODP. One new aspect to deployment is that a legacy program should be developed for tracking of tool performance from design through all deployments. This legacy database not only will track all measurements made by a specific tool, but will keep a history that will be useful in developing new tools and obtaining measurements as it will be a historical record of what works, what works well, and what still needs improvement.

A few other topics related to DHTs were discussed. One aspect of this discussion was setting up a borehole management system. This would not only give a record of what measurements have been made (e.g., wireline, core, DHT) but also what measurements are ongoing or planned. This is instrumental for planning and initiating successful research in the future. A secondary DHT-related discussion revolved around obtaining the technology to enhance cable-to-borehole observatories. With increased desire for long-term monitoring stations, protocols for quickly and easily connecting to boreholes warrants research and development similar to DHT development.

6.0 Technical Recommendations:

We identified five critical technical needs that cut across the ISP and are of a scale that are best championed by individual investigators. We termed these 'Bottom Up' developments.

	Top 5 Bottom-up, Investigator-Driven, Development Needs
1	Solid/fluid/gas/microbiological samples at *in-situ* conditions
2	*In-situ* permeability and stress
3	Pore pressure and temperature in sediments, indurated sediments, and hard rock with high precision to high temperature limits
4	Analyte-specific *in-situ* sensors
5	Side wall sampling (sampling after primary drilling)
6	ole completion methodology – e.g., case then perforate. How does completion affect what tools can be used
7	Soil samples for high quality geomechanical testing. Improved coring technology to get less disturbed samples.
8	Stress measurement in the borehole (lateral stress) in sediments and rock
9	Way to cap holes such that removing cap is easy for returning. Highly simplified, un-instrumented CORK
10	High resolution sampling of seismic wave field
11	Complicated measurements of rheologic parameters. Things that can be cast in constitutive laws

We also identified five critical technical needs that are best addressed with a 'Top-Down' approach. These developments have broad application and serve an array of scientific objectives. They are less likely to be championed by a single investigator or funded by a single grant to a sole PI or small groups of PI's.

	Top 5 Top-Down, Program Development Needs
1	Facilities for testing, calibration, and inter-comparison of tools
2	Rapidly deployable, live, weight-bearing, umbilical
3	Seabed or re-entry cone frame
4	Consider larger pipe diameter (or other approach) to allow more commercial tool deployment
5	Improve drilling/coring/sampling highly fractured and/or high temperature rock

Process Recommendations

We envision five critical steps to the development of a successful DHT:
(1) idea;
(2) design;
(3) construction;
(4) testing;
(5) implementation/institutionalization

As a science-driven program, IODP and its members are very good at generating ideas and conceptual designs and initial fabrication. However, we can strengthen the process by which we test and implement downhole tools. DHT development, to be successful, must have an extensive testing phase. During repeated testing, tools should be progressively optimized, 'ruggedized', and simplified. In this process, scientists and engineers must be encouraged to work together to make incremental improvements in tool development to achieve science goals. Early testing should be accomplished independently from the IODP platforms. Ultimately, the tools must be tested on the platforms so that they will be effective when deployed on a scientific expedition.

Some DHTs have never entered the mainstream of application in ocean drilling. In some cases this is appropriate: the tools might address a very narrow scientific objective that will be addressed by only a few scientists on a limited number of drilling expeditions. However, some DHTs are necessary to meet a broad range of the goals of the ISP. There must be a process to institutionalize these tools into the IODP so that they can consistently used by a range of investigators with success. The process might include bridge grants that take the DHT from '3rd party' to 'standard tool' where investigators and operators are supported for the specific task of implementing a particular tool.

We recommend:

1) Devote a model number of days (perhaps 10) per year on each platform for engineering testing. Develop a competitive proposal process by which investigators apply for testing time. Support the investigators to achieve platform testing. This time could revert to scientific use if justified;
2) Develop a competitive process to support 'top-down tool' development. Pursue a philosophical approach of soliciting the best individuals and/or institutions to meet the specific technical need;
3) Develop a formalized process to institutionalize 'bottom-up' developments that are deemed critical to multiple ISP components. Support investigators and contractors for transfer from 3rd party to standard tool status.

Acknowledgments:

USSSP supported this workshop. The meeting was held at JOI, and the workshop leaders and participants gratefully acknowledge the efforts of JOI staff in assisting all aspects of the meeting.

We close with a broad discussion of what are some of the most critical needs of the program to pursue the science plan. We envision that there are two types of developments that need to proceed. 'Bottom Up Examples' are those that are primarily investigator driven. The scale of the problem or the application of the problem is small enough that it can be spearheaded by a few proponents. At the other end of the spectrum are the 'Top Down' Developments.

BOTTOM UP EXAMPLES:

1) **Solid, fluid, gas, and microbiological samples at in situ P, T, X and maintain in situ conditions**

2) **High quality observations of permeability and stress state**

3) **Pore pressure and temperature in sediments, indurated sediments, and hard rock, to high temperature limits**

4) **Analyte specific sensors to provide continuous records in situ**

5) **Generalized capability for side wall sampling. Secondary sampling mechanism after primary drilling occurred.**

6) Hole completion methodology – e.g., case then perforate. How does completion affect what tools can be used

7) Soil samples for high quality geomechanical testing. Improved coring technology to get less disturbed samples.

8) Stress measurement in the borehole (lateral stress) in sediments and rock

9) Way to cap holes such that removing cap is easy for returning. Highly simplified, un-instrumented CORK

10) High resolution sampling of seismic wave field

11) Complicated measurements of rheologic parameters. Things that can be cast in constitutive laws

Top Down Developments

1) **Access to facilities for testing, calibration and inter-comparison of tools**
2) **Umbilical giving communication and power to be used with downhole tools. Rapidly deployable live weight bearing line. Develop standards for compatibility of electrical, mechanical, and communications**
3) **Broaden DHT capabilities by implementing a seabed and/or re-entry cone frame.**

4) **Explore benefits of moving to larger pipe diameter or other approaches that will allow new tools to be deployed for achieving objectives**
5) **Drilling, coring, casing, collecting samples, making observatories in highly fractured and/or high temperature rock.**
6) **Set aside time for engineering development.**
7) Extending riser capability to 4 km
8) Fulltime deepwater ROV capability.
9) Maintaining a hole status database. Addressing legacy and documentation for past and future. Borehole Management and Tool History

It was felt that a facility for borehole testing is very important. It doesn't have to be a place. It could/should include a shiptime request for testing.

Wherever possible, it is important to keep industry involved because they often have standardization procedures in place that would make our standards in place

One needs to get a working tool and then standardize it is a model. Don't let standardization force you to lose site of your goals

A high-speed conductor cable is routinely used on geotechnical ships and would be low cost yet potentially dramatically advance downhole tool deployment. Temperature limits of these cables should be explored.

1) How to streamline tool development from IDEA – PROPOSAL – DEVELOPMENT – TESTING - IMPLIMENTATION
    a) leader scientist
    b) assemble a working team
        i) expertise in engr, science, and operation
        ii) mini-workshop to flush out idea and feasibility (USSSP ?)
    c) develop full proposal for 'small' tool development
        or
        work with IMI/TAP/SAS to develop RFP for larger tools/improving assets (sea bed frame, hotwire) to serve the wider community
    d) funded proposals – work with open and constant communication between scientists and engineers – make sure the scientific objectives are not compromised
    e) integration of project engineers and scientists with engineers experienced with ODP/IODP
    f) testing of tools
        i) land-based studies and ocean trials in existing holes
        ii) prototype testing
        iii) tested on the drillship or MSP
        iv) develop a protocol for pre-cruise testing of all new tools
    g) implementation
        i) tracking of tool performance
        ii) develop means for keeping a tool legacy

2) Borehole management
    topic that should be pursued within the system

3) Develop technology to conduct cable-to-borehole observatories

4) Recommendations/Suggestions
    i) seabed frame needs to be investigated – feasibility of facilitating many tools with one new piece of equipment; compatibility with drillship

Need to contact appropriate IODP groups early for endorsement. Not a requirement but might help to get SciMP, TAP insights and saying needed technology.

Important for linking tool development to a specific drilling objective or target and to the ISP.

Make your proposals drilling objective/target specific. How does your tool fit into the overall science goals or program. Gives motivation for building and for timeframe.

How do we push an idea up to IMI for funding bigger projects? Potential problem of smearing the science or losing focus.

Where are you going to get the engineering support and insights to write to the initial proposal?

Need slush funds to get initial designs? NSF supplement? USSSP proposal to get money to write a larger proposal?

Tool development: 2/3 is for the design, 1/3 is for getting it to work with the platform

Do we create a separate entity for engineering? Overhead, costs, keeping them busy and up to date with the equipment.

Bring in experts on a necessity basis. Find the best people for the measurement at hand vs a single entity.

Now we have a list of desired needs that are prioritized. How does a leader emerge to take a specific measurement and get it made? Who argues to IMI/SAS to get it going?

How do you differentiate between going from top-down (IMI) and from person-up (NSF)? RFPs from IMI on larger tools?

IMI – top down contract: still need scientist/engineering champion to get the right person to get RFP; SAS insights are used to determine priority structure for RFPs

Need a leader in all tools so the designers/engineers/operators can go back to somebody with routine questions so tools are continually re-modified.

Problems with RFP; there is some flexibility within the RFP. Scientists/engineers who will be using the tool need to be in constant communication with the design.

What about when you spec everything out and the clever engineers design exactly what you spec out but doesn't accomplish any of your goals.

Need a hero that can assemble a team that is capable of completing all of the desired goals for the specific measurement.

Need open communication between engineers and users to make sure that approximations used in design to hinder the desired measurement.

Are we trying to implement a matrix management onto top-down management structures. Is this possible?

It would be worthwhile to have some clearinghouse of engineering insights for getting the original information/sketch for proposal so PI can demonstrate they understand/have thought about the technical details.

How do we create a system that will lead to more success in tool development? Historically we have had more failures than successes.

At some point in the IODP structure, we now need to pay for engineering time (shipboard, development, etc). How do we make sure to incorporate this?

How do you get individual champion efforts to be linked so each tool is not completely different from others? Ease of use on multiple platforms, ease of swapping in and out, etc. Standardized systems to connect in and out need to be developed. Larger effort through IMI?

Need be careful about uniform interfaces; not to exclude tools. Maybe employ a building block approach that are interchangeable. Stress common interchangeable interfaces.

Champion -> seed money before going to RFP or full proposal -> then bring team together to get a full proposal…how do you get the team -> then you can develop

USSSP money to have pilot meetings to get things rolling (scoping groups) -> get operators to come because they may end up with the contract that evolves on the full proposal

Scope groups – have outside expertise to make sure you are not missing things…scientists have what they want to measure, operators and engineers may know things that exist or need to be developed

IMI, re-fit funds for development of infrastructure to make new tools available (e.g., seabed frame)…definitely need to push forward improved devices that will allow us to deploy new tools and measurements that we can't get today (0-200 mbsf).

At what point on expensive tool development do you look for outside funding (e.g, DOE, MMS) that might be used to continue the charge? Do it early in the process to make sure that the appropriate planning can be made.

Seabed frame might be a solution to a lot of tools that have failed in the past. Should explore the capability to use it for expanding our horizons, deploying new tools, making failed tools work.

Testing: pressure testing, pre-sea trial requirements for tools, protocols for testing on land and at sea.

Develop the technology to connect between fiber optic cables and boreholes. Need to come up with means to test that.

iTAP recommended to iSAS that about a week of ship time per year to do engineering tests on separate short legs with the real people who will operate the tool in the real world. Get real sea-test on every tool before it is deployed in a science leg. Plan for this in the schedule.

How do you know that two different tools are giving the same measurement? Quality control during testing phases.

Hotwire umbilical cord during coring to improve assests…something that doesn't interrupt coring to swap in/out cable for running downhole tools.

How do we assess tool performance. Tool legacy. Keep a detailed track record for each tool deployment and it success. Who is in charge of keeping this record, IMI?

Borehole management is critical. We need a structure that is easy to access and understand what is going on in what locations. Keep a cradle to grave record.

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Attachment 1: Workshop Agenda on Downhole Tools in the IODP

Day One - May 24, 2004

Opening. (08:00-08:30) Convenors welcome and introduce participants, and summarize workshop goals.

Session IA. (08:30-10:15) DHTs and the IODP Science Plan (All)
Each theme of the Science Plan will have two leaders. Speakers (*) will describe their component of the Science Plan and what downhole measurements are critical to meeting the plan.
a. 08:30-08:50: The Deep Biosphere and the Subseafloor Ocean (D. Saffer*, M. Lilley)
b. 09:00-09:20: Env. Change Processes and Effects (R. Harris*, B. Price)
c. 09:30-9:50: Solid Earth Cycles and Geodynamics (H. Tobin*, R. Stephen)

(Break)

Session IB. (10:30-12:15): What DHT Measurements are Needed (Working Groups). Summary of session goals by Fisher.
Overview: Thematic working groups (a.,b., and c., above) will meet separately and define DHT measurements and importance to IODP. They will elucidate why DHTs are critical to Science Plan.

PHOTO: (12:15-12:20): Group Photo

(Lunch, downstairs in cafeteria or nearby) Thematic leaders will merge results of each thematic working group over lunch break

Session IIA. (13:15-14:00) Summary of important DHT measurements (All)
Thematic leaders will present merged results to all.

Session IIB. (14:00-15:30) Current Capabilities and Future Goals (Working Groups)
Thematic working groups will analyze current state of DHT measurements, determine the gaps between our current capability and what is needed to achieve the IODP Science Plan, propose appropriate technologies to achieve particular measurements and establish a matrix of priorities vs difficulties

(Break).

Session IIC. (15:30-17:30) Identification and Summary of Current Capabilities and Goals: (ALL)
Thematic leaders will present results from working groups. 10 minutes for each thematic leader, and one hour for discussion.
(Evening) Group Leaders/Reporters/and workshop leaders will merge results of thematic working groups.

6:30-7:30 Refreshments

7:30-9:30 Dinner

(Refreshments & Dinner will be at the Franklin Square City Club in their Park View Annex Room and will include a cash bar. The cost for non USSSP-supported participants will be $20.00.)

Day Two - May 25, 2004

Session IIIA. (08:00-09:45) ODP Tool Development and Future Technological Requirements (All)
a. Overview: Case studies of tool development in ODP, Development Issues, Reentry, & Funding:
  i. 08:00-08:20: K. Becker* - The Drill String Packer Tool Development and Deployement
  ii. 08:20-08:40: K. Moran*, G. Humphrey - Cross Platform, Extreme Borehole Conditions, Common Data Interfaces, and suggestions for improving DHT measurement capability on the riserless vessel.
  iii. 08:40-09:00: B. Ussler* - TCP Tool: Development, Deployment, Results
  iv. 09:00-09:20: F. Spiess*, D. Foster - Wireline and HOV/ROV reentry DSDP/ODP/IODP holes: technical developments, capabilities, and needs.
  v. 09:20-09:40: C. Ruppel* - NSF Perspective on DHT Development and P.I. Responsibilities

(Break)

Session IIIB. (10:00-11:45) How to Achieve Tool Development (Working Groups)
a. Overview: Break two Technical Working Groups: focus on how to achieve desired measurements in a technical sense. What does it take to get where we want to go?
  1) Measuring Physical State (e.g. temp, press, chemistry) (Group Leaders: A. Schultz, H. Villinger)
  2) Collecting Discrete Samples (e.g. fluid, solids, gasses). (Group Leaders: B. Dugan, M. Kastner)

(Lunch, downstairs in cafeteria)

Session IVA. (12:30-13:30) Recommendations for Technical Process of Future Tool Development (All).
Overview: Presentations by Group Leaders and discussion.

(Break)

Session IVB. (13:30-16:30) Tool Development Process: Recommendations

Overview: Workshop Leaders will lead group discussion to focus on larger scale issues of tool development process. What key steps can we recommend to achieve technology development in an efficient manner that achieves the ISP? Address possible mechanisms for funding and for interaction between individual P.I.'s, contractors, funding organizations.

(End of workshop for participants)

Attachment 2:

Table 4: ODP and 3rd Party Tools /Developmental Tools in the ODP

Tool Acronym	**Status**	**Description**.
DVTP	ODP	The Davis-Villinger Temperature Probe (DVTP) is designed to take heat-flow measurements in semiconsolidated sediments that are too stiff for the Advanced Piston Corer Temperature (APCT) tool. Coring must be interrupted to take a temperature measurement. The DVTP can also be run on wireline and hung below the bit (when the bit is off bottom) as a temperature logging tool for borehole fluids. http://www-odp.tamu.edu/publications/tnotes/tn31/cork/cork.htm
PCS	ODP	The Pressure Core Sampler (PCS) is capable of retrieving core samples from the ocean floor while maintaining in situ pressures up to 689.7 bar (10,000 psi). The primary application of the PCS is to recover in situ hydrates. The PCS is free-fall deployable and wireline retrievable. http://www-odp.tamu.edu/publications/tnotes/tn31/pcs/pcs.htm
APCT	ODP	The Advanced Piston Corer Temperature (APCT) tool is an instrumented version of the coring shoe that is run on the Advanced Piston Corer (APC). It is deployed in soft sediments to obtain formation temperatures to determine the heat flow gradient and is essential in determining hydrocarbon maturity for pollution prevention purposes. http://www-odp.tamu.edu/publications/tnotes/tn31/apct/apct.htm
APC	ODP	The APC is a hydraulically actuated piston corer designed to recover relatively undisturbed continuous 9.5 m long oriented core samples from very soft to firm sediments that cannot be recovered well by rotary coring. http://www-odp.tamu.edu/publications/tnotes/tn31/apc/apc.htm http://www-odp.tamu.edu/publications/tnotes/tn10/10toc.html
BIH	ODP	Borehole Instrument Hanger http://www-odp.tamu.edu/publications/tnotes/tn31/bih/bih.htm
CORK	ODP	Circulation Obviation Retrofit Kit http://www-odp.tamu.edu/publications/tnotes/tn10/10toc.html
DIC	ODP	Drill In Casing http://www-odp.tamu.edu/publications/tnotes/tn31/dic/dic.htm
XCB	ODP	Extended Core Barrel http://www-odp.tamu.edu/publications/tnotes/tn31/xcb/xcb.htm
APC-Methane	ODP	Measures conductivity, pressure, and temperature of headspace on an APC core. (Ussler/Paull/ODP)—tracks phase changes as it comes out of water. Primarily used for hydrates. (D. Schroeder, personal comm., June 2003)
WSTP	9	Water Sampler Temperature Probe http://www-odp.tamu.edu/publications/tnotes/tn10/10toc.html

IWS	10	Instrumented water sampler (cross between the Fissler water sampler and the DVTP-P). Run once (D. Schroeder, personal comm., June 2003)
MWD	11	Drilling Sub—for drilling dynamics (wt on bit, torque on bit, annulus pressure, right on top of bit…can pull a core through it. Deployed once). (D. Schroeder, personal comm., June 2003)
DSP	12	Drill String Packer For Formation Testing http://www-odp.tamu.edu/publications/tnotes/tn10/10toc.html
BFS	3rd Party/ deve	Borehole Fluid Samplers http://www-odp.tamu.edu/publications/tnotes/tn10/10viiib.html
GeoProps	3rd Party/ devel.	Geoprops Tool Mechanical and Hydrogeological properties of sediments
LastI LastII Last2	3rd Party/ deve	Lateral strain measurement http://www-odp.tamu.edu/publications/tnotes/tn10/10viiib.html
Flow Meter & Logging Cable Go-Devil	3rd Party/ deve	Allows concurrent logging of pressure and flow rate in zone isolated by drill string packer http://www-odp.tamu.edu/publications/tnotes/tn10/10viiib.html
Active Fluid Sampling	3rd Party/ deve	Schlumberger rft device or Lamont-Doherty water sampler device http://www-odp.tamu.edu/publications/tnotes/tn10/10viiib.html

Attachment 3: List of Attendees

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Attachment 4: Comments by Workshop Applicants

Keir Becker, University of Miami - RSMAS

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Packer experiments to determine permeability
Discrete and continuous subsurface temperature measurements.
Sealed-hole CORK records of long-term temperature and pressure, with implications for hydrological structure at a variety of spatial scales.
When successful, in-situ fluid sampling.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Quick discrete measurements of in-situ pore pressure.
Reliable pore fluid sampling in all environments.

3. What new technology should be implemented in future autonomous DHTs?

Barbara Bekins, U.S. Geological Survey

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Bulk density logs, pressure, temperature.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Precise control pumps and real-time monitoring of flow rates and downhole pressure for in situ hydrologic tests.

3. What new technology should be implemented in future autonomous DHTs?

Ability to do reactive tracer injection and withdrawl tests (aka "push-pull tests").

Nathan Bramall, U.C. Berkeley

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

As a newcomer to ocean drilling research, I have not yet had a chance to familiarize myself with the published literature on downhole tool measurements in ocean boreholes.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

See #1 above. The most exciting feature of our DHTs is that they will provide instant records of the depth-dependence of biological, geophysical, and volcanic signals through the overlying ocean and sediment down into boreholes in subfloor bedrock. From our experience with ice coring, another advantage is that a DHT can get data from the borehole even if the core is lost or damaged upon recovery so that DHTs can provide a continuous, high resolution measurement over the entire depth of the borehole.

3. What new technology should be implemented in future autonomous DHTs?

Buford Price (my advisor), Ryan Bay (a post doc) and I have been doing a lot of thought and DHT design for polar (ice) borehole applications. The project I've been most intimately involved on is the BSL (Biospectral Logger), which is a DHT that measures the depth-dependence of the fluorescence emission spectra of special biomolecules (some of which are ubiquitous to all life and some of which are specific type-markers) including chlorophyll, tryptophan, NADH, and F420 (a fingerprint of archaea). The BSL could map the distribution of bacteria and archaea in the open ocean, sediment, and subfloor bedrock. A temperature sensor could easily be incorporated into the existing device so that microbial concentration vs. depth and temperature could be measured. Our microbial loggers are different than other loggers in that they are specifically designed for borehole studies, being optimized for the scanning of borehole wall surfaces.

I could imagine using a fluorescence and/or multispectral logger to look for banding in sediments due to changes in sediment composition (fluorescence properties, color, etc.) which may serve a a good proxy for climate.

We hope that, as a benefit of attending the DHT workshop, we can come up with new ideas for new borehole instruments.

Matthew Chartier, MIT

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

I am currently working with Dr. Germaine at MIT to design a new Dual Pressure/Temperature Tapered Probe (DPTTP) for deployment in the Integrated Ocean Drilling Program. We will design, test, and provide this probe for deployment on future IODP expeditions in order to improve measurements of pore pressure, permeability, and temperature distributions in sea floor sediments.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

We recommend the implementation of an improved probe that will allow the rapid measurement of in situ pore pressure and permeability within sea floor sediments. This new probe will measure in situ pore pressure at several locations along the length of the probe. These measurements, combined with theoretical soil behavior modeling, will allow this information to be collected much more quickly and accurately than is currently possible.

Richard Dixon, IODP Texas A&M University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Temperature and Pressure

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Brandon Dugan, USGS and Rice University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

The most important DHT measurements made within the ODP for my field of interest were the comparison measurements of the Davis-Villinger Temperature/Pressure Probe (DVTP-P) and the Fugro-McClelland Marine Geosciences Inc.'s piezoprobe on ODP Leg 204. This comparison study documented (1) that fluid pressure can be measured successfully and quickly within the borehole and (2) that tool geometry dramatically influences interpreted pressure and the time required to make in situ pressure measurements. The study provided useful data for ODP Leg 204 on fluid pressure in the gas hydrate system, while opening new research avenues for development of pressure/temperature tools that lend themselves to quicker/easier deployment within the IODP.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

One critical DHT that should be developed for use within the IODP is hydraulic fracture tool to measure least principal stress within the borehole. Least principal stress is a critical measurement for defining the stress tensor for IODP drill sits. The use of such a tool will be of value to understand strength and stability of sediments in drilling targets that are focuses of the IODP, such as accretionary complexes and gas hydrate provinces. This technology is currently employed within industry geotechnical and geological studies, but has yet to be implemented within the IODP.

K. Michelle Edwards, University of Miami

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

ADARA temperature tool, WSTP, Davis-Villinger tool, CORK (Circulation Obviation Retrofit Kit), ACORK (Advanced ....) formation pressure and temperature measurements over an extended period of time (seconds to yrs) and ION/OSN Seismic observatory measurements

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

DHT, as defined for this workshop, in some cases is attempting to reinvent tools already perfected and/or discarded as unworkable in wireline. Development of short-term autonomous tools can in many cases use technology already available. Also, advantages and disadvantages of DHT need to be considered wrt wireline, LWD, and long-term observatories. Dispensing resources for a DHT coring tool, for example, need to be weighed in light of wireline coring tool capabilities and what has been accomplished with Spirit and Opportunity on Mars. A skilled operator on wireline can recover a much bigger and better sample than anything Spirit has done so far. With temporal factors considered, first glance implies wireline is the only way to go. Designating DHT for tasks better done on wireline, LWD, or long-term 0bservatories will serve only to increase the gap between DHT capabilities and achievement of IODP goals

3. What new technology should be implemented in future autonomous DHTs?

Derek Elsworth, Penn State University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Piezoprobes, downhole penetrometers, and permanently installed observatory instruments to record mechanical and fluid/mass/energy transport parameters, and related fluxes.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Achieving dense coverage (continuous profile) and a full suite of measurements for mechanical and fluid/mass/energy transport behavior and related fluxes in a single deployment, and continuously reported in time, as a permanently installed observatory.

3. What new technology should be implemented in future autonomous DHTs?

MEMS

Dean Ferrell, IDOP – TAMU – Engineering Services

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Sediment Temperature and Pressure

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Datalogger design incorporating 100 percent surface mount components to reduce electronics temperature drift.

Interchangeable smart sensors with plug and play design.

Andrew Fisher, UCSC Earth Sciences

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

In-situ thermal measurements (Uyeda tool, WSTP, APC, DVTP, etc.)
Drill-string packer measurements

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Need long-term active experiments to assess hydrogeologic properties. Will require pumps, flow meters. We also need to determine fluid pressures more accurately, if possible, with press-in instruments.

3. What new technology should be implemented in future autonomous DHTs?

Would be great to get multiple parameters/samples with single deployments (i.e., an APC tool that gets P, T and a fluid sample, etc.). Might also be helpful to measure electrical properties, as a proxy for hydrogeologic properties.

Dudley Foster, DSV Alvin, Woods Hole Oceanographic

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Improvements in deployment/retrieval strategies.

3. What new technology should be implemented in future autonomous DHTs?

Minimize weight/mass issues to improve capability of HOV and ROV systems to deploy/recover down hole tools. Improve latching/unlatching techniques.

John Germaine, MIT

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

In Situ Stress, soil modulus, and undrained shear strength

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

This must depend on the specific leg objectives

3. What new technology should be implemented in future autonomous DHTs?

Again this depends on Leg objectives

Gilles Guerin, LDEO/Borehole Research Group – Columbia University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

For heat-flow and in-situ temperature measurements, the DVTP (Davis-Villinger Temperature Probe) and the Adara probes have been the most important, and successful tools. In particular the Adara probe, for it ability to record high-quality data while adding only a minimal time to standard piston coring operations.

The Pressure Coring Sampler (PCS), Fugro Pressure Corer (FPC) and Hyace Rotary Corer (HRC), while not totally "mature" yet (especially the FPC) have provided significant steps in recovering "in situ" samples, which are crucial for gas hydrate sampling, but could also prove useful for microbiology or other applications.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Using a principle similar to the Adara tool, the DSA (Drill String Acceleration) tool or the APC-Methane tool, have been very successful during recent legs in collecting data while adding little or no time to drilling operation. In the same vein, we should develop tools/sensors that would be carried by the coring instruments to make in-situ measurements (such as shear strength,...) without adding to the usually extremely tight schedules of operations.

The existing pressure sampling tools should be improved/made more operational

Sean Gulick, University of Texas Institute for Geophysics

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

The biggest gaps from the perspective of accurate seismic-core-logging integration is accruate in situ velocities. Density measurements, especially from LWD, have proven fairly useful especially when mated with resistivity and resistivity-at-the-bit measurements but velocity continues to be problematic. Additionally, from a monitoring perspective we need to invest in downhole seismometers, strainmeters, tiltmeters, and seafloor geodetics to be able to fully understand the elastic and permanent strain occurring in subduction zones.

3. What new technology should be implemented in future autonomous DHTs?

Borehole shuttle technology or other memory tools in addition to long term observatories. Based on experiences in the Scientific and Measurements Panel there are a lot of intriguing memory tool options available that should be investigated for use in IODP.

Robert N. Harris, University of Utah

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

In-site temperature measurements.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

We need a way to quickly and efficiently make temperature measurements. Overcoming this hurdle would make temperature measurements more routine and allow a greater density of temperature measurements with depth.

3. What new technology should be implemented in future autonomous DHTs?

Martin Heesemann, University of Bremen, Dept. Earth Sciences

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Up to now, the scope of my work concerning the APC Temperature Tool, the DVTP, and the DVTP&P was rather technical. Therefore, I think, there is not much I could contribute to the following questions.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

David Huey, Stress Engineering Services, Inc.

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Continuing high quality engineering support (design, fabrication, testing, installation, and service) is not assured under current IODP/IMI/community organizational setup. A reliable organizational approach will be required to assure those functions are avaialble over the long term (many years). They probably cannot be achieved with the current/past approaches, i.e. turn most engineering problems over to Devel. Engrg. at TAMU.

3. What new technology should be implemented in future autonomous DHTs?

Next generation CORKs and other seafloor observatory hardware, sensors, and data loggers not yet fully defined by scientists.

Gary Humphrey, Fugro McClelland Marine Geosciences, Inc.

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Pore pressure and temperature

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

In situ testing downhole for mechanical properties

3. What new technology should be implemented in future autonomous DHTs?

Downhole piezocone penetrometer, piezoprobe (enhancements), possibly shear vane

Miriam Kastner, Scripps Institution of Oceanography

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

The pressure-temperature and fluid monitorings at CORKed sites and temperature and resistivity data at unCORKed sites. (The lab resistivity data, however, are better when available VSP data
The in situ pore fluid sampler would have been of great importance but did not work well

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Fluid sampling at in situ conditions;
Short and long term monitoring od chemical (some physical) and biological key parameters and chemical fluxes.

3. What new technology should be implemented in future autonomous DHTs?

Directly related to #2 question; need technology for in situ fluid sampling and for long and short term fluid chemical and flux data. Also to be able to remotely download data and interact with the instruments to perform in situ perturbation experiments.

Masataka Kinoshita, JAMSTEC

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

CORK hydrogeological observatory in the spreading centers / accretionary prisms
A-CORK hydrogeological observatory in the Nankai accretionary prism

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Simultaneous monitoring of hydrological parameters (P,T) and geodetic data (strain), in order to discriminate shear strain and isotropic pressure anomalies.

3. What new technology should be implemented in future autonomous DHTs?

A certain breakthrough is necessary for deep holes, especially for high temperatures.

Marvin Lilley, University of Washington

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

My interest is in volatiles in the oceanic crust. To date there are no downhole tools capable of making direct measurements and downhole fluid samplers have not reliably returned samples for volatile analysis.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

We need a downhole fluid sampler capable of maintaining ambient pressure and returning fluids for volatile analysis.

3. What new technology should be implemented in future autonomous DHTs?

I would like to see downhole gas chromatographs or mass spectrometers.

Hui Long, Penn State University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

DVTP, ACORK, and piezoprobe

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Cost and deployment time

3. What new technology should be implemented in future autonomous DHTs?

A dual pressure sensor tapered probe may cut the deployment time down

Chris Marone, Penn State University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

I'm not sure that I know what autonomous means in this context.
Would a borehole seismometer count?
I'm interested in the mechanics of subduction zones and the processes and mechanical factors that define the seismogenic zone and the updip transition from unstable to stable frictional behavior. Borehole sampling of the decollement and the surrounding subduction zone materials, particularly at or near the seismogenic zone, will be a big step forward. However, downhole instruments will likely provide some of the most important data needed to understand the mechanics of faulting and its relationship to the hydrologic cycle. I'd like to

know more about what types of data will be collected and what types of downhole instruments are possible.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Alexei Milkov, BP

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Direct Pressure Core Sample (PCS) measurements of methane concentrations on Legs 164, 201 and 204. These measurements were the key data to estimate the global amount of gas hydrate in marine sediments (Milkov et al., 2003; Milkov, 2004).

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

The PCS tool is great but we have to increase the number of measurements and the number of tested geological setting (and subbottom depths) to fully understand the distribution of methane in marine sediments. Additional modifications are needed to facilitate the ability to degass PCS at the in situ temperature rather than at 273K as it was done previously. I also see a great potential in other similar but more sophisticated tools (e.g., HYACE) that IODP should consider purchasing/constructing.

3. What new technology should be implemented in future autonomous DHTs?

Kate Moran, University of Rhode Island

1. What are the most important autonomous Downhole Tool (DHT) measurements made wduring DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Pore pressure and permeability remain two important measurements. Pore water sampling/in situ measurement in hard formations and rock. All measurements in very high temperature settings.

3. What new technology should be implemented in future autonomous DHTs?

Geotechnical tools (like the CPT with special sensors) could be adapted; standardized tool connections/housings/data acquisition systems for deployment in sediments to measure a wide range of geotechnical/geophysical properties; development of shallow penetration, inexpensive observatories.

Charles Paull, MBARI

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

CORKs

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Power and data transmission

3. What new technology should be implemented in future autonomous DHTs?

Cable-connected boreholes

Tom Pettigrew, Mohr Engineering

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Increased ability to recover and replace seafloor instruments.

3. What new technology should be implemented in future autonomous DHTs?

High speed acoustic data transmission.

P. Buford Price, University of California

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

As a newcomer to ocean drilling research, I have not familiarized myself with the published literature on downhole tool measurements in ocean boreholes.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

See #1 above. To my knowledge, none of the devices I will discuss in #2 and #3 have been used in oceanographic boreholes until now.

The most exciting feature of our DHTs is that they will provide instant records of the depth-dependence of biological, geophysical, and volcanic signals through the overlying ocean and sediment down into boreholes in subfloor bedrock:

1. The BSL (biospectral logger) measures depth-dependence of fluorescence spectra of chlorophyll, tryptophan, NADH, fulvic/humic acids, polyaromatic hydrocarbons, F420 (a fingerprint of archaea), and several other biomolecules in both living and dead microorganisms. The BSL could map the worldwide distribution of bacteria and archaea in ocean, sediment, and subfloor bedrock. By returning to the same boreholes after an interval of several months, one could estimate the rate of formation of microbial mats on borehole walls.
2. The DL (dust/ash logger) measures depth-dependence of particles that scatter and absorb light of a predetermined wavelength in ocean water and boreholes. Volcanic ash layers typically 1 to 20 mm thick can be recorded, and biomolecule types and concentrations above, in, and below such ash layers can be used to study effects of volcanoes on the ozone layer (which would reduce microbial concentration) and on fertilization of the ocean (via soluble iron and sulfur compounds). By virtue of their bright albedo, one might detect layers of coccoliths, which are conjectured to reduce global temperature as a result of their bloom and increased albedo in the shallow ocean in the aftermath of a large volcano.
3. The ATV (acoustic televiewer) emits a 1.3 megahertz ultrasonic beam in a 1-mm searchlight that rotates in a horizontal plane and maps impedance changes in a borehole wall. With sub-mm resolution, one maps the locations of fluids, cracks, and changes in rock and

sediment texture. It may help in locating gas hydrate formations, annual sediment layers, coral colony layers, and possibly ice-rafting debris.

3. What new technology should be implemented in future autonomous DHTs?

Nathan Bramall (my student), Ryan Bay (my senior post-doctoral collaborator), and I propose to use the three instruments listed in #2 in downhole logging experiments. They will need to be modified to withstand pressures at the ocean floor. This should be relatively straightforward.

1. The DL is much better than the transmissometer used in the 1970s by Zaneveld et al. (School of Oceanography, Oregon State University). Their instrument measured only light attenuation in a device through which water could pass.
2. Pan Conrad, JPL, has built a 7-channel fluorescence sensor that records spectra from outside objects such as hydrothermal vents, whereas we put our BSL inside a borehole and look outward onto or through the walls. We will design and build an improved BSL which contains pulsed lasers at three excitation wavelengths: 224, 370, and 420 nm, and about 10 miniaturized phototubes each with a notch filter from which we would obtain emission spectra in 10 channels.
3. We collaborate with ALT, Inc., a Luxembourg-based firm that makes the ATV for us. We will have them redesign it for pressures at the ocean floor. They created the pre-eminent software used in most or all megahertz ultrasonic televiwers.
4. In general, the vertical resolution can be ~1 mm or less, depending on proximity of the tool to the borehole wall. Ideally, the clearance between wall and tool would be made only ~1 or a few mm.
5. We hope that, as a benefit of attending the DHT workshop, we can come up with new ideas for new borehole instruments.

Frank Rack, Joint Oceanographic Institutions

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

In situ temperature and pressure measurements have been the most common measurements made during DSDP/ODP, although osmosamplers have come on strong in recent years for fluid sampling as part of CORK and ACORK installations.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

I am looking for the participants to answer this question for the program.

3. What new technology should be implemented in future autonomous DHTs?

I am looking for the participants to answer this question for the program.

Demian Saffer, University of Wyoming, Dept 3006

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

pore fluid pressure, temperature, stress state
Secondary importance: geochemical sampling

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Technological and operational problems with RELIABLE instruments for real-time down-hole measurements; and with multiple packed intervals in boreholes (for observatory science)
2. Community access to DHT data
3. Tool management

3. What new technology should be implemented in future autonomous DHTs?
Capability for high-T (>100 deg C)

Derryl Schroeder, IODP Texas A&M University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Temperature tools APCT and DVTP

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Fluid sampling and pore pressure measurements

3. What new technology should be implemented in future autonomous DHTs?

Adam Schultz, College of Oceanic & Atmospheric Sciences, Oregon State University

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

isobaric high pressure, controlled temperature fluid sampling, storage and incubation DHT required for controlled kinetics to permit meaningful understanding of biogeochemical interactions in deep biosphere and impact on water-rock mineralization reactions; also require new methods of operating in frozen hydrate hosted areas, and to accommodate real-time transmission of power, telemetry and bidirectional command/control; require downhole in situ chemistry

3. What new technology should be implemented in future autonomous DHTs?

Controlled temperature/pressure; reliable fluid pumping system through manifold to seafloor; power transmission/telemetry; greater use of optrodics and related non-membrane chemical sensor approaches.

Elizabeth Screaton, University of Florida Geological Sciences

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Temperature measurements. During ODP, these were made with the ADARA shoe for piston coring, and the DVTP.

Pressure measurements. During ODP, several versions of inserted pressure tools were tried, including the LAST-II, the GEOPROPS, with the DVTP-P being the most recent.

During packer deployments, pressure measurements were made with a 3rd party pressure recorder.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

In terms of current tools: The ADARA shoes worked well, but were reaching the ends of their useful lives by the end of ODP. Replacement APC devices are needed. The DVTP for temperature worked well, and the greatest need is regular calibration and maintenance. For in-situ pressure measurements, the tool design needs to be revisited.

In reaching deep objectives (as during SEIZE), we will need to extend the robustness of in-situ probes to achieve as great a depth as possible. We will also need to consider strategies for T and P measurements/approximations within the borehole, such as extrapolation of open hole temperature measurements, and pressure determinations from mud weights, and from more common use of packer deployments.

To make temperature and pressure measurements "routine" as suggested in the Hydro PPG report, there will need to be additional tools, maintenance, calibration, and technician support

3. What new technology should be implemented in future autonomous DHTs?

Fred Spiess, UCSD/SIO/MPL

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

This is a combined answer to all three questions:

My interests and possible contributions are in means for carrying out down-hole research in general. This was first focused in a workshop in 1987 (Langseth and Spiess 1987) and in carrying out the first wireline re-entry experiment from a conventional research ship (Spiess et al, 1992). This led to construction of a re-entry support vehicle (Control Vehicle - CV) funded by NSF for the ODP (Spiess 1992). Three types of research-ship-supported re-entry operations have been carried out - seismometer placement and recovery (Stephen, Spiess, et al 2003); down-hole TV viewing and packer and instrument string placement (Becker, et al, 2001) and retrieval of instruments from conventional CORKS (de Moustier, et al, 2000).

I realize that this workshop and the related advanced CORK session are focused on things that might be carried out in the future from the various drilling platforms visualized as IODP facilities rather than those that would be carried out from conventional research ships per se; however, I believe that my participation could be useful in several ways.

First, in relation to the background statement "One important issue that has not received attention during previous planning and review efforts is how to handle instrument standards to maximize possibilities for use of tools across a range of platforms. In some cases, this can be accommodated through establishment of developmental standards, but in other cases, it may require creation of "adapters" or other tool components. A related issue is how tools are to be deployed and supported on different platforms having a range of scientific, technical, and operational staff and physical facilities."

Second, I may be able to provide some insight into ways in which the responses to your question #3 - (What new technology should be implemented in future autonomous DHTs?) might be realized.

Third, involvement in discussions of new types of tools and down-hole experiments will broaden the possibilities for generation of new wireline approaches for use by conventional ships, broadening the range of down-hole research.

Becker, Keir, Earl E. Davis, Fred N. Spiess, Christian de Moustier and DRIFT 03 Technical Party; Wireline CORKS Deployed for long term hydrogeological investigations in holes 504B and 896A, Costa Rica Rift, and the first in-situ video collected from within upper oceanic crust; Eos Trans. AGU, Fall Mtg., Suppl., Abstract OS218 0454, 2001.

de Moustier, C., F. N. Spiess, D. Jabson, P. Jonke, G. Austin and R. Zimmerman; Deep-sea borehole re-entry with fiber optic wireline technology; Proceedings of the 2000 International Symposium on Underwater Technology, Tokyo, Japan; 23-26 May, 2000.

Langseth , M. G., and Spiess, F. N., Science opportunities created by wireline re-entry of deep sea boreholes. Report of workshop. Joint Oceanographic Institutions, 65 pgs, February, 1987.

Spiess, F. N., D. E. Boegeman, and C. D. Lowenstein; First Ocean-Research-Ship-Supported Fly-in Re-entry to a Deep Ocean Drill Hole; J. Mar. Tech. Soc., v26, no. 3, pp 3-10, Fall, 1992.

Spiess, F. N.; JOI/MPL wireline reentry system; OSN Newsletter, vol. 2, no.2, pgs1-2, winter 1992-93.

Stephen, R. A.; Spiess, F. N.; Collins, J. A.; Hildebrand, J. A.; Orcutt, J. A.; Peal, K. R.; Vernon, F. L.; Wooding, F. B.; Ocean Seismic Network Pilot Experiment ; Geochem. Geophys. Geosyst., Vol. 4, No. 10, 1092; DOI 10.1029/2002GC000485; 31 October 2003

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Ralph Stephen, WHOI

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

VSP tools, borehole seismic arrays (1-100Hz) and broadband borehole seismometers (0.001-10Hz)

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

High temperature tools are essential for many deep borehole objectives.

Power and data telemetry are also important issues.

3. What new technology should be implemented in future autonomous DHTs?

We should take advantage of nanotechnology where ever possible

Harold Tobin, New Mexico Tech

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Past measurements of temperature and, to a lesser extent pressure, have been both successful and useful in understanding accretionary prism mechanics and fault dynamics. If pressure and stress measurements had been more successful in the past, these would likely have been the most important and useful downhole measurements from my perspective.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

See above--the performance of downhole horizontal stress and pore pressure measurement would be most useful, and so far we have not really done a good job. Being able to perform drill stem tests, active hydraulic fracturing, in situ pore fluid pressure measurements, and/or lateral stress tests reliably is the most pressing need for the future. Additionally, we need the capability to run tools that will perform well at high temperature--up to ~200 C.

3. What new technology should be implemented in future autonomous DHTs?

Bill Ussler, Monterey Bay Aquarium Research Institute

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

Measurements of sediment gas content using the Pressure Core Sampler (PCS) have been the most important and useful measurements for my field of interest. I am one of the lead scientists involved in the development of the ODP Temperature, Pressure, and Conductivity Tool (TPC), also known as the APC-Methane Tool, that is the next step in the effort to develop DHTs suitable for measuring sediment gas content. This tool has been run over 122 times on ODP Legs 201 and 204. Analysis of the data is still on-going, however the results are encouraging.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

One of the biggest gaps in our ability to make chemical measurements is obtaining routine, reliable gas concentrations at in situ conditions. The PCS is the first DHT that has worked successfully for quantifying sediment gas concentrations, however it is difficult to operate and requires special tool runs. Thus, the PCS in its present form is not a routine measurement tool. The TPC was the next step in creating a suite of DHTs that can meet science needs for understanding sediment gas distribution within marine sediments, however it is not a mature tool. The distribution of methane and other gases within marine sediments (including methane gas hydrates) is a first-order scientific problem because methane is such an important gas for fueling microbial processes on and within the seafloor. Methane clearly controls the global distribution of a significant number of microbial and macro-faunal life forms and ecosystems on and within the seafloor, however we have little understanding of where it is formed, and how it is concentrated, spatially distributed and moves through the sediment column.

3. What new technology should be implemented in future autonomous DHTs?

New chemical sensors or sensor suites for the detection, identification, and quantification of sediment gases are needed. Coupling these sensors with more sophisticated electronics, longer-lived batteries, and wireless communications ability is an integral part of providing the next generation of DHTs that can run for long periods of time (i.e., 4+ days), be operated in a passive, autonomous mode that does not interfere with the tempo of drilling operations, and can be easily interrogated and reprogrammed between coring runs.

Heinrich Villinger, University of Bremen

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

confirmation of seafloor heat flow measured with conventional heat probes (with a penetration depth of 3 - 5 m) by downhole temperature measurements with different DHT during DSDP and ODP

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

much better mechanical decoupling of drill string from tool during measurements is extremely important
- fluid sampling

3. What new technology should be implemented in future autonomous DHTs?

Richard von Herzen, WHOI (visiting UCSC until May 04)

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

In-hole temperatures and pressures. Appropriate measurements can be used to deduce vertical flow in boreholes, and their variations over time. The vertical heat flux in the vicinity of the borehole can also be determined. Experiments with CORKed holes and crosshole correlations can be used to deduce lateral physical properties (e.g., fluid permeability) of ocean crust.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

3. What new technology should be implemented in future autonomous DHTs?

Detailed (spatially and temporally) low velocity flow measurements. The spatial variations may be used to map horizons of influx or egress of fluid - particularly useful in crustal rock and in hydrothermally active regions. Would also be useful to incorporate measurements of chemical species to obtain elemental mass fluxes.

Geoff Wheat, University of Alaska Fairbanks

1. What are the most important autonomous Downhole Tool (DHT) measurements made during DSDP/ODP for your field of interest?

The most important autonomous DHT that I have used during ODP are the WSTP, OsmoSamplers, and the Scripps wireline reentry tool. The WSTP-Fissler tool needs further development along the lines of the temperature shoe that Andy Fisher is working on so that its use can be fully incorporated into HPC coring. We have used the WSTP within boreholes to collect fluids that were venting to the seafloor, but we are temperature limited. OsmoSamplers provide a means to monitor the change in fluid chemistry within the borehole resulting in data useful for hydrologic and microbiologic applications (Wheat et al, 2003). The Scripps wireline tool can be used to monitor temperature, get a water sample within the hole (electronics have to be improved to handle temperatures >60C), and provide video of the hole. Additional instruments can be attached to this tool.

2. What is the greatest gap between current DHT capability and what we need to achieve regarding IODP science goals?

Long-term chemical analyzers need to be designed, fabricated, and tested for future applications where a cable can be provided that allows one to manipulate experiments. These instruments could provide needed data to address hydrologic and microbiological questions.

3. What new technology should be implemented in future autonomous DHTs?

Attachment 5: Working groups for Day One and Day Two

Day One – May 24, 2004

The Deep Biosphere and the Subseafloor Ocean

Leaders: D. Saffer, M. Lilley

Barbara Bekins, U.S. Geological Survey
Matthew Chartier, Massachusetts Institute of Technology
K. Michelle Edwards, University of Miami
John Germaine, Massachusetts Institute of Technology
Martin Heesemann, University of Bremen, Dept. Earth Sciences
Gary Humphrey, Fugro McClelland Marine Geosciences, Inc.
Miriam Kastner, Scripps Institution of Oceanography
Hui Long, Penn State University
Kate Moran, University of Rhode Island
Charles Paull, MBARI
Tom Pettigrew, Mohr Engineering
Adam Schultz, College of Oceanic & Atmospheric Sciences, Oregon State University
Fred Spiess, UCSD/SIO/MPL
Geoff Wheat, University of Alaska Fairbanks

Environmental Change Processes and Effects

Leaders: R. Harris, B. Price

Bill Ussler, Monterey Bay Aquarium Research Institute
Alexei Milkov, British Petroleum
Brandon Dugan, USGS and Rice University
Bill Gwilliam, National Energy Technology Laboratory
Nathan Bramall, U.C. Berkeley
Gilles Guerin, LDEO/Borehole Research Group – Columbia University
Richard von Herzen, WHOI

Solid Earth Cycles and Geodynamics

Leaders: H. Tobin, R. Stephen

Keir Becker, University of Miami – RSMAS
Derek Elsworth, Penn State University
Sean Gulick, University of Texas Institute for Geophysics
Kinoshita Masataka, JAMSTEC
Chris Marone, Penn State University
Elizabeth Screaton, University of Florida Geological Sciences
Heinrich Villinger, University of Bremen
David Huey, Stress Engineering Services, Inc.

Day Two – May 25, 2004

Measuring Physical State (e.g. temp, press, chemistry)

Leaders: A. Schultz, H. Villinger

Keir Becker, University of Miami – RSMAS
Matthew Chartier, Massachusetts Institute of Technology
Derek Elsworth, Penn State University
Gilles Guerin, LDEO/Borehole Research Group – Columbia University
Robert Harris, University of Utah
Martin Heesemann, University of Bremen, Dept. Earth Sciences
Gary Humphrey, Fugro McClelland Marine Geosciences, Inc.
Kinoshita Masataka, JAMSTEC
Hui Long, Penn State University
Alexei Milkov, British Petroleum
Kate Moran, University of Rhode Island
P. Buford Price, University of California
Stuart Robinson, LDEO Columbia University
Elizabeth Screaton, University of Florida Geological Sciences
Ralph Stephen, WHOI
Bill Ussler, Monterey Bay Aquarium Research Institute
Richard von Herzen, WHOI
David Huey, Stress Engineering Services, Inc

Collecting Discrete Samples (e.g. fluid, solids, gasses)

Leaders: B. Dugan, M. Kastner

Barbara Bekins, U.S. Geological Survey
Nathan Bramall, U.C. Berkeley
K. Michelle Edwards, University of Miami
Dudley Foster, DSV Alvin, Woods Hole Oceanographic Institute
John Germaine, Massachusetts Institute of Technology
Sean Gulick, University of Texas Institute for Geophysics
Miriam Kastner, Scripps Institution of Oceanography
Marvin Lilley, University of Washington
Charles Paull, MBARI
Tom Pettigrew, Mohr Engineering
Demian Saffer, University of Wyoming
Fred Spiess, UCSD/SIO/MPL
Harold Tobin, New Mexico Tech
Geoff Wheat, University of Alaska Fairbanks