Oceanographic Research and Deepwater Oil and Gas Operations

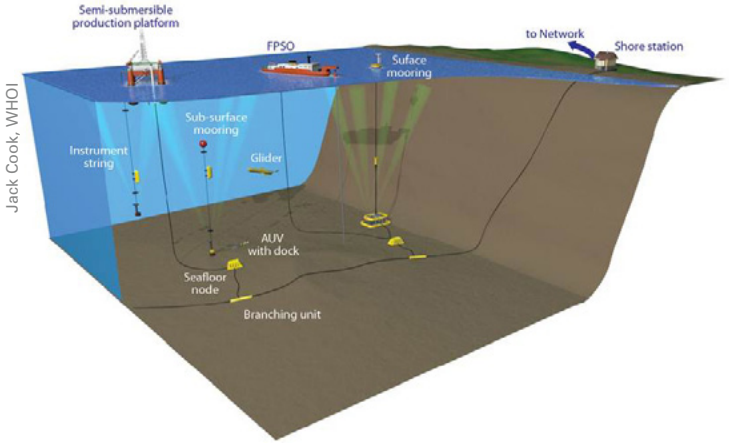
at Woods Hole Oceanographic Institution

The offshore oil and gas industry operates in deep water and harsh environments. Many production facilities in the Gulf of Mexico, West Africa and Brazil currently operate in water depths exceeding 2,000 meters, with more being developed or deployed around the world, including in high latitudes. Traditionally, oceanographic research activities help such developments meet permit requirements and support infrastructure design, construction, and operations. The *Deepwater Horizon* oil spill demonstrates the need for basic oceanographic research to fulfill an expanded role, with objectives that include:

- Establish a baseline of knowledge specific to individual sites and potential impact areas
- Proactively characterize physical, chemical, and biological settings
- Provide data to support analyses and modeling of potential events
- Support the development and maintenance of relevant expertise, tools, and processes
- Support ongoing training of industry personnel and first responders
- Establish protocols for handling physical samples and data
- React to an event in a manner that is timely, comprehensive and meets the requirements of the various stakeholders

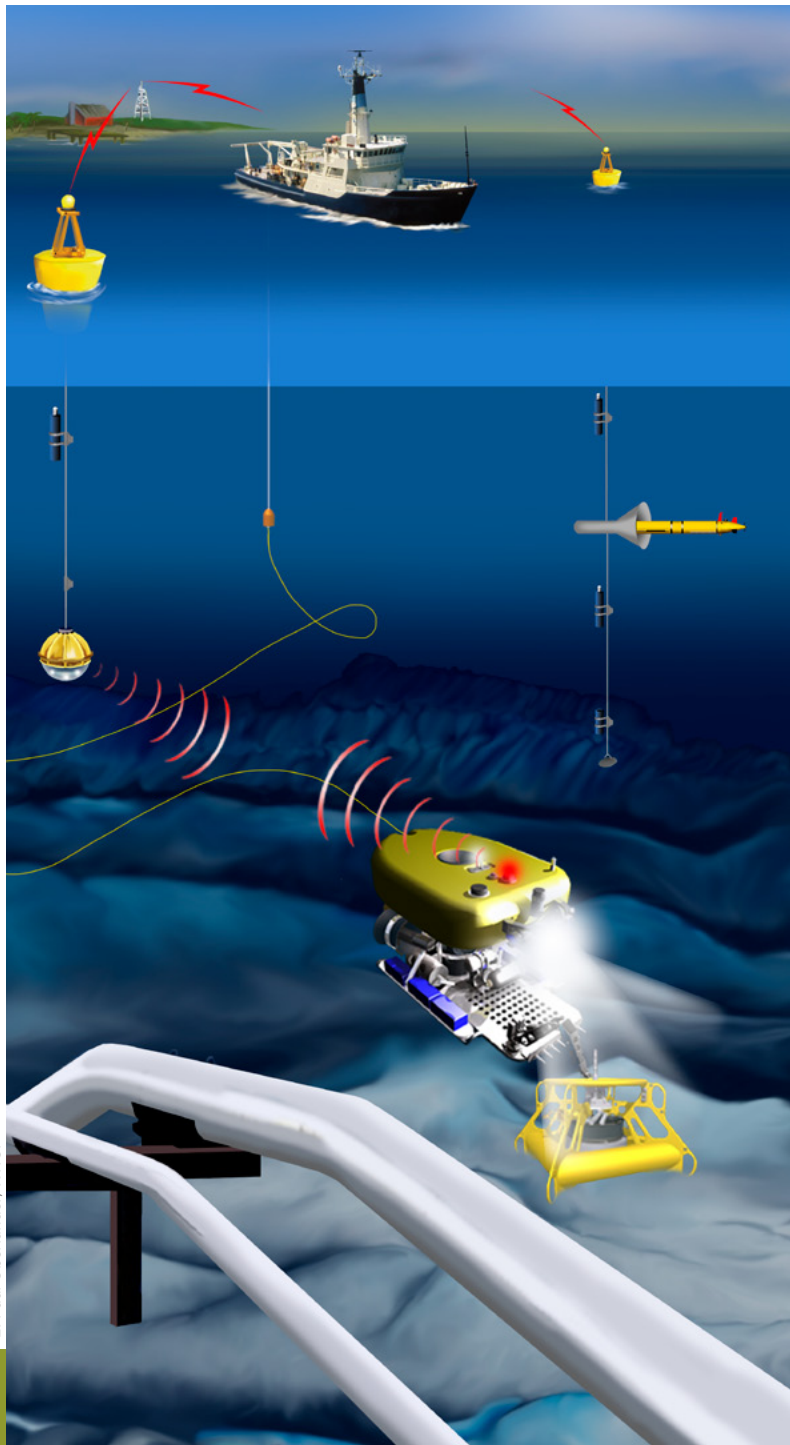
The scientists and engineers at the Woods Hole Oceanographic Institution (WHOI) have made many of the discoveries that underlie what is currently known about the ocean and its interaction with the planet's atmospheric, terrestrial, biological, and human systems. This basic capability has been applied for over four decades to hydrocarbons in seawater, whether naturally occurring in seeps, hydrothermal vents, or mud volcanoes, or as a result of human activity. WHOI is also a leader in research in the deep ocean and the high latitudes and has both the expertise and the tools to conduct oceanography in the harshest environments.

WHOI has developed ocean observing networks that provide continuous baseline monitoring and real time data communication which can be autonomous or incorporated into existing infrastructure.



Jack Cook, WHOI

WHOI's deep submergence program includes an untethered remotely operated vehicle (UTROV) that will open new frontiers of oceanography, exploration and intervention.



E. Paul Oberlander, WHOI

ABOUT WHOI

The Woods Hole Oceanographic Institution (WHOI) is a private, non-profit institution dedicated to research and education in the ocean sciences and engineering. Founded in 1930, WHOI has grown to a staff of 1,000 and an operating budget of $200 million. Operations are funded by the U.S. Government, foundations, industry, and private donations.

WHOI is distinguished by its singular focus on ocean science and by the independence with which its scientists and engineers pursue their research. This focus allows WHOI to maintain an unparalleled depth and breadth of scientific and technical talent in oceanographic research and education as well as a reputation for objective, unbiased scientific research. The Institution combines a unique complement of assets including world-leading scientists who study many of the most pressing and complex questions about the relationship between humans and the oceans, innovative engineers who invent and deploy leading-edge tools and technology, and research vessels and deep-submergence vehicles that provide unparalleled access to the sea.

WHOI's preeminence in ocean research spans all areas of marine science and engineering through five principal departments: Applied Ocean Physics and Engineering, Biology, Geology and Geophysics, Marine Chemistry and Geochemistry, and Physical Oceanography. The Institution also operates four interdisciplinary institutes—Ocean and Climate Change, Coastal Ocean, Ocean Life, and Deep Ocean Exploration, as well as the Marine Policy Center and the Woods Hole Center for Oceans and Human Health.

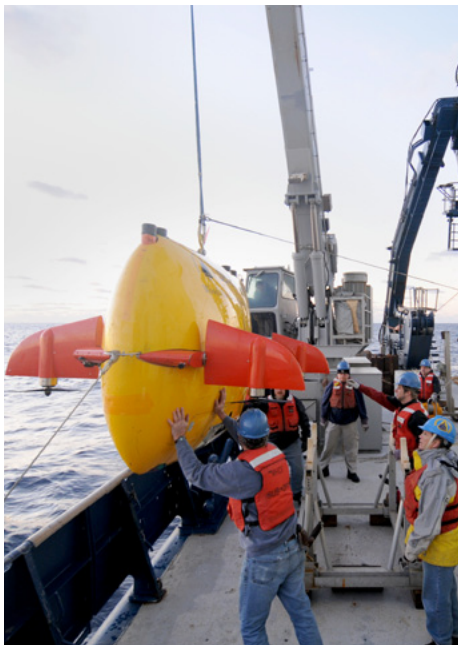
WHOI's engineering and seagoing capabilities have historically presented unmatched tools and methods facilitating ocean science research. Today, the Institution operates two ocean-going research vessels, the R/V *Atlantis and* R/V *Knorr*, as part of the University-National Oceanographic Laboratory System (UNOLS) and the coastal research vessel R/V *Tioga*. WHOI is also home to the National Deep Submergence Facility (NDSF), which operates deep-sea exploration vehicles for the benefit of the entire U.S. oceanographic community and includes the U.S. Navy-owned human occupied vehicle (HOV) *Alvin,* the remotely operated vehicle (ROV) *Jason* and the autonomous underwater vehicle (AUV) *Sentry*. In addition, WHOI has developed and operates a wide range of next-generation vehicles such as the REMUS-class AUVs.

WHOI occupies more than 50 buildings on two campuses in the Woods Hole village of Falmouth, Massachusetts. The Village Campus houses laboratories, shops and marine facilities, including nearly 700 feet of deep-water berthing. The Quissett Campus is a major complex of laboratories and administrative offices that house such world-leading assets as the National Ocean Sciences Accelerator Mass Spectrometry Facility, the Northeast National Ion Microprobe Facility, a dedicated computed tomography (CT) scanning facility for marine mammal research, and a deep-sea sediment core repository. WHOI also hosts extensive on-site capability for the design, fabrication, and testing of oceanographic instrumentation.

As part of its educational mission, WHOI conducts a joint graduate program with the Massachusetts Institute of Technology, conferring degrees in oceanography and applied ocean science and engineering. Alumni of WHOI have gone on to become international leaders in oceanography and regularly return to campus as visiting scholars or for international symposia and colloquia.

Ken Kostel, WHOI

WHOI's deep-submergence capability includes autonomous, remotely operated and human-occupied vehicles, all of which were deployed to the Gulf of Mexico in response to the *Deepwater Horizon* oil spill.



Ken Kostel, WHOI

***Sentry*, a fully autonomous underwater vehicle capable of exploring the ocean down to 4,500 meters (14,764 feet), carries the TETHYS mass spectrometer and has been used to locate and quantify hydrocarbon seeps and the *Deepwater Horizon* plume.**

HYDROCARBONS IN THE OCEAN

WHOI scientists and engineers have developed a suite of tools and methods to detect, measure, sample, map, and analyze oil and gas compounds that naturally occur in the ocean. These have enabled researchers to characterize oil and gas seeps off Southern California and in the Gulf of Mexico, as well as methane from mud volcanoes and hydrothermal vents.

One of these instruments, the TETHYS mass spectrometer can be deployed on an AUV and enables real-time mapping and analysis of oil-contaminated water. WHOI researchers have also developed a device that retains the ambient pressure of fluid samples for laboratory analysis, and have devised sensors to measure the flow rate at hydrothermal vents that provided precise estimates of oil and gas flowing from the *Deepwater Horizon* (DWH). Our analytical capabilities include the Fourier Transform Mass Spectrometer Facility, which enables ultra-high resolution measurements of the water-soluble components of oil, and a two-dimensional gas chromatography lab devoted to studying the long-term fate of hydrocarbons in the environment.

Since 1969, WHOI has been the lead organization studying the effects of oil spilled from the barge *Florida* in Buzzards Bay. The assessment and monitoring effort developed in response to this event is considered a model for studying the long-term fate and impacts of oil in the marine and coastal environments. Since then, WHOI scientists have been called upon to study and monitor physical, chemical, and biological characteristics of spills in diverse environments and conditions, including those from the *Exxon Valdez, Prestige, Cosco Busan* and *Hebei Spirit*. This enabled WHOI to make significant contributions to the National Research Council's report *Oil in the Sea III* and to play a leadership role in developing industry and academic best practices in responding to oil spills.

WHOI provided a significant response to the *Deepwater Horizon* oil spill, leveraging expertise from every department, including numerous deployments to the Gulf of Mexico and considerable laboratory analysis in Woods Hole. The National Incident Command repeatedly drew upon WHOI's unique deep submergence assets and capabilities during *Deepwater Horizon* assessment and containment operations.

WHOI 2010 RESPONSE TO *DEEPWATER HORIZON*

Project	Sponsor	Objective
Hydrography	NOAA	Collected hydrographic samples to map oil in the water column from the NOAA research vessel R/V *Thomas Jefferson.*
Flow-Rate Measurements	USCG	Made precision flow-rate measurements from the DWH leak sites—measurements currently being used by the U.S. government in official oil spill estimates.
Current Measurements	NSF-RAPID	Conducted long-term mapping and monitoring of the Gulf Loop Current and eddies using the Spray glider.
Sample Collection	USCG	Using an instrument developed to collect fluids from hydrothermal vents, obtained and analyzed the only existing end-member fluid (oil and gas) samples retrieved from the DWH blowout preventer and riser pipe.
Plume Mapping	NSF-RAPID	Mapped the DWH plume using AUV *Sentry* equipped with TETHYS mass spectrometer. Augmented the TETHYS data with traditional oceanographic sampling to study plume composition and potential toxicity.
Oil Droplet Imaging	NSF-RAPID	Using a holographic imaging system developed to study plankton, photographed oil droplets suspended in the water column to help refine oil plume transport models.
Seabed Imaging	IEC	Gathered 100,000 images of the seafloor using the towed vehicle Seasled to study deepwater benthic habitats.
Laboratory Analysis	NSF	Analyzed seawater samples from various cruises for soluble components of crude oil dispersant using an ultra-high resolution mass spectrometer tuned specifically for environmental sample analysis.
Sediment Flux Analysis	NSF-RAPID	Expanded an existing, long-term study of particulates settling to the ocean bottom by quickly deploying additional instruments to the seafloor in the vicinity of the DWH.
Oceanography	NSF	Operated the R/V *Oceanus* and deployed a suite of traditional oceanographic tools and sensors in the vicinity of the DWH.
Seafloor Imaging and Sampling	NOAA	Deployed the ROV *Jason* from the NOAA vessel R/V *Ron Brown* to collect high-resolution images and to sample deepwater benthic environments in the vicinity of the DWH.
Seafloor Imaging and Sampling	NSF	Operated the R/V *Atlantis* near the DWH to deploy HOV *Alvin* to map and photograph the seafloor and sample deepwater benthic environments.

SPECIALIZED TOOLS AND TECHNIQUES

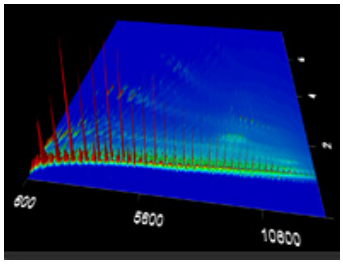
VEHICLES

AUV *SENTRY*
An autonomous underwater vehicle (AUV) developed at WHOI and used to study the composition of oil in seawater.

SPRAY GLIDER
An autonomous ocean developed at WHOI that moves through the water without external propulsion and used to track currents in the Gulf.

MEASUREMENT AND ANALYSIS

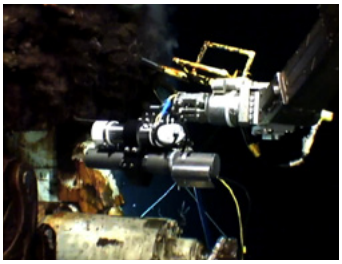
TETHYS MASS SPECTROMETER
A compact mass spectrometer developed at WHOI used to do *in-situ* chemical analysis of oil in seawater.



TWO-DIMENSIONAL GAS CHROMATOGRAPHY (GCxGC)
A relatively new analytical technique, GCxGC is able to provide high resolution data of complex samples or of materials in complex mixtures.

FOURIER-TRANSFORM ION CYCLOTRON RESONANCE MASS SPECTROMETER (FT-ICR-MS)
An ultra-high sensitivity mass spectrometer capable of detecting small quantities of a substance in complex samples and used to measure the fate of dispersants in Gulf waters.

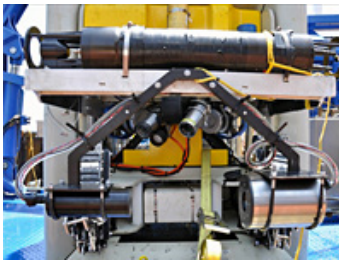
SAMPLING AND COLLECTING



ISOBARIC GAS-TIGHT SAMPLER
Originally designed to sample fluids issuing from hydrothermal vents—and to keep those fluids at their native pressure—this device was used to make the only original samples of oil and gas flowing from the ruptured *Deepwater Horizon* well.

SEDIMENT TRAP
Sediment traps are containers that scientists place on the seafloor or in the water column to collect particles falling down from above.

IMAGING



HOLOGRAPHIC IMAGING SYSTEM (HoloPOD)
A tool used to photograph and study microscopic and macroscopic life in the ocean and adapted to capture images of oil droplets and marine plankton in the Gulf plume.

VIDEO PLANKTON RECORDER (VPR)
An underwater video microscope system that takes images of plankton and particulate matter as small as 50 microns and up to a few centimeters in size.

CONTACTS

OFFSHORE OIL & GAS PROGRAM

Mr. Rob Munier
Vice President
Marine Facilities and Operations
rmunier@whoi.edu
508 289 3335

DIRECTOR OF RESEARCH

Dr. Larry Madin
Executive Vice President
lmadin@whoi.edu
508 289 2515