FY09 Annual Report

Integrated Ocean Drilling Program
U.S. Implementing Organization

Discrete core sampling

Integrated Ocean Drilling Program

A historical perspective

The Integrated Ocean Drilling Program (IODP) is an international marine research program that conducts seagoing expeditions to explore Earth's history and structure as recorded in seafloor sediments and rocks and to monitor subseafloor environments. IODP builds upon the earlier successes of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Program (ODP), programs that revolutionized our view of Earth's history and global processes through ocean basin exploration. IODP's principal research themes are outlined in the Initial Science Plan: "Earth, Oceans and Life: Scientific Investigations of the Earth System Using Multiple Drilling Platforms and New Technologies."

IODP greatly expands on the previous programs by simultaneously using multiple drilling platforms—a riserless drilling vessel, a riser drilling vessel, and mission-specific platforms—to achieve its scientific goals. The riserless drilling vessel allows IODP to drill more deeply than is possible with the other platforms while continuing to expand global sampling coverage and disciplinary breadth that were characteristic of DSDP and ODP. The riser drilling vessel allows IODP to drill for months to a year or more at a single location. Mission-specific platforms allow drilling in environments unsuitable for either the riserless or riser vessel, such as near the shoreline in shallow-water areas and in climatically sensitive or ice-covered regions.

Three implementing organizations (IOs) serve as science operators for the various platforms: the USIO is responsible for operating the riserless drilling vessel *JOIDES Resolution*, Japan's Center for Deep Earth Exploration (CDEX) for the riser drilling vessel *Chikyu*, and the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO) for the mission-specific platforms. Each IO sails one Staff Scientist, who participates as a member of the expedition Science Party, providing consistency from one expedition to the next.

IODP Management International, Inc. (IODP-MI), a nonprofit U.S. corporation with an international membership of academic institutions, serves as the central management organization for IODP and is responsible for Program-wide science planning and oversight, as well as provision of continuous performance evaluation and assessment of all elements of IODP. Science planning is provided by the Science Advisory Structure (SAS), which involves many scientists and engineers on many standing committees and panels. Each of the IOs provides liaisons with appropriate expertise to interact with SAS panels and other IODP-MI working groups and task forces.

The USIO comprises the Consortium for Ocean Leadership, Inc. (Ocean Leadership) and its partners, Lamont-Doherty Earth Observatory (LDEO) of Columbia University and Texas A&M University (TAMU). Ocean Leadership is the prime contractor with the National Science Foundation (NSF) with ultimate responsibility for all contractual obligations entered into by the USIO. LDEO and TAMU serve as subcontractors that contribute distinct but complementary capabilities that collectively support the full range of activities necessary for implementation of riserless drilling vessel scientific drilling programs. Administrative services in support of TAMU activities are provided by the Texas A&M Research Foundation (TAMRF). In this document, references to TAMU include TAMRF.

Sunset in the Pacific

FY09 Annual Report

Integrated Ocean Drilling Program

United States Implementing Organization

Consortium for Ocean Leadership, Inc.

Lamont-Doherty Earth Observatory of Columbia University

Texas A&M University

National Science Foundation
Contract OCE-0352500

IODP Management International, Inc.
Contract IODP-MI-05-03

1 October 2008–30 September 2009

JOIDES Resolution, ***Ogden Pier, Victoria, British Columbia, Canada***

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Cover photo:* JOIDES Resolution, *departing Honolulu, Hawaii

Back cover photo: Rhizon interstitial water sampling

David Divins

Director of Ocean Drilling Programs
Consortium for Ocean Leadership, Inc.

David Divins joined the Consortium for Ocean Leadership (formerly Joint Oceanographic Institutions) in January 2006 as the Associate Director, Ocean Drilling Programs, and became Director, Ocean Drilling Programs, in August 2006. Divins came to Ocean Leadership from NOAA's National Geophysical Data Center in Boulder, Colorado, where he was a member of the Marine Geology and Geophysics Division from 2000 to 2005. Before joining NGDC, Divins was a Research Scientist at the University of Colorado Cooperative Institute for Research in Environmental Science from 1991 to 2000. Divins received his B.A. from Boston University (1981) and his Ph.D. in Oceanography from Texas A&M University (1991). While at Texas A&M, he was involved in many Ocean Drilling Program activities, including sailing on an ODP expedition and working in the data management group.

David Goldberg

Director, Borehole Research Group
Lamont-Doherty Earth Observatory of Columbia University

Dave Goldberg joined the Lamont-Doherty Earth Observatory (LDEO) of Columbia University as a Research Scientist in 1987 and has served as Director of the LDEO Borehole Research Group since 1992. Goldberg earned his S.B. in Geophysics (1981) and S.M. in Marine Geophysics (1981) from Massachusetts Institute of Technology and his Ph.D. in Geophysics (1985) and M.B.A. (1989) from Columbia University. He has sailed on nine DSDP and ODP expeditions and is involved in many synergistic activities, including the Department of Energy's Methane Hydrate Advisory Committee; LDEO and Columbia University's Earth Microbiology Initiative; the LDEO Laboratory for Ocean Drilling, Observation, and Sampling (LODOS); and IODP's International Scientific Logging Consortium.

Brad Clement

Director, Integrated Ocean Drilling Program
Texas A&M University

Brad Clement, former Professor and Chair of the Department of Earth and Environment at Florida International University in Miami, was appointed Director of IODP at Texas A&M University effective 1 August 2009. Clement chaired the U.S. Science Advisory Committee (USAC) and has a long history of involvement with IODP, having sailed on four expeditions, worked as an Ocean Drilling Program Staff Scientist, and served on the JOIDES Ocean History Panel. Clement earned his B.S. in Geology from the University of Georgia (1979) and his M.A. (1981) and Ph.D. (1985) in Geology from Columbia University. He previously served as Associate Program Director for the Ocean Drilling Program in NSF's Ocean Sciences Division from 2001 to 2003 and as Adjunct Associate Professor of Geophysics at Texas A&M University from 1984 to 1988. Clement was Associate Editor of the *Journal of Geophysical Research* and has served on several American Geophysical Union committees.

Executive Summary

JOIDES Resolution *in the Pacific*

The Integrated Ocean Drilling Program (IODP) U.S. Implementing Organization (USIO) successfully achieved its overarching goals for Fiscal Year 2009, which included complete refurbishment of the U.S. scientific ocean drilling vessel (SODV); readiness assessment of the ship systems, technological enhancements, and redesigned analytical systems; and return to international operations for IODP Phase 2.

The renovated *JOIDES Resolution* completed Expedition 320T: Sea Trials and Assessment of Readiness Transit (START) and returned to operations for Phase 2 expeditions. In support of the return to operations, the USIO revised and expanded operational and technical support in the areas of technology development and enhancement, technical documentation, data management, and support for international IODP partners. The USIO also continued its mission to preserve the Program's legacy and share the expanding body of knowledge gained from decades of ocean drilling research with the scientific community and the public.

The enhanced research vessel JOIDES Resolution provides all new science facilities, new and improved scientific capabilities, improved core handling capabilities, expanded information and technology network and infrastructure, enhanced logging

capabilities, and larger and better organized living and working spaces. The USIO continues to address recommendations made by the Readiness Assessment Team (RAT) during Expedition 320T according to assigned priority.

The *JOIDES Resolution* returned to international operations on 5 March 2009 with Expedition 320/321 (Pacific Equatorial Age Transect), followed by Expeditions 321T (Juan de Fuca Hydrogeology Cementing Operations), 323 (Bering Sea Paleoceanography), and 324 (Shatsky Rise Formation). Despite the short transit after the shipyard period, major equipment and system tests were completed successfully during the *JOIDES Resolution's* return to scientific operations.

Expedition 320/321 recovered a series of continuous historical sediment records back to 53 Ma from the equatorial Pacific, one of the largest and most climatically important ocean regions on Earth. Studies of this sediment archive will allow scientists to determine the rates of environmental change in a time period that includes some of the best analogs for abrupt climate change and extreme climate events. The results could give insights into the potential impacts of future climate change.

Expedition 321T revisited the Juan de Fuca Ridge and cemented reentry cones around two subseafloor borehole observatories (circulation obviation retrofit kits [CORKs]) originally installed during IODP Expedition 301 to serve as long-term monitoring points for large-scale crustal testing. The CORKs were designed to seal and stabilize open holes for future sample and data collection via remotely operated vehicle and submersible expeditions, but observations since Expedition 301 had shown that both CORKs were leaking.

Expedition 323 collected a continuous sediment record of climate change in the Bering Sea to decipher the history of the Bering Strait gateway and determine its impact on global and regional climatic and oceanic processes. This expedition fully load-tested our shipboard systems for the first time. New cores will help us understand the exchange of heat and chemical elements running through the Bering Strait and how those may have influenced Arctic and North Pacific environments. It also will help us understand how sea ice accelerates climate change and how subpolar ecosystems respond to climate change.

Expedition 324 revisited Shatsky Rise to test competing theories on the formation of oceanic plateaus. The expedition cored five sites at Shatsky Rise to examine the history, source(s), and evolution of the plateau. The wide range of samples obtained will enable scientists to address the fundamental question of whether Shatsky Rise and other large oceanic plateaus were formed by

More from the leadership

"The Resolution *carries science teams whose research will help us better understand Earth's current climate and its ancient sea levels. This research will help resolve the puzzles of continental drift, volcano formation, and the onset of earthquakes."*
—Ardent L. Bement, Jr., NSF Director

"I am very proud and excited to see the JOIDES Resolution *back in action—providing the world's science community with unique information essential for unlocking the evolution of our planet, and providing the framework for understanding our future changing climate."*
—Robert Gagosian, President and CEO of the Consortium for Ocean Leadership

"More than 6,000 scientists from all over the world have conducted research on this ship on a scale that could be compared to the Hubble Space Telescope. It has been the mainstay and the workhorse of ocean drilling for the past 25 years. It truly is a state-of-the-art vessel and the renovations that have been done will enable the JOIDES Resolution *to make research history for at least the next 20 years."*
—Steve Bohlen, Interim Director, IODP-USIO, TAMU

Helipad

Cores to be split

a deep-rooted mantle plume or by shallow, plate tectonic–related processes.

The USIO continued to broaden its efforts to reach scientists, the public, students, and teachers about scientific ocean drilling through scientific publications and education and outreach activities. The USIO provided publication services to international IODP implementing organization (IO) partners. In addition, the USIO School of Rock program returned to sea during Expedition 321T. The workshop hosted 15 educators on the *JOIDES Resolution*, 4 of whom were selected by the international IOs, thus setting a precedent for Program-wide participation in future workshops. An education representative sailed during each of the FY09 expeditions, fulfilling a shipboard role that has expanded from that of the IODP Phase 1 Teachers at Sea. Public relations activities took place at all ports of call during FY09, including Honolulu, Hawaii; San Diego, California; Victoria, British Columbia, Canada; and Yokohama, Japan. USIO representatives attended scientific, political, and educational conferences in FY09 to engage these communities in IODP research, and the Deep Earth Academy Web site continues to offer an ever-growing selection of online educational resources.

This IODP-USIO Fiscal Year 2009 Annual Report details these accomplishments and other activities undertaken in support of National Science Foundation (NSF) Contract OCE-0352500 and IODP Management International, Inc. (IODP-MI) Contract IODP-MI-05-03 during the period from 1 October 2008 to 30 September 2009.

Deliverables outlined for FY09 are detailed in the FY09 IODP-USIO Annual Program Plan and its Appendix. Operational achievements in support of these deliverables are presented in the following chapters. Contractual information and financial tables describing the execution of the FY09 IODP-USIO Program Plan are provided in the final chapter. Additional information on FY09 activities is available in the USIO quarterly reports.

More online

IODP-USIO: www.iodp-usio.org/

IODP Science Plan: www.iodp.org/isp/

IODP-USIO FY09 Annual Program Plan: iodp.tamu.edu/publications/PP.html

IODP-USIO FY09 Quarterly Reports: iodp.tamu.edu/publications/AR.html

Derrick and passive heave compensator

Return to Operations

First core on deck

Already a 20-year workhorse on behalf of scientific ocean drilling, the *R/V JOIDES Resolution* has been completely refurbished and is back in service, enabling IODP to continue to expand the boundaries of ocean drilling research by collecting unique subseafloor samples and data that would otherwise remain inaccessible to researchers. Data from *JOIDES Resolution* expeditions have contributed to improved scientific understanding of the causes of natural geologic hazards such as earthquakes, volcanoes, and tsunamis; Earth's changing climate conditions over the past 100 million years; methane hydrates—"frozen" deposits of methane gas with the potential to be a major factor in climate change—that may offer solutions to energy needs; and future rising sea levels by examining evidence of past sea level rise and climate change contained in the archive of seafloor sediments.

The SODV Project

The JOIDES Resolution spent 29 months (September 2006–January 2009) in the Jurong Shipyard in Singapore, where the ship's hotel and laboratory structure was replaced and the marine and drilling systems were completely refurbished. This reconstruction project, known as the U.S. Scientific Ocean Drilling Vessel (SODV) Project, was funded by a grant from the National Science Foundation (NSF) Major Research Equipment and Facilities Construction (MREFC) account. The

Natural Gamma Ray Logger (NGRL)

SODV Project replaced nearly everything inside the hull of the ship from the derrick forward, including the laboratories, accommodations, and bridge. Vessel and drilling systems throughout the *JOIDES Resolution* were overhauled and refurbished, notably the top drive and passive heave systems and the propeller shafts, screws, and thrusters. Downhole logging operations were also completely renovated, including a new wireline heave compensator (WHC) and support systems. In tandem with construction work in Singapore was a complete redesign of the science laboratories with new and redesigned analytical systems, as well as extensive new software, databases, and information technology (IT) infrastructure.

Following renovation of its interior spaces, operating systems, and laboratory facilities, the *JOIDES Resolution* successfully completed initial sea trials in the South China Sea. Equipment and system testing satisfied the American Bureau of Shipping representatives, with a few minor adjustments required. The ship temporarily remained in Singapore while the ship's crew completed final details and USIO personnel finished installing the science equipment. All shipboard personnel helped to secure equipment and instruments throughout the ship's laboratories and support facilities to ensure their seaworthiness in preparation for departure. Multidisciplinary teams focused on preacceptance and acceptance testing of the various systems as they came online.

Splitting core

Readiness Assessment Team members using Imaging Logger

Expedition 320T: Sea Trials and Assessment of Readiness Transit

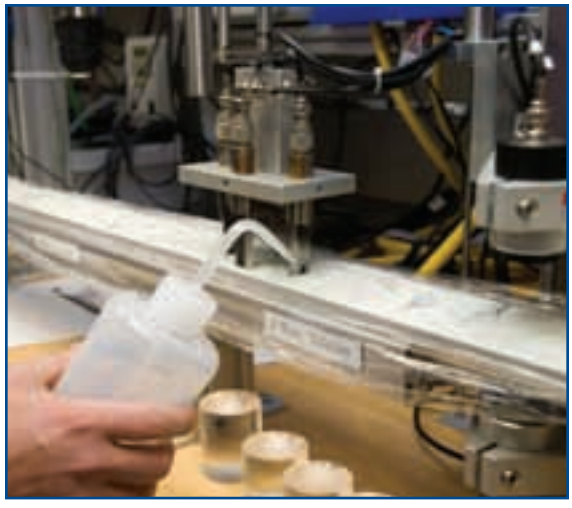
In order to gauge the overall readiness of the research vessel prior to the beginning of Expedition 320 in March 2009 in Honolulu, Hawaii, the USIO planned a ~6 week transit expedition that marked the final phase of the SODV Project. The Sea Trials and Assessment of Readiness Transit (START), Expedition 320T, achieved several important goals, including testing of drilling and coring systems and performance of the new WHC and logging tools at sea. The transit expedition also assessed the overall readiness of the science systems, accommodations, and IT system for carrying out full IODP expeditions.

The *JOIDES Resolution* covered almost 6000 nmi in its voyage from Singapore to Honolulu during Expedition 320T. On 26 January 2009, the ship sailed from Singapore toward Guam, where she made her first port call. The ship's crew and USIO staff worked throughout the transit to troubleshoot initial electrical problems, set up analytical systems, conduct pre-acceptance testing, and work toward drilling package readiness.

During the Guam port call, the *JOIDES Resolution* passed a complete U.S. Coast Guard annual inspection with no deficiencies cited and received complimentary comments regarding the ship's condition. Additional technical staff boarded the ship, along with a group of seven independent scientists that served as an external Readiness Assessment Team (RAT) to evaluate the ship's readiness for international scientific operations.

On 9 February 2009, the *JOIDES Resolution* departed Guam en route to Ocean Drilling Program (ODP) Site 807 on the Ontong Java Plateau, with readiness assessment and internal acceptance testing activities continuing in parallel throughout the transit. During ODP, a reentry cone was left in Hole 807C, a 1500 m hole into basement that was identified as a safe and appropriate location for testing not only the WHC and tool responses but also the ship's dynamic positioning (DP) system, Global Positioning System (GPS), vibration-isolated television (VIT) camera frame, beacons, and thrusters. The START plan also included drilling at a new site (Site U1330), a reoccupation of Site 807 situated near the Equator (~3°N) in a basement graben feature of the Ontong Java Plateau.

During transit, the RAT was introduced to the renovated *JOIDES Resolution* through a series of presentations ranging from onboard life to vessel capabilities, drilling, and wireline logging capabilities and key software applications including the Laboratory Information Management System (LIMS), sample assignment



P-wave velocity measured with the Gantry System

Training in the Chemistry Laboratory

(Sample Master), descriptive data capture (DESCLogik), stratigraphic correlation (Correlator), and data retrieval (Web Tabular, LIMS2Excel, and Crystal Reports) applications. The team received demonstrations and hands-on training for shipboard analytical systems (chemistry and physical properties), and a complete core flow dry run was conducted with the USIO staff and the RAT.

Once drilling began, new core on deck provided an opportunity for the RAT to evaluate almost all of the science and IT systems and for new rig floor crew and USIO technical staff to organize collecting, curating, and evaluating core flow through the new laboratories. All routine shipboard analytical measurements and descriptive observations of the recovered core material and the corresponding data were uploaded to the new LIMS. Lithostratigraphic and biostratigraphic observations were essentially consistent with findings previously reported for Site 807.

The Expedition 320T downhole logging program was specifically designed to determine the new WHC system's efficiency by using uphole (surface) and downhole acceleration data to evaluate heave compensation efficiency and by comparing the new logging data with the data collected from Site 807 during ODP Leg 130. As with the core data, the new logging results correlated well with previously reported data. Performance testing of the WHC both in pipe and in open hole in Hole U1330A proved satisfactory, a finding that was confirmed by high-resolution Formation MicroScanner (FMS) images (sensitive to heave conditions) that showed excellent agreement of layering and sedimentary features recorded during different runs. Further fine tuning and testing of the WHC will continue over the next few years to evaluate the system's response under varying heave conditions.

The Readiness Assessment Team report

The RAT took a majority of the ship's systems through a series of realistic tests using both archived and fresh cores, engaging fully with the functionality of analytical instruments and the integrated software in the context of core flow. The assessment report detailed recommendations for immediate and near-term action in three areas: SODV deliverables, major science systems, and system integration. More than 80 recommendations were made, some of which affect all aspects of science operations and some of which were specific to certain laboratories or systems.

The RAT recommendations were combined with other SODV punch list items by the SODV Project Management Office (PMO) into a cumulative

Readiness Assessment Team

list of issues, which was then categorized by Ocean Leadership and NSF into SODV and non-SODV responsibilities. The USIO has addressed all RAT issues on the SODV responsibilities list and resolved many RAT issues on the non-SODV responsibilities list as well. As issues were corrected, an onshore review of the corrective activity was conducted to determine the appropriate long-term resolution of the issue. In addition, technical staff members were held over at each port call to provide additional training and address resolution of emerging science delivery issues. Expedition 321T had a limited science party, so the USIO took advantage of the extended transit to sail a full complement of programming and technical staff to implement prioritized changes to analytical systems. Efforts in support of non-SODV issues and future developments are ongoing, but precedence is given to implementing solutions that are immediately required to sustain operability. As an integral part of continued improvement activities, the USIO developed plans for internal and external reviews of science systems that will be implemented in FY10.

Return to international operations

Successful deployment of the advanced piston corer (APC) and rotary core barrel (RCB) coring systems and the retrieval of ~103 m of drill core (with an average recovery rate of 93%), full onboard processing of the cored material and subsequent scientific examination (largely confirming the results reported for Site 807), and successful runs of new and standard logging tools using the new WHC during Expedition 320T proved the operational readiness of the drillship and its analytical systems. The cores recovered during Expedition 320T are allocated as USIO cores (rather than IODP) and will be used primarily for education and training.

The *JOIDES Resolution* arrived in port in Honolulu, Hawaii, on 5 March 2009, ready to begin the first IODP Phase 2 expedition.

More online

Expedition 320T daily reports: iodp.tamu.edu/scienceops/expeditions/sea_trials.html

Expedition 320T Preliminary Report*: publications.iodp.org/preliminary_report/320T/*

More from the leadership

"We are extremely pleased to see the JOIDES Resolution *set sail once more for science—with a vastly improved capability for performing cutting-edge research into the secrets of Earth's past climate, past ocean conditions, deep biosphere and interior."*
—Tim Killeen, NSF Assistant Director for Geosciences

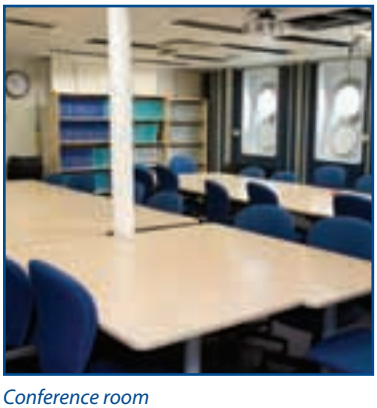
"This is a long-awaited day for the world of ocean research. The JOIDES Resolution *is operational again for IODP expeditions at an extremely important time, when our need for scientific understanding of our ocean planet—and climate and energy challenges—is at its greatest. The research pursuits of thousands of scientists around the globe will be enhanced in a major way by the future work of the* JOIDES Resolution."
—Robert Gagosian, President and CEO of the Consortium for Ocean Leadership

The people in the trenches were put into very tough positions that included moving targets and changing deadlines. We need to acknowledge the tremendous work that took place under severe time and fiscal constraints. The IODP and Transocean staff we interacted with during Expedition 320T and this readiness assessment continually rose to this challenge with professionalism and a can-do attitude.
—Readiness Assessment Team report

Paleomagnetics Laboratory

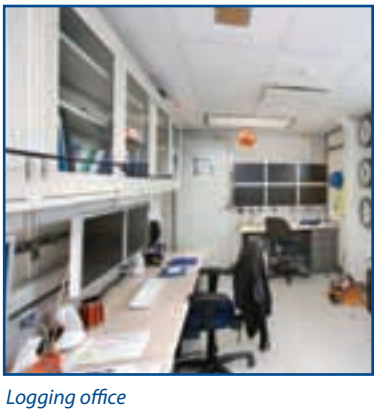
Physical Properties Laboratory

Publications Specialist office



Conference room

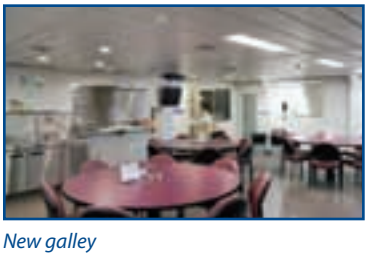
Microbiology Laboratory



Logging office

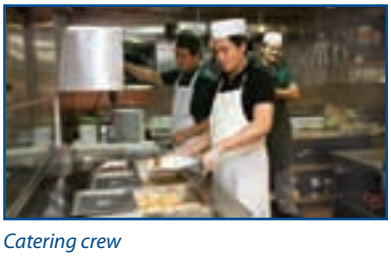
Microscope Laboratory

Chemistry Laboratory



New galley

Shipboard gym



Catering crew

A storm approaches at sunset

IODP-USIO Phase 2 Expeditions

Expedition 320 working group

Along with two working transits, the U.S. Implementing Organization (USIO) completed three full expeditions during FY09 and began a fourth. Over the course of these expeditions, the USIO drilled in locations that have not been drilled previously, added detail to existing transects to test hypotheses regarding massive magmatic episodes, and collected continuous sediment sequences that will allow completion of high-resolution age-diagnostic studies and refinement of the timeline of Earth's climatic changes.

Expedition 320/321: Pacific Equatorial Age Transect

Expeditions 320 and 321, sailing from 5 March to 4 May 2009 and 4 May to 22 June 2009, respectively, were two parts of a single science program designed to study ocean circulation and productivity in the tropical Pacific, one of the largest and most climatically important ocean regions on Earth, and to fine tune the Cenozoic geological timescale with higher resolution data than have been previously available.

More from the IODP scientists

"The sediments collected during this expedition offer an unprecedented window to the evolution of the tropical Pacific, one of the largest and most climatically important ocean regions on Earth. In focusing on a time period that includes some of the best analogs for abrupt climate change, extreme climate events, ocean acidification, and 'greenhouse' worlds, the results will give us insights into the potential impacts of future climate change."
—Julie Morris, Director of NSF's Division of Ocean Sciences

"It's truly remarkable to see 53 million years of Earth's history pulled up onto the drill ship's deck, then pass through our hands, and move past our eyes. We saw first-hand the effects of Earth's climate machine in action."
—Heiko Pälike, Expedition 320/321 Co-Chief Scientist

"We can use the microfossils and layers of this superb sediment archive as a 'yardstick' for measuring geological time. This will allow us to determine the rates of environmental change, such as the rapid first expansion of large ice sheets in the Antarctic 33.8 million years ago. This polar process had a profound impact on phytoplankton even at the Equator. We managed to catch several records of this important climatic transition."
—Hiroshi Nishi, Expedition 320/321 Co-Chief Scientist

During these expeditions scientists recovered a series of continuous historical sediment records back to 53 Ma, including the warmest period of Earth's history during the Cenozoic, known as the greenhouse Earth. At that time there were no significant polar ice caps and greenhouse gas concentrations were several times higher than they are today. This period includes the best analogs for abrupt climate change, extreme climate events, and ocean acidification, giving insights into potential impacts of future climate changes.

Over the last 55 million years, global climate has varied dramatically from extreme warmth to glacial cold; these climate variations have all been imprinted on the biogenic-rich sediments that accumulate in the equatorial zone. The calcium carbonate compensation depth (CCD) in most of the Paleogene is very shallow, making it difficult to obtain well-preserved carbonate sediments. Using the strategy of drilling at the paleoposition of the Equator at successive crustal ages to overcome this challenge, Expedition 320/321 scientists were able to recover a unique sedimentary biogenic sediment archive for several important stratigraphic intervals, such as the Paleocene/Eocene boundary event, Eocene cooling, the Eocene–Oligocene transition, the "one cold pole" Oligocene, the Oligocene–Miocene transition, and the Miocene.

The continuous record recovered during Expedition 320/321 will help scientists understand how Earth was able to maintain very warm climates, relative to the 20th century, even though solar radiation received at Earth's surface remained nearly constant for the last 55 million years. Combined with seismic reflection studies of regional sedimentation, equatorial Pacific sediment history can be reconstructed with high confidence to improve upon earlier reconnaissance work.

Microfossil studies from equatorial Pacific sediments will help determine the rates of past environmental changes, including ice sheet expansion, which took place at about 34 Ma during a cooling period. At that time, ocean acidification decreased rapidly and the climate transitioned from warm to cool in less than 100,000 years, less than the time that humans have lived on Earth.

Studies of these sediments will contribute toward resolving questions of how and why paleoproductivity of the Pacific Equator changed over time, providing rare material to validate

Microscope Laboratory

Examining core

and extend the astronomical calibration of the Cenozoic geological timescale, determining sea-surface temperatures and nutrient profiles over time, enhancing our understanding of biostratigraphic and magnetostratigraphic datums at the Equator, and providing information about rapid biological evolution during times of climatic stress.

Expedition 320/321 collectively cored eight sites from the sediment surface to at or near basement, with basalt aged between 53 and 16 Ma, covering the time period following maximum Cenozoic warmth, through initial major glaciations, to today. The 6140 m of recovered sediments allow reconstruction of extreme changes of the CCD across major geological boundaries during the last 53 million years. Using this archive together with older Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) drilling data from the equatorial Pacific, the position of the paleoequator and variations in sediment thickness can be delineated from about 150°W to 110°W longitude.

Downhole log measurements from Holes U1337A and U1338B were used to define three logging units in each hole. Variations in density, electrical resistivity, *P*-wave velocity, and natural gamma ray (NGR) were used to define these units. The downhole density and NGR measurements as well as resistivity images were instrumental for identifying and defining chert layers that were only partially recovered in the cores. The vertical seismic profile (VSP) measurements provided the basis for a traveltime-depth conversion that allows correlation of seismic reflectors to stratigraphic events.

Two major continuous, essentially complete Neogene equatorial Pacific sedimentary sections were recovered during Expedition 321 from Holes U1337A–U1337D (0 to >23 Ma) and Holes U1338A–U1338C (0 to >17 Ma), just above the Oligocene/Miocene boundary. These represent the only complete Neogene sections in the equatorial Pacific, possibly for all the tropics, that have high enough sedimentation rates to resolve orbitally forced sediment cycles. One additional hole (U1338D) was drilled at Site U1338 to provide practice sediment cores for the upcoming Bering Sea Paleoceanography Expedition 323 Science Party. Expedition 320 drilled three other sites that also define Neogene sedimentation in the equatorial Pacific (Sites U1334–U1336).

The cores recovered from Expedition 320/321 provide the raw material to address Neogene PEAT objectives for the equatorial Pacific megasplice. Shipboard research provides the framework of studies to define the lithology, show continuity of the sediment section, and define the basic time framework. Shore-based work will refine the chronostratigraphy through orbital tuning and will measure proxies of surface and deep water change

Electronics Technician at work

Orienting rock pieces

and paleoproductivity/carbon cycles to show how the modern equatorial Pacific developed as the icehouse world developed.

Expedition 321T: Juan de Fuca Hydrogeology Cementing Operations

During Expedition 321T, a working transit expedition that sailed from 22 June to 5 July 2009, the USIO cemented reentry cones around subseafloor borehole observatories (circulation obviation retrofit kits [CORKs]) in Holes U1301A and U1301B. These borehole observatories, originally installed during Expedition 301, were designed to seal and stabilize the open holes for future sample and data collection via remotely operated vehicle and submersible expeditions. The observatories serve as long-term monitoring points for large-scale crustal testing. Observations since Expedition 301 have shown that both observatory systems were leaking.

Expedition 321T benefited from excellent weather and sea conditions in an area where working conditions can be poor, even during an optimal weather window. All planned operations were completed more quickly and with less difficulty than anticipated. Holes U1301A and U1301B were reentered and filled with cement without incident; observations with the subsea television showed cement pouring up and out of the holes on the platform, suggesting that both cones were successfully filled with cement.

Proponents visited the two CORKs in August 2009 with the submersible *Alvin* to download data, determine if the observatories remained sealed, and replace downhole instrument strings in preparation for completing the full suite of interdisciplinary experiments. Divers discovered that warm water is still venting around the outside of Hole U1301A and hypothesized that the cement did not set up quickly enough and thus sank down into the annular holes surrounding the wellhead and likely into the open hole. They were, however, able to recover the short instrument string from the CORK, replace it with a long instrument string, and download pressure data. Divers were also able to download pressure data from Hole U1301B, but they could not recover the instrument string, which will require the greater pulling force of the *JOIDES Resolution* during the planned Juan de Fuca expedition in FY10. Pressure data indicate that Hole U1301B cementing appears to have been sufficient to allow this hole to recover toward equilibrium conditions.

Expedition 323: Bering Sea Paleoceanography

Expedition 323, which sailed from 5 July to 4 September 2009, was designed to recover high-resolution paleoenvironmental and paleoclimatic records in the North Pacific—an area underrepresented in previous reconstructions. Data from Expedition 323 will provide the first

Bering Sea core on the catwalk

comprehensive, high-resolution records of environmental and oceanographic conditions in the Bering Sea over the past 5 million years to reconstruct the history of this important marginal sea that connects the Pacific and Arctic oceans and study its role in global climate and oceanographic changes. The recovered sediments will also provide vital information on subseafloor microbial activity and diversity in an extremely high productivity environment.

Over the last 5 million years, global climate has evolved from being warm with only small Northern Hemisphere glaciers and ice sheets to being cold with major Northern Hemisphere glaciations occurring every 100 to 40 thousand years (Milankovitch cyclicity). The reasons for this major transition and the mechanisms controlling glacial/interglacial- and millennial-scale climate oscillations are unknown. The Pacific is the largest ocean with arguably the largest potential to influence global climate. There are data to show that the Pacific experienced oceanographic reorganizations that were just as dramatic as those in the Atlantic, but the scarcity of data in critical regions of the Pacific has prevented an evaluation of the role of North Pacific processes in global paleoceanography and climate evolution.

Cores recovered during Expedition 323 provide a previously unavailable continuous sediment record of climate change in the Bering Sea. Higher latitudes like the Bering Sea offer more detailed sediment records because of high accumulation rates caused by glaciers grinding down rocks and depositing them as sediment. The Bering Sea is fairly isolated, so major climate changes in the past have caused major changes in sea ice, salinity, and biological activity, which are traceable in sediment cores. The Bering Strait is the main pathway for flux of heat, salt, and nutrients between the Pacific and Atlantic Oceans. Results from Expedition 323 will help our understanding of transitions in global ocean heat and nutrients.

The Bering Sea offers the opportunity to constrain global models of organic-fueled subseafloor respiration, subseafloor biomass, and the impact of subseafloor microbes on global biogeochemical fluxes in an extremely high productivity region of the ocean. In addition to providing important sedimentary records of past climate change, the

Core on deck

Examining core

Bering Sea is a region of relatively high surface productivity, elevated intermediate and deepwater nutrient concentrations, and, presumably, microbial-mediated biogeochemical cycling. Thus, Expedition 323 provides the first examination of subseafloor biomass and microbial processes in a high-productivity region.

The approximately 5-million-year sediment record obtained during Expedition 323 will provide an understanding of the evolution of Pliocene–Pleistocene surface water conditions, paleoproductivity, and sea-ice coverage, including millennial- to Milankovitch-scale oscillations; the history of production of the Pacific intermediate and/or deep water masses within the marginal sea and its link to surface water processes; the interactions between marginal sea conditions and continental climate and the Pacific Ocean; and an evaluation of how the ocean/climate history of the Bering Strait gateway region may have affected North Pacific and global conditions.

The seven sites drilled during Expedition 323 covered three different areas: Umnak Plateau, proximal to the modern Alaskan Stream entry; Bowers Ridge, proximal to the glacial Alaskan Stream entry; and the Bering Sea shelf region, proximal to the modern sea ice extent. Thirty holes, including four deep holes that ranged in depth from 600 to 745 m, were drilled below seafloor, recovering a total of 5741 m of sediment spanning the last 5 million years in age. The water depths ranged from 818 to 3174 m to characterize past vertical water mass distribution and circulation. Highlights of the expedition's findings include the following:

1. An understanding of the long-term evolution of surface water mass distribution during the past 5 million years, including the expansion of seasonal sea ice to Bowers Ridge between 3.0 and 2.5 Ma and the intensification of seasonal sea ice at both Bowers Ridge and the Bering slope from ~1.0 Ma leading into the 100,000-year cycles of the late Pleistocene ice ages.
2. The characterization of intermediate and deep water masses, including evidence from benthic foraminifers and sediment laminations, for episodes of low-oxygen conditions in the Bering Sea throughout the last 5 million years.
3. The terrigenous and biogenic sedimentary history of the Bering Sea, including evidence for strong climatological and sea level control of siliciclastic deposition at all sites. Records of lithostratigraphic variations indicate that Bering Sea environmental conditions were strongly linked to global climate change; this is apparent both in long-term million-year trends and in the orbital, millennial, and shorter oscillations within the lithostratigraphic records generated at sea.
4. A large range of inferred microbial activity with notable site-to-site variations, including significant activity as deep as 700 m below

seafloor at the Bering slope sites and, in contrast, very low rates of microbial-mediated sulfate reduction at Bowers Ridge.

Expedition 324: Shatsky Rise Formation

Scientists participating in Expedition 324, which began on 4 September and ended on 4 November 2009, traveled to one of the best locations on Earth to test competing theories on the formation of oceanic plateaus. Shatsky Rise, located ~1500 km east of Japan, is the only existing large oceanic plateau formed during a time of magnetic reversals. These reversals provide a record of spreading ridge locations, which will give Expedition 324 scientists insight into the formation of Shatsky Rise and, in turn, may answer one of the most fundamental questions of modern geodynamics—whether oceanic plateaus like Shatsky Rise were formed from a deep-sourced mantle upwelling (mantle plume) or solely by interaction of plate boundaries and the lithosphere with the shallow mantle.

The formation of Shatsky Rise during a time of magnetic reversals permits its tectonic setting to be resolved. Magnetic lineations show that the plateau formed along the trace of a triple junction and its formation was intimately related to ridge tectonics. Existing data, however, demonstrate that several aspects of Shatsky Rise's history (e.g., massive, rapid initial growth, transition from large to small magma flux, capture of ridges) fit the plume model. On the other hand, the coincidence of volcanism with the triple junction, ridge jumps, and the lack of isotopic evidence for a hotspot-type mantle source can all be interpreted as favoring a plate-controlled origin.

Expedition 324 cored five sites at Shatsky Rise to examine the history, source(s), and evolution of the plateau. Igneous rocks recovered during coring will be analyzed to determine if they are the hypothesized product of plume head eruption, and radiometric age dating will be used to determine the time span of the eruption that formed the plateau. The recovered core will be used for geochemical and isotopic studies to determine the source of magma, infer its temperature and depth of melting and crystallization, deduce the degree of partial melting, and track its evolution with time. In addition, collected samples will be used for a number of non-geochemical studies focusing on varied aspects of rise geology and volcanology (e.g., paleolatitude, eruption style, igneous products, and physical structure of Shatsky Rise). Samples recovered from the sediments overlying the igneous basement will indicate the

World record APC coring during Expedition 321

Expedition 324 sampling

paleodepths of sediment deposition, information that is important for understanding the eruption and subsidence history of the volcanic edifices. The wide range of samples obtained will enable scientists to address the fundamental question of whether Shatsky Rise and other large oceanic plateaus were formed by a deep-rooted mantle plume or by shallow, plate tectonic–related processes.

Two of the Expedition 324 sites were occupied during the reporting period. Site U1346 was drilled to 191 m below seafloor with an average recovery rate of 29% overall and a recovery rate of 39% for basement. The hole was successfully logged with the triple combination tool string, but hole conditions and sea state were not appropriate for deployment of the Formation MicroScanner (FMS)-sonic tool. Site U1347 was drilled to 317.5 m below seafloor with an average recovery rate of 62% for basement. Preparations for logging were under way at the end of the reporting period.

IODP-USIO FY09 expedition coring and logging summary

Expedition	Meters cored	Cores recovered (number)	Core recovered (m)	Core recovery (%)	Sites logged (%)
Expedition 320/321: Pacific Equatorial Age Transect	6,322.0	712	6,141.0	97.1	50
Expedition 323: Bering Sea Paleoceanography	5,896.5	669	5,740.9	97.4	57
Total	**12,218.5**	**1,381**	**11,881.9**	**97.3**	**54**

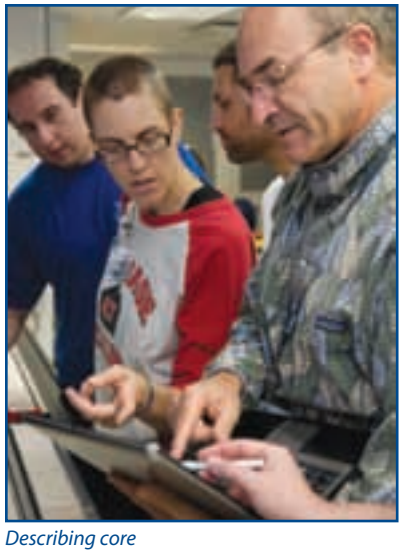
More from the IODP scientists

"The Bering Sea drilling plan is essential to our ability to decipher the history of the Bering Strait gateway and determine its impact on global and regional climatic and oceanic processes. New cores will help us understand the exchange of heat and chemical elements running through the Bering Strait, and how those may have influenced Arctic and North Pacific environments. It also will help us understand how sea ice accelerates climate change, and how subpolar ecosystems respond to climate change."
—Christina Ravelo, Expedition 323 Co-Chief Scientist

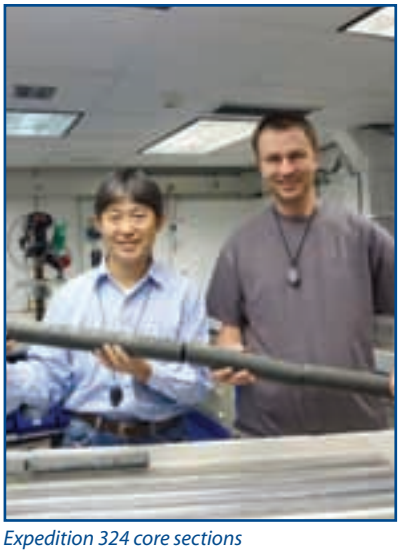
More online

IODP expedition pages: iodp.tamu.edu/scienceops/expeditions.html

IODP expedition reports: www.iodp.org/scientific-publications/



Describing core



Expedition 324 core sections

Logging Staff Scientists on the rig floor

Preparing a smear slide

Retrieving the beacon

Operational and Technical Support

Despite challenging circumstances during FY09, the USIO moved into IODP Phase 2 ready to support IODP expedition operations with an expanded array of tools and testing capabilities and improved data accessibility. Although shipyard delays and funding issues required careful prioritizing throughout the year, the USIO achieved significant goals in the areas of administrative and operational support, data management, and engineering and tool development and support. In addition, the USIO continued efforts toward Program integration and planning for the future.

New USIO Phase 2 business model

The USIO faced a business environment during FY09 that included shortfalls in anticipated funding exceeding 30% and an NSF directive for the USIO to cut costs and adjust staffing levels to match reduced science expedition schedules, increase efficiency to maximize science delivery within a reduced portfolio of science services, and build a foundation for industry-academic partnerships for use of the drillship when not funded by NSF. In response to these challenges, the USIO developed a more efficient and cost-effective Phase 2 business model to meet organizational objectives outlined by NSF and support delivery of the four expeditions planned for FY09.

Operational planning

USIO operational planning during FY09 included working with the Operations Task Force (OTF) to develop a revised FY09 operations schedule based on U.S. scientific ocean drilling vessel (SODV) progress, planning and staffing for IODP Phase 2 expeditions, and acquiring clearances needed for those expeditions.

Expedition planning and staffing

A new operations schedule was published in October 2009 based on a revised SODV delivery date of 25 January 2009 from the shipyard, with international operations commencing in March 2009. The USIO accommodated changes to the operations schedule with revised *Scientific Prospectuses* that reflected increased operations time for the Pacific Equatorial Age Transect program and incorporated Ancillary Project Letter 739, which added a microbiological program to the Bering Sea Paleoceanography Expedition. Science staffing was reevaluated based on the revised operations schedule, and the USIO

FY09 USIO expedition science staffing breakdown

Member country/consortium	Expedition 320	Expedition 321	Expedition 323	Expedition 324	Total
United States Science Support Program (USSSP)	8	8	8	8	32
Japan Drilling Earth Science Consortium (J-DESC)	7	9	8	8	32
ECORD Science Support and Advisory Committee (ESSAC)	9	7	8	8	32
Korea Integrated Ocean Drilling Program (K-IODP)	1	0	1	1	3
People's Republic of China (IODP-China)	0	1	1	1	3
Australia-New Zealand IODP Consortium (ANZIC)	1	0	1	1	3
India	0	1	1	0	2
Total Science Party participants	**26**	**26**	**28**	**27**	**107**

worked with Program Member Offices (PMOs) and Co-Chief Scientists to fill vacant Science Party positions. Science staffing for the rescheduled expeditions was completed during FY09.

Clearances

Territorial clearance was obtained to operate in Canadian and New Zealand waters for the Juan de Fuca cementing operations and the Canterbury Basin Expedition, respectively. Clearance from Russia to drill two primary sites during the Bering Sea Expedition was not obtained despite U.S. State Department efforts that continued into the expedition until it was no longer operationally feasible to occupy the sites.

Environmental assessment

A third-party company was contracted to produce an environmental assessment for seismic activities for the Bering Sea Expedition (although approval was not obtained in time), and approval was secured from the New Zealand Department of Conservation to use only USIO marine mammal observers during the Canterbury Basin Expedition.

Engineering and tool development and support

The USIO completed several engineering projects in FY09 and continued others, making significant progress with technology enhancements and providing tool support for others.

Technology enhancements

The USIO completed a number of technology enhancements in FY09 that will improve shipboard data acquisition and upgrade shore-based capabilities. Key accomplishments for the fiscal year are highlighted below.

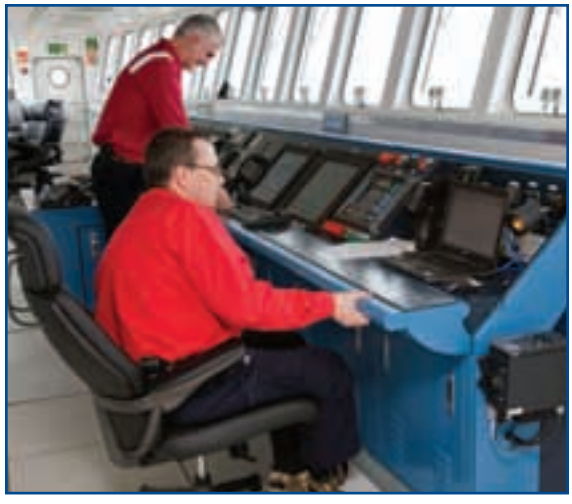
Advanced piston corer temperature tool model 3: Two advanced piston corer temperature tool model 3 (APCT3) tools were calibrated and sent to Singapore for use during the shakedown cruise of the *JOIDES Resolution* and the first IODP Phase 2 expeditions. The APCT3 tools were run several times during Expeditions 320 and 321, with very good results.

Working on drilling system

Common downhole data acquisition system: Common downhole data acquisition (CDAQ) systems were installed in two sediment temperature (SET) tools that were tested during Expedition 320T sea trials and deemed ready for deployment. CDAQ system firmware was enhanced for use in the sediment temperature (SET) and sediment temperature and pressure (SETP) tools, and two SET tools were deployed successfully during Expeditions 320 and 321.

Telemetry projects: The USIO-Schlumberger tool string interoperability project was successfully completed during Expedition 320T sea trials with a test in Hole U1330A where the magnetic susceptibility sonde was deployed in a Schlumberger tool string. This combination was also successfully deployed in Holes U1331A and U1332A.

In a related effort, the multifunctional telemetry module (MFTM) was completed and successfully bench tested with the Schlumberger telemetry



Bridge of the JOIDES Resolution

Geosciences Laboratory XRF core logger

systems. The MFTM is expected to eventually allow any combination of third-party tools to run in a Schlumberger tool string and log data through Schlumberger logging systems.

Wireline heave compensator system: The new wireline heave compensator (WHC) system was tested during Expedition 320T sea trials and subsequent IODP expeditions. During Expedition 320, the hydraulic valve controlling pressure to the WHC and the Schlumberger winch transmission failed and required immediate repairs during the Expedition 321 port call. Four Schlumberger engineers and two Electro-Wave engineers attended the Expedition 321 port call to implement the repairs, and hardware was shipped back to the respective manufacturers for detailed failure analyses. An Electro-Wave engineer sailed during Expedition 321 to provide engineering and software support for WHC testing, during which a robust analysis of downhole tool dynamics relative to ship surface movement led to extensive changes to the controlling software. Logging operations were successfully completed during Expedition 321, indicating that the repair efforts were successful.

Lockable flapper valve project: A Lockable Flapper Valve Task Force (LFVTF) was established to draw on the professional experience of others to explore different options of addressing the recurring problem of the lockable flapper valve (LFV) unlatching prematurely. The LFVTF comprises engineering personnel from LDEO and TAMU, Schlumberger logging engineers, Overseas Drilling Limited core technicians, and a consultant from Stress Engineering. Several new designs of the flapper on the LFV were generated during FY09 and the LFVTF began reviewing the designs.

Geosciences laboratory (ODASES): TAMU collaborated with the Texas A&M University College of Geosciences in selecting an X-ray fluorescence (XRF) core logger for the Ocean Drilling and Sustainable Earth Science (ODASES) Geosciences Laboratory at IODP-TAMU. The College of Geosciences purchased and arranged installation of the XRF core logger, and IODP staff were trained in its operation and maintenance. Ownership of this instrument will be transferred to IODP as part of the ODASES-IODP agreement.

Technical documentation and development

Using the technical documentation system developed in FY08, the USIO technical, editorial, and management staff continued to work together to produce IODP Phase 2 laboratory analytical user guides and technical systems documents for maintenance and repair.

Data management

The main data management projects for the USIO in FY09 were finalizing and deploying the

Inventory Asset Management System (AMS), implementing the Laboratory Information Management System (LIMS), integrating European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO) data into the log database, and implementing a mirror log database on board the *JOIDES Resolution*.

Inventory asset management system

The AMS was successfully deployed on the *JOIDES Resolution* during Expedition 320T. Some modules were used for the first time during sea trials (e.g., Shipping/Receiving, Inventory Update), and shipboard users identified problems that were quickly resolved. Users requested enhancements that were either implemented during sea trials or scheduled for completion at a later date. At the end of sea trials, the AMS application was deemed ready for work on future USIO expeditions.

LIMS database

The new LIMS database was implemented during the Expedition 320T transit from Singapore to Honolulu, Hawaii. Data from Expeditions 320T, 320, and 321 were collected and input into the shipboard database and then successfully transferred to shore, merged with the cumulative LIMS database, and made available online to participating scientists.

Log database

ESO and USIO personnel worked together to process Expedition 302 log data for inclusion in the new IODP log database. Center for Deep Earth Exploration (CDEX) and USIO staff continued discussions on reformatting CDEX data files to enable searches from the LogDB tools. In addition, USIO data from Expeditions 320T, 320, and 321 were fully processed for inclusion in the IODP database.

A mirror copy of the shore-based log database was installed on board the *JOIDES Resolution* to provide a local asset that scientists could use to search for logging data. Automatic synchronization of important data stored between ship and shore was implemented, and downloading procedures were streamlined and tested for both the shore-based and shipboard databases.

APCT3 downhole temperature tool

Program integration and support for others

During FY09, the USIO continued to collaborate with and support CDEX and ESO. The USIO uploaded into the Janus database all legacy core samples taken at the Kochi Core Center. In addition, the USIO calibrated and sent three APCT3 electronics sections to CDEX for deployment during Expedition 319. In support of CDEX Expedition 322, the USIO supplied SET and SETP tools, a colleted delivery system, and the services of one Engineer/Technician to deploy temperature and pressure tools.

Planning for the future

The USIO worked with IODP-MI and the other IOs to plan for the future through panel, task force, and PMO meetings throughout the year. The USIO also participated in Charting the Future Course of Scientific Ocean Drilling (CHART), an online workshop to gather input from the U.S. science community regarding future research directions of scientific ocean drilling, and the subsequent large international science planning meeting, IODP New

Passive heave compensator from the rig floor

More from the numbers

	Visitors hosted	Samples requested
Gulf Coast Repository	*145*	*18,408*
	Visitor sessions	**Query hits**
Janus Web database	*13,192*	*102,919*
Log Web database	*5,256*	*30,307*

Ventures in Exploring Scientific Targets (INVEST), in Bremen, Germany, in September 2009.

The purpose of INVEST was to define the scientific research goals of a new ocean drilling program, expected to replace IODP late in 2013. USIO staff attended the meeting, presented posters, and participated in discussions of both established and new research fields, such as the co-evolution of life and the planet, processes in Earth's core and mantle, climate change, and new approaches to capture and store CO_2 in Earth's crust. The outcome of the INVEST meeting will lead to a new science plan, enabling scientific ocean drilling to take on a central role in environmental understanding and stewardship of our planet in the 21st century.

More online

IODP expedition schedule: www.iodp.org/expeditions/

Core database: iodp.tamu.edu/database/

Log database: iodp.ldeo.columbia.edu/DATA/index.html

IODP core repositories: www.iodp.org/repositories/3/

IODP-USIO FY09 Quarterly Reports: iodp.tamu.edu/publications/AR.html

Rig floor

Command center for drilling operations: "the driller's shack"

Breaking the core shoe

Receiving core from the rig floor

JOIDES Resolution *at anchor*

School of Rock 2009

Broader Impacts

Sharing Integrated Ocean Drilling Program (IODP) contributions to promote a global understanding of Earth's ocean basins is a primary goal of the U.S. Implementing Organization (USIO), which continually seeks innovative and improved ways to expand the visibility of IODP as a cutting-edge international earth science research program to new and existing audiences. The USIO and Deep Earth Academy, of which the USIO is a partner, accomplished major advancement in support of this goal during FY09 through publications, education, and outreach efforts.

Publications

IODP scientific publications are the primary method of disseminating IODP research to the scientific community and the public. The extent of the impact of IODP publications can be inferred from the number of times Program publications were accessed online through the digital object identifier (DOI) system during FY09 (IODP publications were accessed more than 37,000 times and Deep Sea Drilling Program [DSDP] and Ocean Drilling Program [ODP] publications were accessed nearly 121,000 times). All DSDP, ODP, and IODP scientific publications are now available online, and the USIO provides print or electronic copies of legacy publications upon request. During FY09, the USIO distributed 859 IODP *Proceedings* volume DVDs and 95 DSDP/ODP publication volumes.

Program-wide scientific publications

FY09 marks the third year in which the USIO produced and published the *Scientific Prospectuses,*

More from the educators

"I keep thinking of how I will incorporate my experience on the JR into my classroom… I have plans to form a group of G/T [gifted/talented] or just generally interested 8th graders to do some N. pachyderma *analysis of our own, using samples I brought back, and incorporating a field trip to the Gulf Coast Core Repository. But I'm also wondering if I could sustain a "JR year," where everything we do (as mandated by state standards) could be connected back to the science found on the JR… The ultimate goal would be to increase student learning by making connections between what we have to learn, and why it is interesting in the real world."*
—Elizabeth Abernathy, 8th grade teacher, Austin, Texas

"Participating in the School of Rock on the JOIDES Resolution *was an experience beyond my expectations... I learned many aspects of the whole scientific operation which complement and enhance each other including: oceanography, micropaleontology, plate tectonics, ocean-floor hydrology, analytical and instrumental methods for core analysis, the process of conducting large scientific endeavors, the lives of scientists and crew and tangential skills that are necessary for large scientific endeavors to operate. As a scientist, often I don't see how these things connect, but they become very apparent while on board the* JOIDES Resolution. *I think IODP and Deep Earth Academy offer a once-in-a-lifetime opportunity for earth science educators to immerse themselves in ocean drilling operations and marine science. The experience brings a sense of excitement and wonder for the world around them, which will certainly translate into an engaged classroom."*
—Patricia Cleary, Assistant Professor of Geosciences, University of Wisconsin-Parkside

Preliminary Reports, Expedition Reports, and data report contributions to the Proceedings of the Integrated Ocean Drilling Program volumes for all three IODP implementing organizations (IOs), successfully integrating IODP publication services Program-wide.

In addition to the NanTroSEIZE Stage 1 *Proceedings of the Integrated Ocean Drilling Program* volume, which incorporates expedition reports from Expeditions 314, 315, and 316, the USIO produced and updated Phase 2 *Scientific Prospectuses* for the USIO, European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO), and Center for Deep Earth Exploration (CDEX); coordinated postexpedition research publications; published *Preliminary Reports* for USIO Phase 2 expeditions, and published data reports for all USIO and ESO Phase 1 expeditions.

NanTroSEIZE Stage 2 publications support

The USIO provided both shipboard and shore-based publications support for CDEX NanTroSEIZE Stage 2 expeditions this year. The USIO sent Publications Assistants to the riser drillship *Chikyu* to coordinate shipboard reports during CDEX's first three IODP expeditions during FY08, and CDEX requested that the USIO provide similar publications support services during the FY09 CDEX NanTroSEIZE Stage 2 expeditions. An IODP Publications representative participated in related pre-expedition planning meetings, and Publications Assistants from the USIO participated in CDEX Expeditions 319 and 322.

The USIO and CDEX negotiated a training arrangement wherein a Marine Works Japan (MWJ) shipboard technician will train at the IODP Publications office at TAMU for a minimum 6-month period to learn about IODP seagoing and shore-based publications responsibilities. CDEX and MWJ representatives made a site visit to College Station, Texas, in August 2009 and scheduled the MWJ technician's training to begin in October 2009.

Education

The USIO, through Deep Earth Academy, continued to create and refine methods for educating others about Earth's structure and history as understood through ocean basin

School of Rock 2009 participants

School of Rock 2009

School of Rock 2009

exploration. USIO representatives conducted outreach at 30 workshops, conferences, and other events; worked to develop and strengthen ongoing relationships with national and international museums; and distributed thousands of educational materials, reflecting a 25% increase in orders over 2008. FY09 activities that may have the most far-reaching impacts include the new JOIDES Resolution Web page production and social networking efforts, videos and videoconferencing advances, the shipboard School of Rock workshop, and Teacher-at-Sea and Historically Black Colleges and Universities (HBCU) Educator-at-Sea programs.

Social networking and joidesresolution.org

Major efforts this year were devoted to developing and populating the new Web page, *JOIDES Resolution:* Exploring Beneath the Ocean Floor (joidesresolution.org), which showcases the new *JOIDES Resolution* and targets a broader audience of teachers, students, and families. The joidesresolution.org site has seen steady growth in visitors and page views. The site debuted during the second quarter of FY09, and page views and site visits had increased by more than 70% by the end of the fourth quarter.

The joidesresolution.org site provides background information on the ship and its role in science research, as well as details about its capabilities. Additional features of the site include regularly updated blogs from sea, photos, and engaging videos that record the story of the expeditions; interactive features such as games, polls, and opportunities to comment on blogs or send questions to scientists; and links to Ocean Leadership and *JOIDES Resolution* pages on social media sites YouTube, Twitter, Flickr, TeacherTube, and Facebook, all of which have rapidly growing fan bases. The site also features exciting new educational materials such as a papercraft model of the *JOIDES Resolution* for use with museum programs, a beach-ball globe for use in conjunction with the Web page to track the ship and mark its location, and a series of graphic novel–style comic books about the *JOIDES Resolution*.

Videos and videoconferencing

A professional videographer sailed during the second Pacific Equatorial Age Transect (PEAT) Expedition and recorded the story of the expedition in a ten-part video series framed as PEAT News Network (PNN). The series brought humor and excitement to the science of the expedition while educating a broad audience about the PEAT science objectives, core flow on the ship, postexpedition sampling and core handling, life at sea, the drilling process, and more. The videos are available at joidesresolution.org and the Ocean Leadership YouTube channel.

Port call tour

Ship tour during Return to Operations celebration

The USIO provided regular ship-to-shore programming (video broadcasts) to schools and museums. At least 30 live broadcasts were facilitated by USIO staff and educators at sea and made possible through a partnership with IOCOM, Ocean Leadership's video conferencing provider. IOCOM agreed to supply free software and technical support for any collaborating school or institution.

School of Rock 2009

"School of Rock 2009: Cores, CORKS, and Hydrology on the Juan de Fuca Ridge," the first shipboard workshop since the inaugural School of Rock 2005, took place during the Expedition 321T transit from San Diego, California, to Victoria, British Columbia, Canada. Participants in this workshop included 11 teachers from the United States, 2 from Japan, and 1 each from France and Portugal. This was the first School of Rock workshop to include international participants, who were selected by their respective implementing organizations (IOs) in Japan and Europe. This integrative effort set a precedent for Program-wide participation in future workshops.

This year's workshop curriculum focused on subseafloor observatories in Holes U1301A and U1301B and the hydrogeologic, monitoring, and sampling experiments conducted there. The transit and cementing operations allowed plenty of time for an immersive introduction to 100 cores and data from 42 sites (mostly eastern Pacific) and the workings of the *JOIDES Resolution*. Teachers worked in teams to access and analyze data, sample cores, conduct investigations, and discuss their conclusions. The workshop also provided teachers with time to brainstorm and begin planning classroom activities and outreach events based on their research and new knowledge.

Shipboard educators promoting IODP science

A high-school physics teacher from Atlanta, Georgia, sailed as Teacher at Sea during the Bering Sea Expedition. During the Shatsky Rise Expedition, an instructor from the University of the Virgin Islands Center for Marine and Environmental Studies sailed as HBCU Educator at Sea and a Japanese educator from the Museum of Nature and Science in Tokyo sailed as Museum Educator.

The USIO made great strides in promoting IODP science to a broader audience by expanding the role of teachers and museum educators who sailed as participants during the Bering Sea Paleoceanography and Shatsky Rise Formation expeditions. In addition to creating expedition-related educational materials for use in shore-

More from the numbers

Web sites	Site visits	Page views
U.S. Implementing Organization	*231,900*	*1,010,800*
ODP legacy	*762,883*	*3,819,674*
DSDP legacy	*109,446*	*461,953*
IODP publications	*85,903*	*286,746*
Deep Earth Academy	*29,852*	*42,024*
JOIDES Resolution	*20,084*	*90,989*
Total Program-related Web sites	**1,240,068**	**5,712,186**

based classrooms, the educators were charged with such tasks as managing joidesresolution.org Web site content; blogging and facilitating blog entries from expedition participants; conducting videoconferences with classrooms and museums; and posting photos, comments, and video entries to *JOIDES Resolution* social networking sites.

The first HBCU Educator at Sea sailed during the Shatsky Rise Formation expedition to help the USIO reach out to HBCU institutions and minority-serving teachers and their students (eighth grade and high school). Through educational outreach activities that included conducting live videoconferences to HBCU institutions, the HBCU Educator at Sea raised the profile of the Ocean Leadership HBCU Fellowship and career opportunities in scientific ocean drilling for HBCU students and promoted IODP science and the *JOIDES Resolution* as ideal vehicles for earth systems science education.

Outreach

USIO outreach activities served a critical role in publicizing specific IODP achievements and scientific ocean drilling in general through publications and events geared to raise public and media awareness. Nearly 20 news releases were distributed in FY09 to keep the media and public informed of IODP activities and achievements. Forums including the American Association for the Advancement of Science (AAAS) Meeting and the 15th Annual Coalition for National Science Funding (CNSF) Capitol Hill Reception and Exhibition provided opportunities for the USIO to engage the science and political communities in IODP research. In addition to congressional outreach, key outreach activities in FY09 focused on publicizing the progress and completion of the U.S. Scientific Ocean Drilling Vessel (SODV) Project, the *JOIDES Resolution*'s return to operations, and Phase 2 expeditions.

Congressional outreach

FY09 congressional outreach included an IODP overview and Gulf Coast Repository tour for a staffer in Texas Congressman Chet Edwards' office. IODP scientists conducted Congressional Hill visits after the Coalition for National Science Foundation Capitol Hill Reception and Exhibition, and the USIO held a policy panel for the Marine Geoscience Leadership Symposium that featured policy makers from Congress and the Office of Management and Budget. USIO representatives also briefed U.S. Advisory Committee for Scientific Ocean Drilling (USAC) members regarding all upcoming outreach activities, set up a meeting with the Office of Science and Technology Policy (OSTP) regarding the Ocean Research Priorities Plan, and briefed the Ocean Policy Task Force at the Council on Environmental Quality.

SODV outreach

The USIO produced an updated version of the brochure *"Overhaul and Enhancement*—JOIDES Resolution" and a series of videos focused on SODV conversion progress and upcoming USIO expeditions that were key components of FY09

outreach activities. The videos were displayed at high-profile conferences, including the 2008 Geological Society of America (GSA) Joint Meeting and the American Geophysical Union (AGU) Fall 2008 Meeting, and online on the Ocean Leadership YouTube channel, which gained a loyal following. USIO staff also developed a series of graphic novel–style comic books about the *JOIDES Resolution* featured on joidesresolution.org that educated a broader audience about the ship's renovation and return to operations, and USIO representatives published an article on the SODV's return to operations in IODP-MI's journal, *Scientific Drilling*.

Port call outreach: return to operations

Outreach activities were conducted at each port call following the Expedition 320T sea trials, beginning with ship tours for University of Hawaii faculty and students during the Expedition 320 port call and a celebration of the widely publicized return to scientific ocean drilling during the Expedition 321 port call, both in Honolulu, Hawaii. Media placements for the Expedition 321 port call included two Honolulu newspapers and one Honolulu television station. Festivities included a reception at the Waikiki Aquarium hosted by the National Science Foundation (NSF), the USIO, and the University of Hawaii at Manoa's School of Ocean and Earth Sciences and Technology (SOEST). Representatives from NSF, IODP member countries, the University of Hawaii, and local community and business leaders attended the ship's rededication event at Honolulu Harbor, which included a Hawaiian blessing of the ship, a press conference, and guided ship tours for more than 125 visitors. Related educational activities included a science lecture, a career-focused workshop for high-school students, and a workshop for teachers. During the port call events, the USIO distributed an array of promotional items designed to celebrate the *JOIDES Resolution*'s return to international scientific operations.

USIO representatives gave tours to faculty and students from The Scripps Research Institute during the Expedition 321T port call in San Diego, California, and 130 oceanography students and faculty from the University of Victoria and Royal Roads University and staff from Natural

"Polarpalooza"

Videoconference from the JOIDES Resolution

Resources Canada toured the *JOIDES Resolution* during the Expedition 323 port call in Victoria, British Columbia, Canada. Related press releases promoted the School of Rock and Teacher-at-Sea educational programs.

During the port call for Expedition 324 in Yokohama, Japan, USIO staff conducted ship tours for approximately 150 visitors from the National Museum of Nature and Science; Japan Agency for Marine-Earth Science and Technology (JAMSTEC)/CDEX; Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT); Kyushu University; Tokyo University of Marine Science and Technology; The University of Tokyo; Ibaraki University; Tokyo Institute of Technology; and the Agency for Natural Resources and Energy. Additionally, an NSF-led ship tour was conducted for staff from the U.S. Embassy and the NSF Tokyo Regional Office. Media placements for the Expedition 324 port call in Yokohama, Japan, included *Science, Scientific American, Ships of the World,* three Japanese newspapers, and a Japanese television station. Related press releases promoted the first HBCU Educator at Sea to sail on an IODP expedition.

More online

IODP scientific publications: www.iodp.org/scientific-publications/

IODP-USIO FY09 Quarterly Reports: iodp.tamu.edu/publications/AR.html

IODP-USIO FY09 Annual Program Plan: iodp.tamu.edu/publications/PP.html

2009 Ocean Drilling Citation Report: iodp.tamu.edu/publications/citations/AGI_study.pdf

Deep Earth Academy: www.oceanleadership.org/education/deep-earth-academy/

JOIDES Resolution*: www.joidesresolution.org/*

School of Rock teacher workshops: www.iodp-usio.org/Education/SOR.html

HBCU Fellowship program: www.oceanleadership.org/education/diversity/hbcu-fellowship/

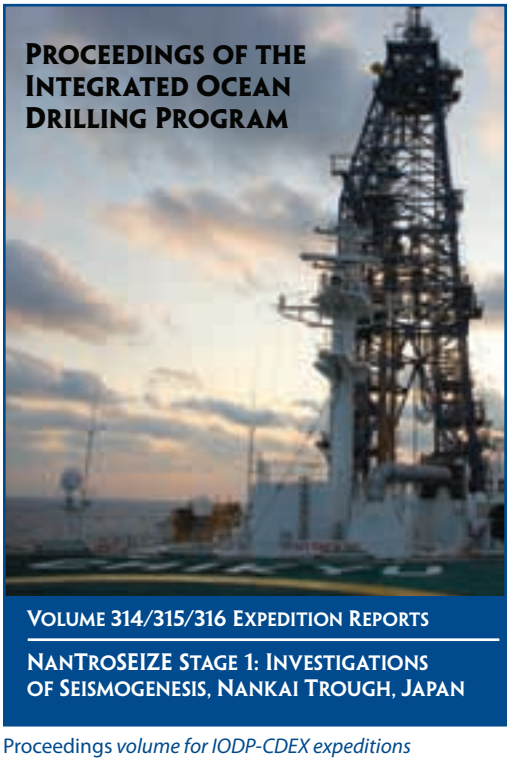
HBCU Educator-at-Sea program: www.oceanleadership.org/education/diversity/hbcu-educator/

USIO Newsroom: www.iodp-usio.org/Newsroom/default.html

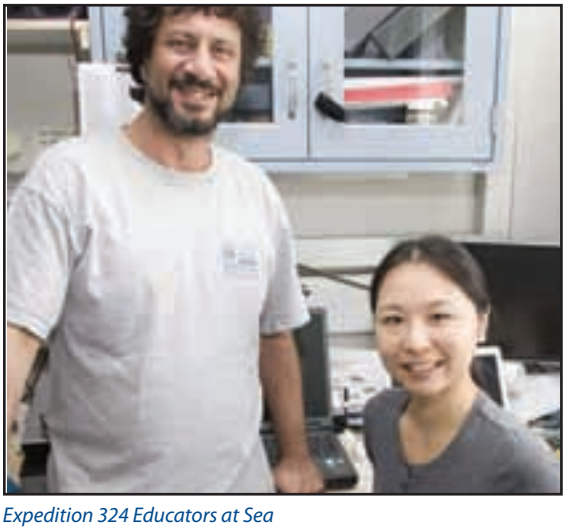
Tales of the Resolution: *www.ldeo.columbia.edu/BRG/outreach/media/tales/index.html*

USIO videos: www.youtube.com/user/OceanLeadership

Tales of the Resolution*: an educational outreach comic series*



Proceedings *volume for IODP-CDEX expeditions*



Expedition 324 Educators at Sea

Return to operations logo

Core archive halves aboard ship

Rig floor

Contractual and Financial Overview

IODP is funded by several entities acting as international partners. The U.S. National Science Foundation (NSF) and Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) are lead agencies, and ECORD is a contributing member. Associate members include the People's Republic of China Ministry of Science and Technology (MOST); the Interim Asian Consortium, represented by the Korea Institute of Geoscience and Mineral Resources (KIGAM); the Australian Research Council (ARC) and New Zealand Institute for Geological and Nuclear Sciences (GNS), Australian/New Zealand Consortium; and the Ministry of Earth Sciences (MoES), India.

The USIO provides all deliverables through contracts with NSF for platform operating costs (POC) and with IODP Management International, Inc. (IODP-MI) for science operating costs (SOC). The commingled funds that make up the SOC budget come from IODP-MI's international partners as part of their membership fees used to fund IODP science. POC funds for each implementing organization are the responsibility of the agency supplying the platform capability.

USIO contractual relationships

The U.S. Implementing Organization (USIO) was formally established in 2003 when Ocean Leadership, formerly known as Joint Oceanographic Institutions, established subcontracts with Lamont-Doherty Earth Observatory (LDEO) of Columbia University and the College of Geosciences at Texas A&M University (TAMU) through Texas A&M University Research Foundation (TAMRF). Each of the three USIO institutions (Ocean Leadership, LDEO, and TAMU) provides fiscal and contractual administration, and the organizational structure employed by the USIO accommodates the work breakdown element accounting structure used by IODP. This structure also aligns the organization to efficiently and economically provide the full array of USIO deliverables.

USIO prime contractor

As the U.S. Systems Integration Contractor, Ocean Leadership is ultimately responsible to NSF and IODP-MI for overall program leadership; technical, operational, and financial management; and delivery of services for the *JOIDES Resolution* and related activities. Ocean Leadership leads long-term planning development for the USIO and represents the USIO and the Program as a whole, when appropriate.

USIO subcontractors

LDEO and TAMU contribute distinct but complementary capabilities that directly support the full range of scientific and technical activities necessary for implementing a scientific riserless drilling program. LDEO is responsible for logging-related shipboard and shore-based science services and technological support and for leading an international logging consortium to participate in scientific ocean drilling operations. LDEO provides downhole logging equipment and engineering support through a contract with Schlumberger.

TAMU is responsible for providing services directly related to the scientific and engineering activities necessary to support science cruises (vessel and drilling operations and ship- and shore-based science laboratories), as well as managing expedition-related shore-based functions (data management, core curation, and publications). Administrative services in support of TAMU activities are provided by TAMRF. On behalf of the USIO, TAMRF contracts with Ocean Drilling Limited (ODL) for the services of the *JOIDES Resolution,* the riserless drilling vessel for USIO operations.

Waiting for core

USIO FY09 Annual Program Plan and Appendix

FY09 USIO contractual requirements for SOC and POC funds are outlined in the IODP-USIO FY09 Annual Program Plan; U.S. Systems Integration Contract costs (SIC) are outlined in the Appendix to the FY09 Annual Program Plan.

The Annual Program Plan and Appendix set forth the goals of the USIO, the scope of USIO work for IODP deliverables, definitions of projects, and details of required budgets that incorporate funding allocations from NSF or IODP-MI for science operations and from NSF for platform operations and U.S.-sponsored tasks (education and outreach efforts and associated management and administrative support).

The complex nature of IODP operations requires Annual Program Plans spanning operational years to establish priorities and allow procurement of long–lead time equipment and services. The FY09 Annual Program Plan was based on (1) the mission forecast provided on 29 April 2008 for the USIO by NSF and IODP-MI and (2) the USIO operations schedule that was approved by the Operations Task Force (OTF) and Science Planning Committee (SPC). The USIO operations schedule included costs associated with the necessary planning and purchase of long–lead time items and additional items to support expeditions scheduled for FY10. Project delays in the Singapore shipyard where SODV conversion took place resulted in revisions to the FY09 operations schedule and, consequently, multiple iterations of the FY09 Annual Program Plan. The final version was accepted in April 2009, seven months into the fiscal year.

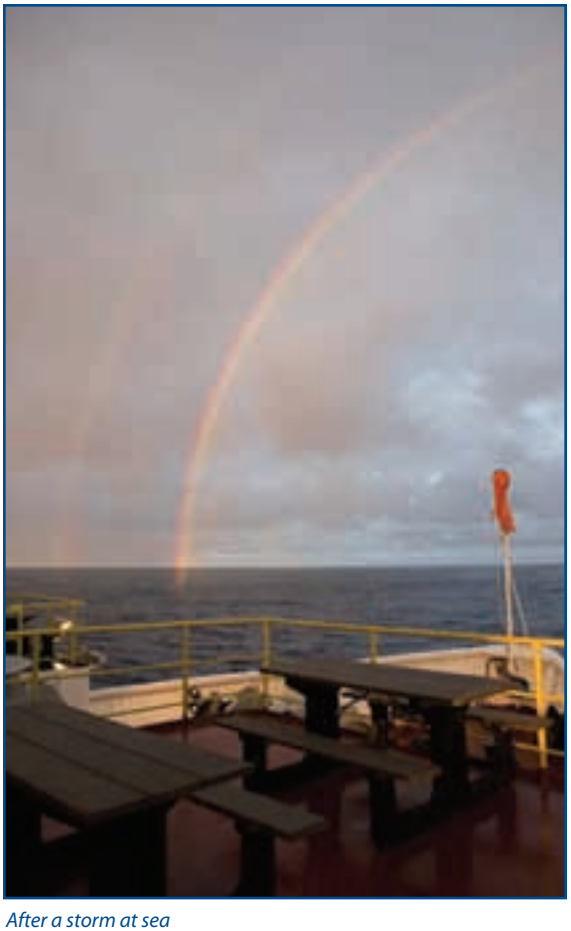
Financial tables

The following financial tables provide a detailed overview of the FY09 IODP-USIO Annual Program Plan budget, FY08 carryforward of obligated and unobligated funds, budget modifications that took place throughout the fiscal year, expenditures that were made to execute the Annual Program Plan, and end-of-year totals of obligated and unobligated funds pending approval for transfer to FY10.

These tables individually represent

- IODP-USIO FY09 end-of-year financial summary, which encompasses SOC, POC, and SIC budgets for the USIO with detail provided for each USIO institution (Ocean Leadership, LDEO, and TAMU);
- IODP-USIO FY09 end-of-year summary for the POC budget;
- IODP-USIO FY09 end-of-year summary for the SIC demobilization budget (for additional U.S.-sponsored activities funded by NSF);
- IODP-USIO FY09 end-of-year summary for the SIC nondemobilization budget (for additional U.S.-sponsored activities funded by NSF);
- IODP-USIO FY09 end-of-year summary for the SOC (NSF and IODP-MI) budget; and
- IODP-USIO FY09 end-of-year summary for the SOC Nonoperations (IODP-MI only) budget.

Stairway to the rig floor

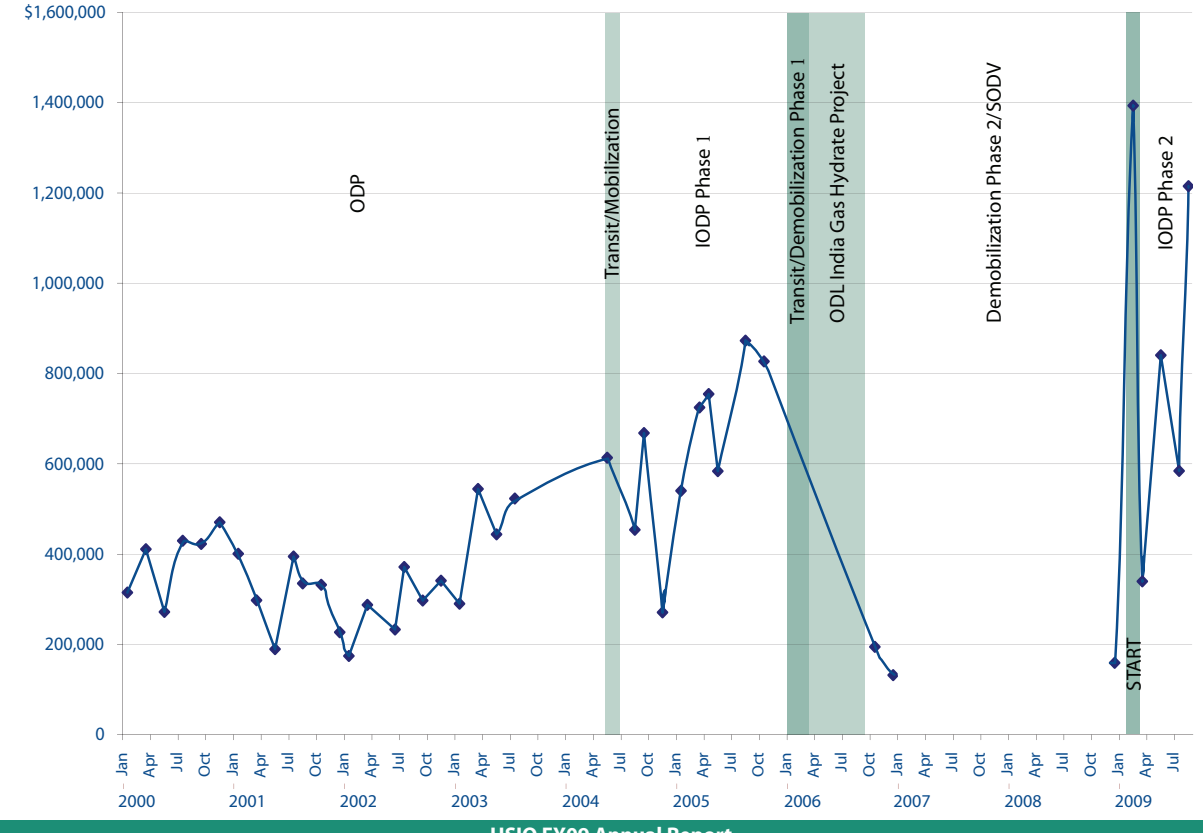


After a storm at sea

Handling a core

Pilot's window on a JOIDES Resolution *lifeboat*

Actual fuel cost FY00–FY09



Please contact info@oceanleadership.org for hard copies of the financial pages (pages 45–65).

Core boat for Natural Gamma Ray Logger

JOIDES Resolution, ***Yokohama, Japan***

FY09 Annual Report

Integrated Ocean Drilling Program
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NSF

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