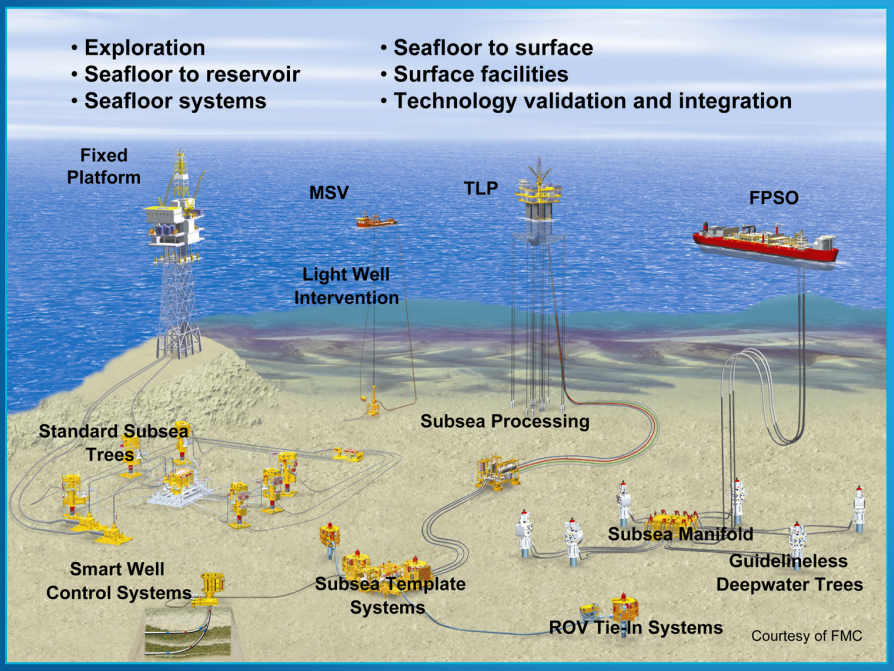
OFFSHORE RESEARCH PROGRAM



PROGRAM OVERVIEW

The Department of Energy's (DOE) Office of Fossil Energy (FE) supports research and policy options to ensure clean, reliable, and affordable supplies of oil and natural gas for American consumers. The National Energy Technology Laboratory's (NETL) Technology Development and Integration Center (TD&IC) implements a portfolio of FE research and development (R&D) programs aimed at protecting the environment while enhancing domestic oil and gas exploration and production. These R&D portfolios include research conducted by NETL as well as extramural projects awarded through competitive solicitations.

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

Natural gas and crude oil provide approximately two-thirds of our Nation's primary energy supply and will continue at that level for decades as the Nation transitions to a more sustainable energy future. The oil and gas resource estimated to exist within the United States has expanded significantly, but because much of the offshore resource is increasingly harder to locate and produce, new technologies are required to safely extract it. Challenges associated with these efforts, such as high temperature and high pressure (HPHT) conditions, geohazards, the need for increasingly sophisticated seismic imaging to visualize deep and complex reservoirs, flow assurance issues in deepwater pipelines, and operation of subsea production equipment under extreme conditions, are just a few of the obstacles that cause oil and gas to be increasingly difficult to locate and safely recover.

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Current DOE offshore research has its roots in the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research (UDW) Program launched in 2007 by EPAct 2005. The public/private partnership was designed to benefit consumers by developing environmentally-friendly technologies to increase America's domestic oil and gas production while reducing the nation's dependency on foreign imports. Subsequent to the Macondo (Deepwater Horizon) incident, the UDW Program became focused on safety and environmental sustainability. This mission and synergistic research to support the DOE/ Bureau of Safety and Environmental Enforcement's (BSEE) memorandum of collaboration form the basis of the current Offshore Program.

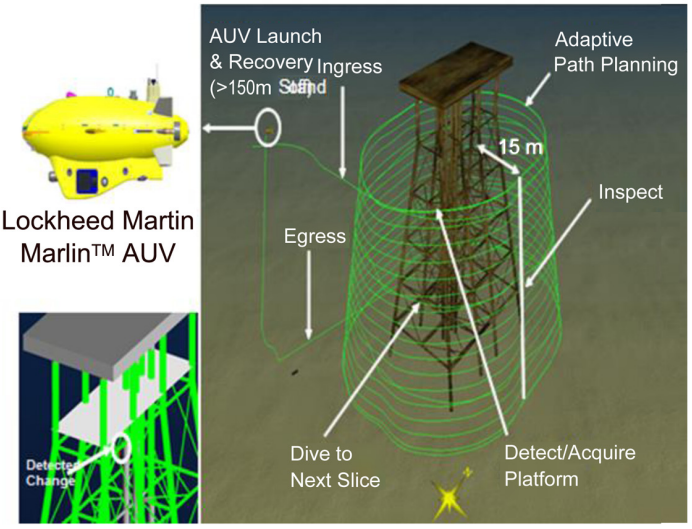
EXTRAMURAL RESEARCH

Although the Title IX, Subtitle J, Section 999 of the Energy Policy Act of 2005 (Sec.999) was rescinded by Congress with passage of the FY14 budget, projects continued through September 2016. These can be grouped under four technology areas that support a safety and environmental sustainability focus:

- **Geologic Uncertainty**—Predicting and early detecting of subsurface conditions and geohazards
- **Drilling & Completion Systems**—Reducing risk and supporting informed decision-making
- **Surface Facilities and Umbilicals**—Improving systems and performance for extreme environments
- **Subsea Systems Reliability**—Improving systems reliability through automation and advanced technology

The research portfolio includes approximately 40 recently completed projects. One-third of the projects were completed in September 2016. The entire portfolio, managed over a decade, represents a DOE investment of almost $114 million. Numerous projects have been commercialized and made an impact on industry. Most notably, Lockheed Martin's Autonomous Utility Vehicle (AUV), in combination with 3D at Depth's laser imaging system, are providing next generation capabilities in underwater metrology. Continuous measurements to the millimeter scale enabling engineering "as-built" drawings, and detailed change analyses are now possible. Other recent accomplishments include:

- Development and validation of advanced computational fluid dynamics (CFD) software for modeling gas explosion incidents, to facilitate surface facility designs that enhance safety and minimize the consequences of explosion incidents
- Enhanced understanding of the physical mechanisms that cause periods of elevated current velocities in the Gulf of Mexico



Lockheed Martin's Marlin™ AUV:
Next Generation Subsea Metrology

NETL IN-HOUSE RESEARCH

The in-house offshore R&D program includes projects focused on developing tools, approaches, and data needed to provide a robust foundation for risk assessments to support scientifically based regulatory and future R&D decision making.

The current in-house offshore R&D program portfolio is divided into the following topic areas and projects:

- **Wellbore Integrity – Improved Science Base of Materials**
  - Characterizing the behavior of metal-based systems used for control devices in extreme environments
  - Improving science-base for wellbore integrity and foam cements
  - Evaluating wellbore integrity in extreme offshore systems
- **Risk Reduction – Mitigating Knowledge & Knowledge Gaps in Offshore Systems**
  - Quantifying complex fluid-phase properties at HPHT
  - Assessing risks and the potential for environmental impacts associated with offshore hydrocarbon resource development
- **Rapid Detection and In Situ Characterization – Improving Safety**
  - Improving deepwater drilling safety through enhanced understanding of multiphase flow dynamics of hydrocarbon mixtures
  - Detecting Kick at the drill bit—adaptation of existing technology to reduce risks associated with offshore drilling

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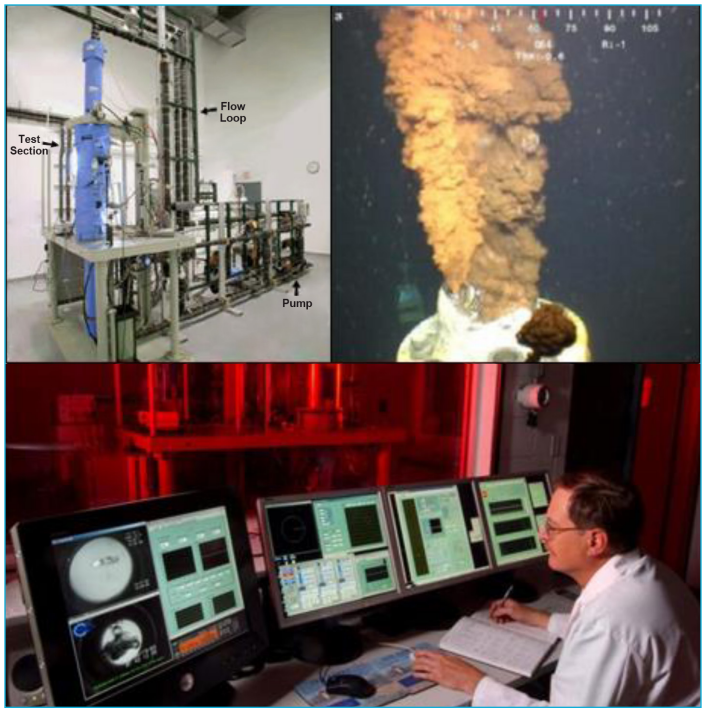
NETL studies following BP's Macondo incident supported the development of an offshore integrated risk assessment model (IAM), and resulted in the establishment of the first continuously updated database and geographical information system in 2015. Early successes from the development of this model and database attracted additional funding from BSEE for maximum discharge rate studies in the Gulf of Mexico and other areas considered for offshore leasing. Two patent applications are being reviewed for potential commercialization—the IAM's Variable Grid Method (VGM) and an early kick detection method using existing logging-while-drilling technology.

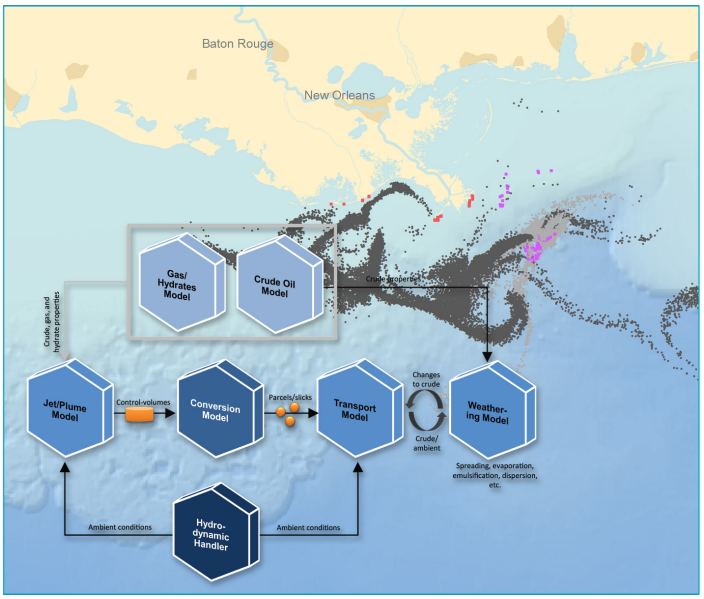
At the same time, industry collaboration was initiated for evaluation of field-generated foam cement, resulting in the American Petroleum Institute (API) incorporating NETL's foam cement studies into its API Recommended Procedures. BSEE and the Bureau of Ocean Energy Management (BOEM) have expressed interest in further work with the IAM. The efforts have been enhanced by the establishment of the NETL-developed Energy Data Exchange (EDX) portal.

Another significant growth area in the Program going forward will be expansion of the Foam Cement JIP and additional cement studies focused on minimizing risks involved with developing essential barriers. The outputs from all of these studies are incorporated in the Integrated Risk Assessment Model



Lab and field resources related to quantification and characterization of hydrocarbon plumes.

EDX homepage, edx.netl.doe.gov



Map of hypothetical spill simulation and trajectory analyses in support of risk modeling for spill prevention

EDX is a data curation system, a tool for rapidly locating authoritative data from key outside sources, and a coordination/collaboration system. Research data, analytical tools, and other results from NETL's offshore program are made available via EDX when ready for public dissemination. The risk assessment modeling tools, approaches, and datasets, which include connections to authoritative datasets from other agencies (e.g., BSEE and BOEM), can be used by stakeholders to reduce knowledge gaps, identify technology needs, and guide science-based decision making.

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