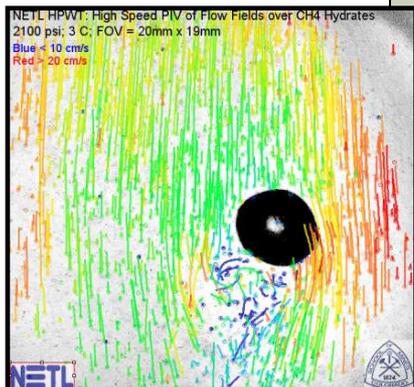
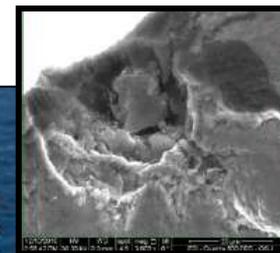




# NATIONAL ENERGY TECHNOLOGY LABORATORY



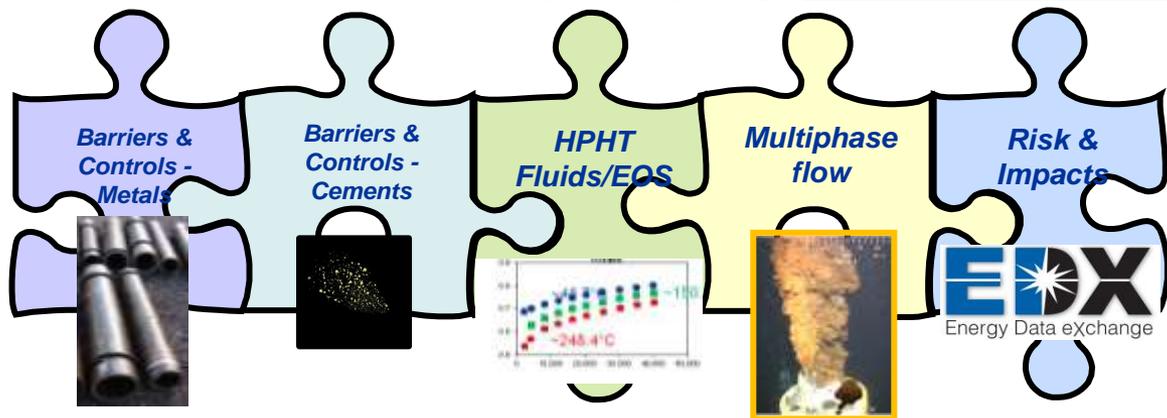
## EPAct Complementary Program- Extreme Offshore

### NETL Complementary Program Research

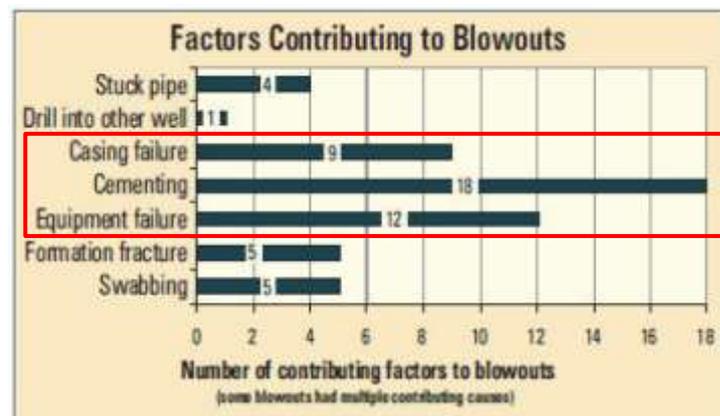
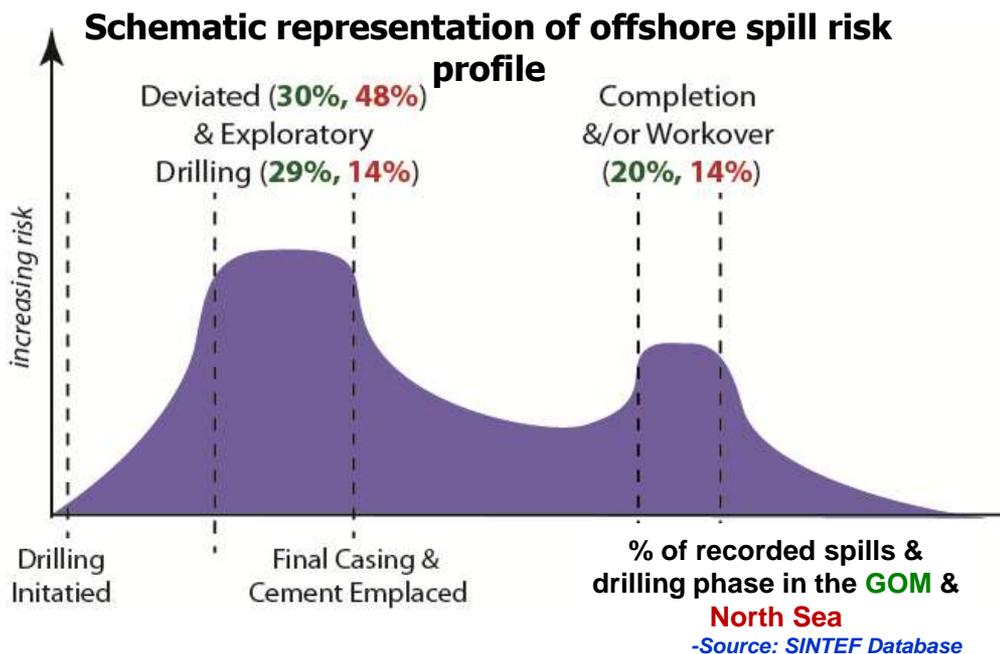
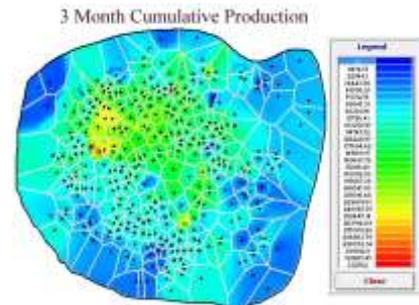
Office of Research and Development  
National Energy Technology Laboratory  
September 26<sup>th</sup>, 2012



# The NETL Complementary Program - Targeting top offshore/UDW spill risks



IAM Tools for GOM



-Izon et al. 2007

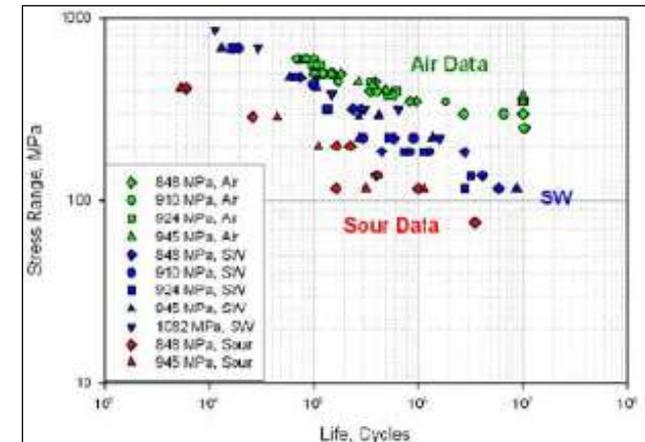
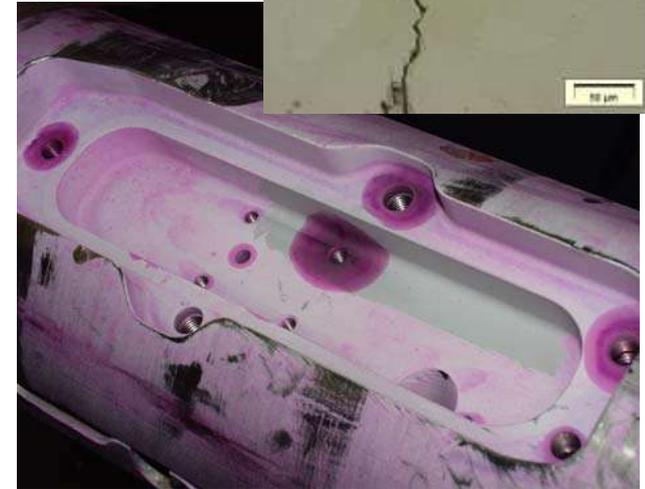
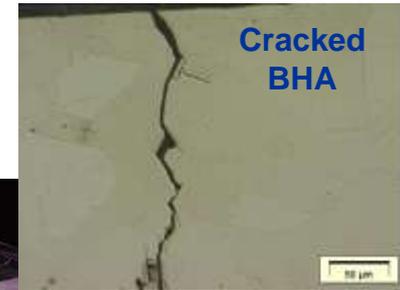
- Cementing Failures
- Equipment & Casing Failures
- Higher risk targets, "exploratory" systems

# Characterizing the behavior of metal-based systems used for control devices in extreme environments

Initial risk assessment requires a firm basis of materials behavior in extreme environments. Complementary Program is focused on key offshore materials for which data in extreme environments are limited, including tubulars for all operations & BOP components

## NETL deepwater material experimental studies:

- Evaluated strength/corrosion potential of most common **UDW** alloys at extreme conditions (pressure, temperature, H<sub>2</sub>S, etc)
  - Will result in a pit/fatigue model *tool to assess catastrophic failure potential and predict how, when, etc...*
- Research to evaluate effect of surface treatments on corrosion & fatigue behavior at HPHT



# FY13: Characterizing the behavior of metal-based systems used for control devices in extreme environments

## Continue *testing Corrosion Resistant Alloys (CRA's)* to study:

- Corrosion fatigue behavior alloys in sour environments
- The role of anodic dissolution behavior in corrosion fatigue process
- The expanded use materials to HPHT conditions.

## Experimental analysis of UDW material interrelationships under HPHT and sour conditions

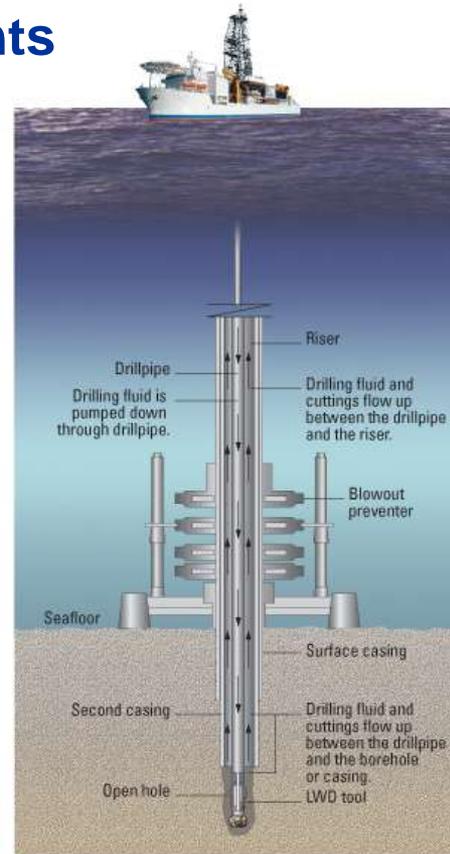
- Focus on 4 most commonly used alloys

## Evaluate effect of surface treatments on corrosion & fatigue behavior at HPHT/sour cond.

- Hammer peening vs. Low Plasticity Burnishing (LPB) vs. laser peening

## Evaluate the catalytic properties of H<sub>2</sub>S in the corrosion degradation of high-strength steels

- H<sub>2</sub>S molecules have catalytic properties and adversely influence corrosion resistance of the carbon and low alloy steels.



### Recent/Upcoming Presentations:

Effects of Hammer Peening and Aging Treatment on Microstructure, Mechanical Properties and Corrosion Resistance of Oil-Grade Alloy 718," Superalloys 2012: 12<sup>th</sup> International Symposium on Superalloys, 9-13 September 2012 (T.Chen, H. John, J. Xu, J.A. Hawk and X. Liu).

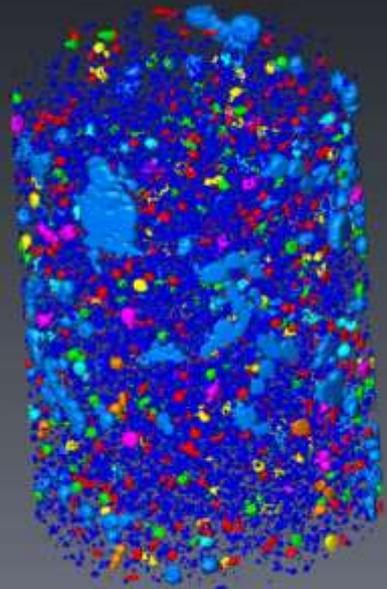
Effect of Sour Environment pH on Crack Morphology in Ultra Strength Drilling Steel under Cyclic Stress," accepted 222<sup>nd</sup> Electrochemical Society Meeting, 7-12 October 2012 (M. Ziomek-Moroz, J. A. Hawk, R. Thodla, and F. Gul).

# Deepwater Cement Barriers

Initial risk assessment requires a firm basis of materials behavior in extreme environments. Complementary Program is focused on key offshore materials for which data in extreme environments are limited, including foam cements

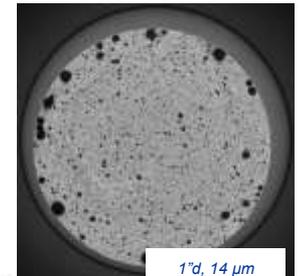
## NETL deepwater cement studies:

- Demonstrated proof-of-protocol for laboratory-based characterization of deep offshore foam cements
- Initiated experiments to evaluate performance of deep offshore foam cements under *in situ* conditions
  - Utilizing NETL's unique facilities and capabilities from hydrate program, Macando response, and onshore subsurface cement R&D
- Experiments at *in situ* conditions on lab and potential field generated samples



Improve knowledge to **ensure safe operation in which foam cements are used** in the deep offshore environment

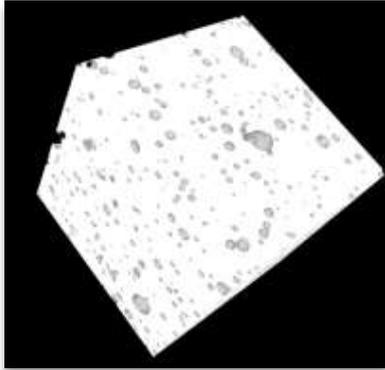
Foam cement bubble size distribution (color coded), NETL CT video



1" dia, 14  $\mu$ m resolution

ENERGY TECHNOLOGY LABO

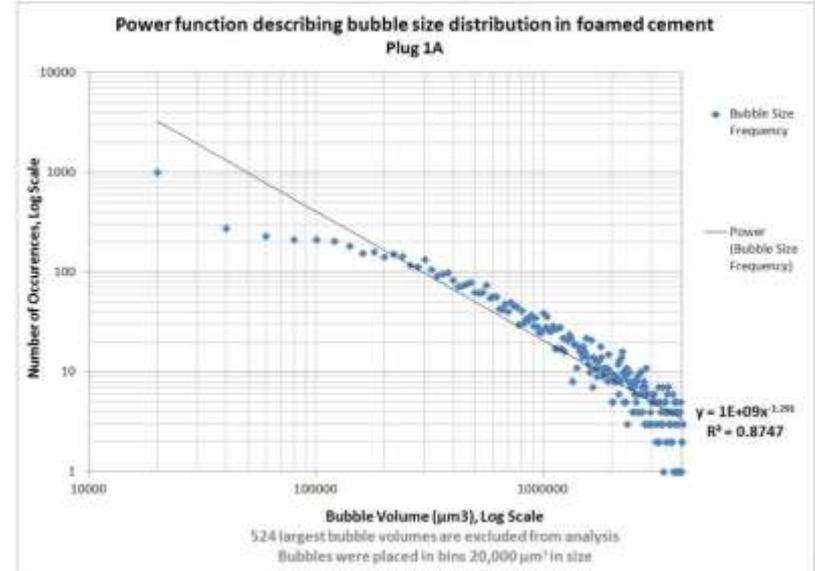
# NEW RESULTS 2.2 DETERMINING THE PHYSICAL AND CHEMICAL BEHAVIOR OF CEMENT BARRIERS USED IN ULTRA-DEEP WATER SYSTEMS



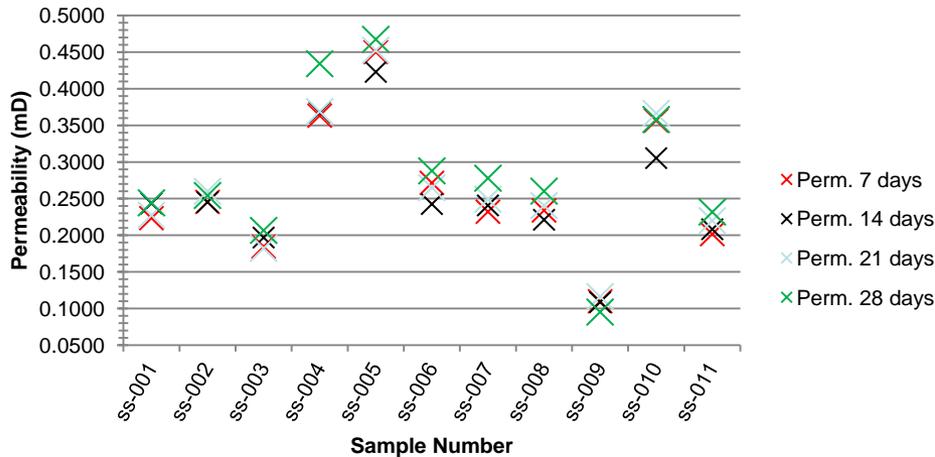
*A log log plot suggests a possible power law relationship between bubble volume and frequency.*



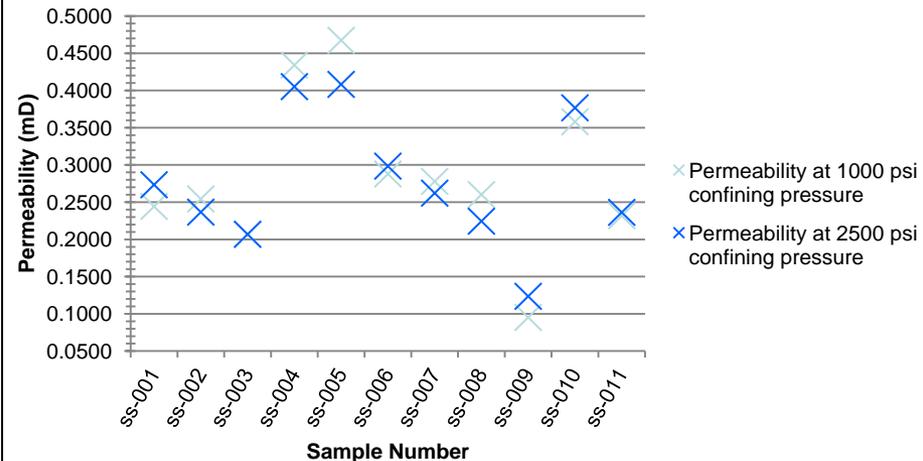
*Ultraperm-500 flow-through unit*



**Absolute Permeability Changes During Curing Time**



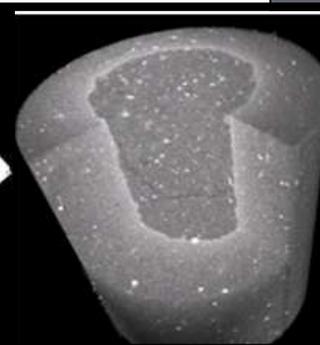
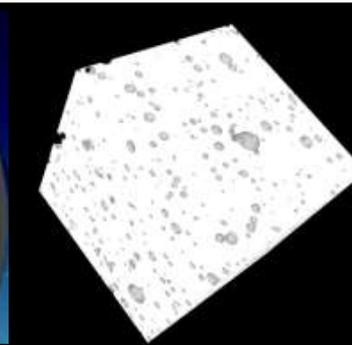
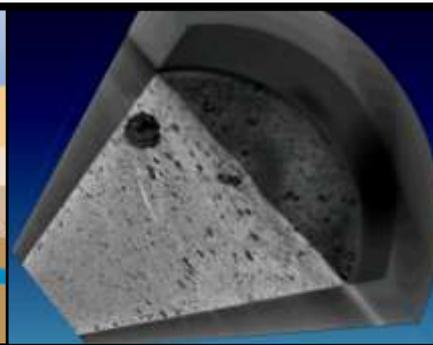
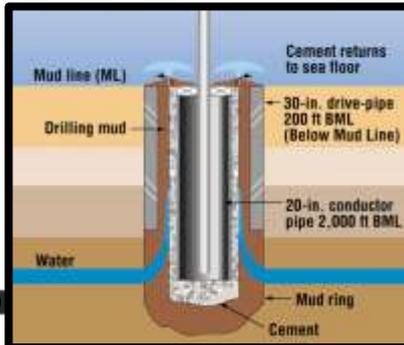
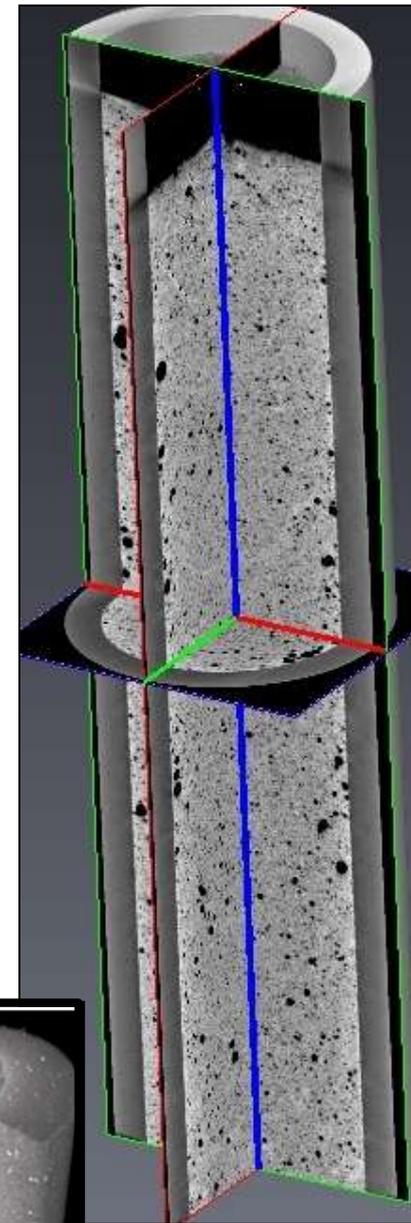
**Absolute Permeability using different Confining Pressures**



**Preliminary Information Only**

# FY13: Deepwater Cement Barriers

- Foamed cements are being studied using NETL's industrial and medical CT scanners. These have the capability to provide *submicron to micron* resolution and 3D imaging data.
  - Bubble size and spatial distribution of the bubbles are being visualized and measured under a variety of conditions.
- **Execute experimental studies on samples including:**
  1. Atmospheric foam generated with the current test method (API RP 10B-4)
  2. Pressure generated foamed cement in the lab (using Schlumberger's Pressure Foamed Cement Generator)
  3. Potential for **field generated** foamed cement sample
- **Modeling spatial distribution of gas bubbles in foamed cement systems**
  - Correlate existing test method
- **New effort** examining integrity of formation:cement:casing seal & barrier



# UDW Portfolio - HPHT Fluids

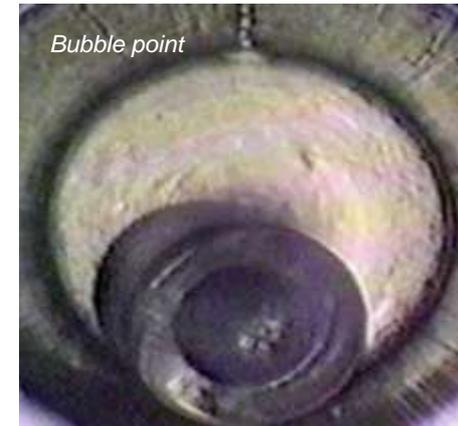
Developing critical data for predicting in situ conditions required for assessing risk, borehole/drilling design, loss of control conditions in deepwater & ultra-deepwater settings

Data are needed to predict fluid flow under extreme conditions.

Based on unique experimental capabilities, NETL deepwater EOS/HPHT fluids studies focus on:

- Expanding density and viscosity databases for hydrocarbon compounds to UDW
- Integrating NETL database with existing lower T and P data for comprehensive database
- Development of equations of state with greatly improved accuracy
- Extend modeling and experimental studies into polymer (additives) + hydrocarbon phase, density, and viscosity behavior
- **Deploy interactive database of results & tool for science-based decision making needs**

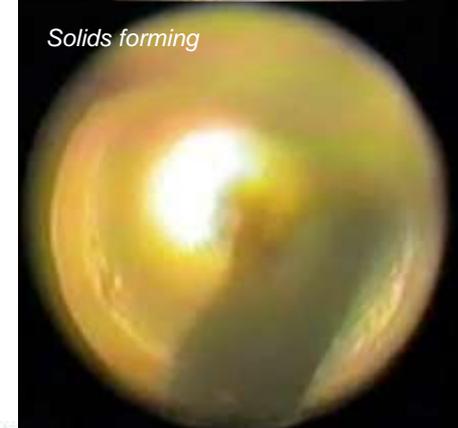
Inside view of Density cell



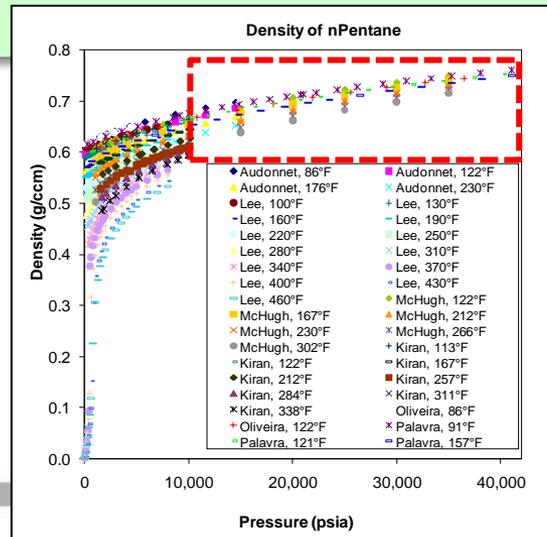
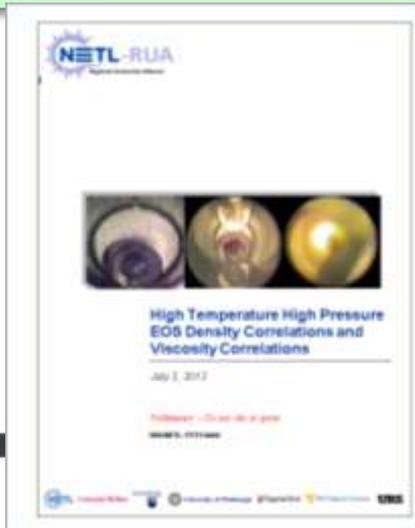
Bubble point



Liquid-Liquid-Vapor

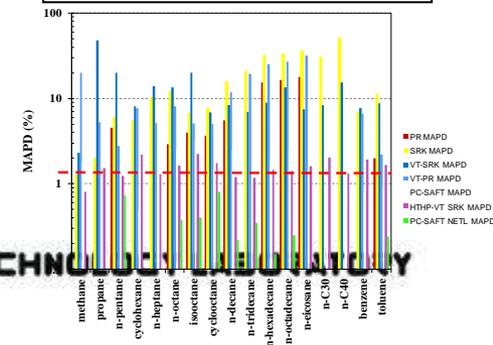
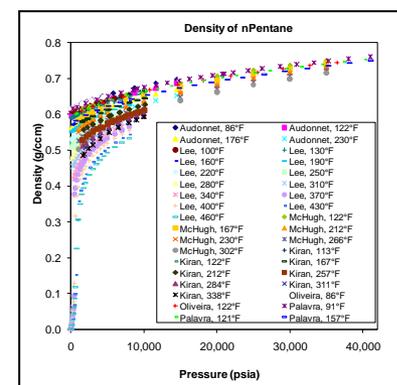
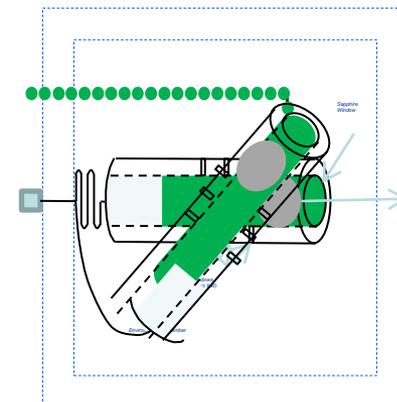
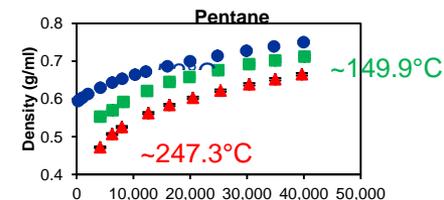


Solids forming

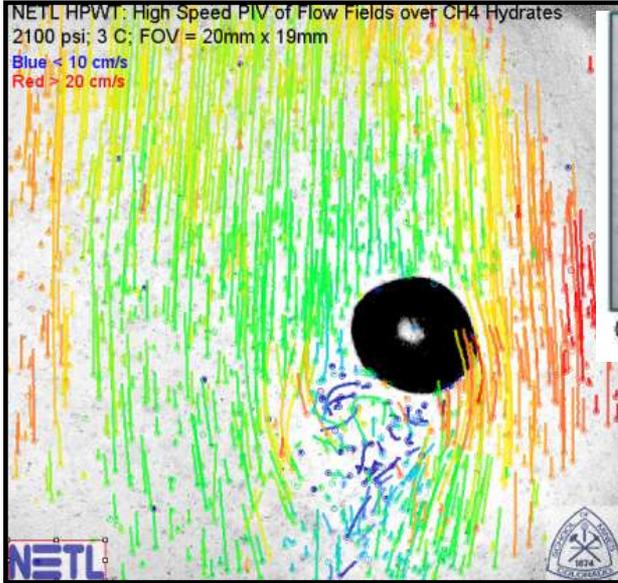


# FY13: Quantifying complex fluid-phase properties at high pressure / high temperature (HPHT)

- Complete viscosity tests for 10 focus hydrocarbons:
  - $C_3H_8$ , (propane)  $C_5H_{12}$ , (n-pentane)  $C_8H_{18}$ , (n-octane)  $C_8H_{16}$ , (cyclo-octane)  $C_8H_{18}$ , (2,2,3-trimethyl pentane)  $C_{10}H_{22}$ , (n-decane)  $C_{16}H_{34}$ , (n-hexadecane)  $C_{18}H_{38}$ , (n-octadecane)  $C_{20}H_{42}$ , (n-eicosane) and  $C_7H_8$ , (toluene).
- Extend the density data base over the entire PT range
- Extend the viscometer cell to allow simultaneous measurement of density with the viscosity at the same conditions.
- Phase behavior and density studies on binary and ternary mixtures
- Extend modeling and experimental studies into polymer (additives) + hydrocarbon phase, density, and viscosity behavior
- Deploy online, interactive database of results for industry, regulatory, science-based decision making needs (through EDX)



# Improving deepwater drilling safety through enhanced understanding of multiphase flow dynamics of hydrocarbon mixtures



C1/C2/C3 mix bubbles with hydrate

HSHD videography enables detailed PIV analysis of individual hydrocarbon bubbles.

These data enable determination of bubble rise velocity and flow field visualization around a bubble.

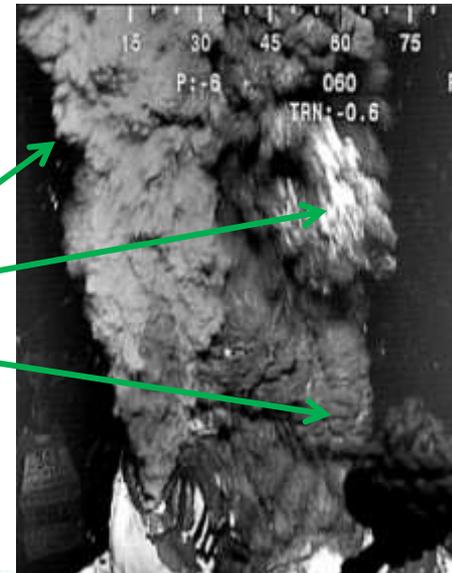
Response study, addresses major issues relative to deepwater leaks from wells and production equipment:  
***How much is leaking? What is the composition of the mixture? What is the hydrocarbon fate in the water column?***

## NETL deepwater HPLT flow research includes:

- Leveraging work initiated during Macondo spill response
  - Obtained first direct observations of hydrate formation on Macondo-surrogate gas at deepwater conditions
- Producing data necessary to predict fate of hydrocarbons in water column (both velocity and dissolution)
  - Based on unique experimental facility
- Delineate hydrate formation conditions (as function of P, T, salinity, gas composition)
- Testing of ROV deployable tool & predictive models for independent assessment/spill estimates & rapid response

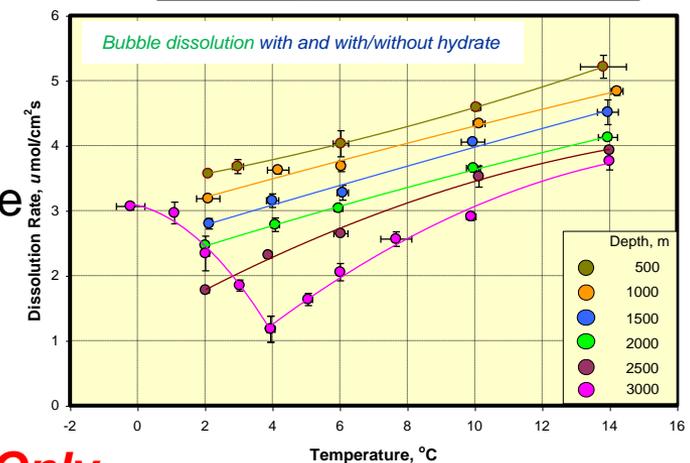
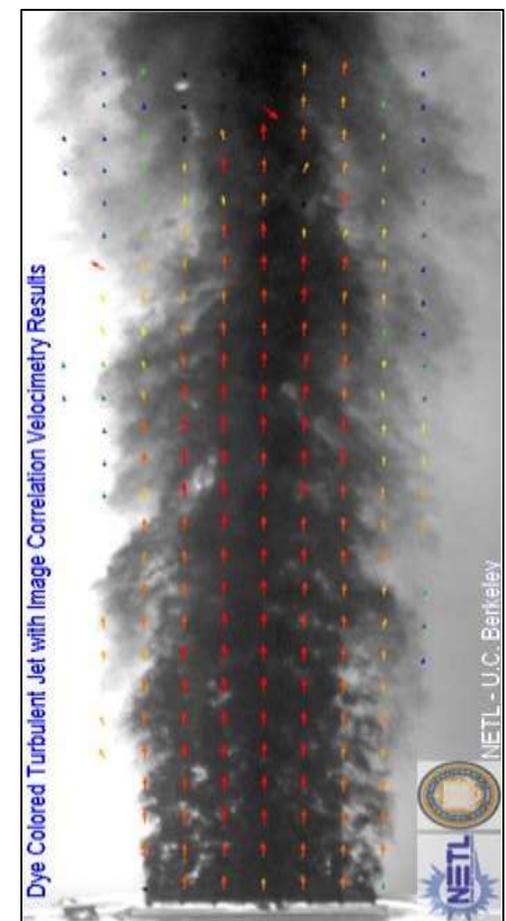
Image from Macondo blowout showing features of interest for this research:

- Turbulent Eddies
- Possible hydrates
- Vortice



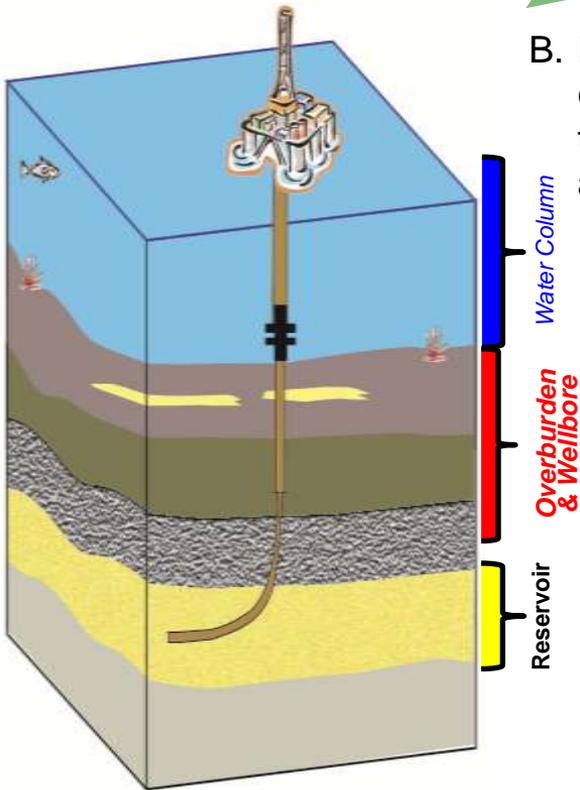
## **FY13: Improving deepwater drilling safety through enhanced understanding of multiphase flow dynamics of hydrocarbon mixtures**

- **Facilitate the development of ROV compatible tools to:**
  - Rapidly and accurately determine the leak rate.
  - Rapidly determine the presence of gas hydrates.
- **Complete research in HWTF on hydrate morphology and hydrodynamics.**
  - Determine the feasibility of utilizing this data for in-situ hydrate detection.
- **Determine the feasibility of using other techniques, such as Raman spectroscopy or acoustics, for rapid, in-situ detection of gas hydrates.**
- **Complete additional large scale experiments, builds on initial 3 week study performed in tow tank at UC Berkeley in July, 2012.**
  - Use this information to begin development of the FTV technique for rapid in-situ leak detection.
- **Perform additional large-scale experiments in FY13.**

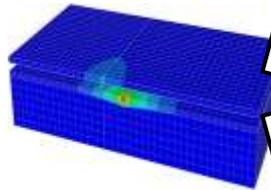


# The NETL Complementary Program - Approach to quantifying system behavior relies on integrated assessment models (IAMs)

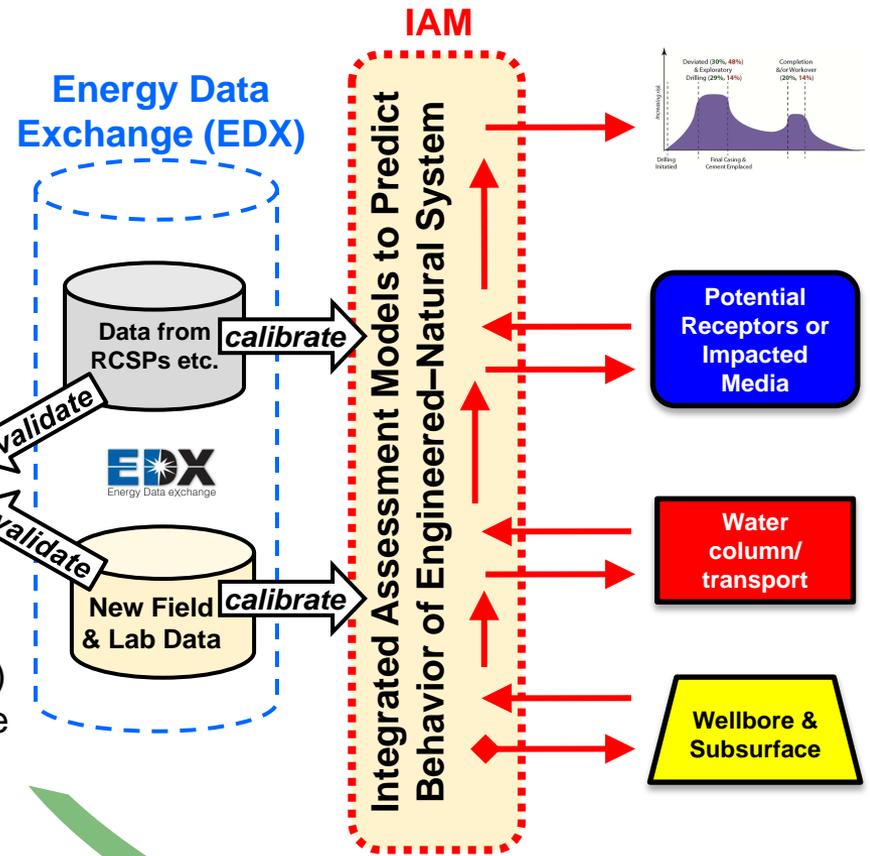
A. Divide system into discrete components



B. Develop detailed component models that are validated against lab/field data



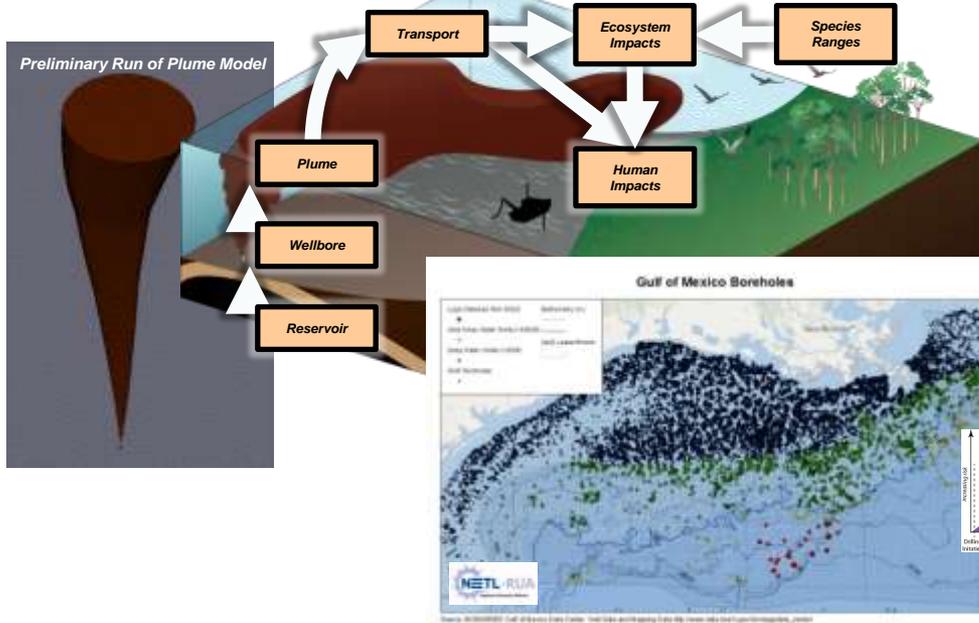
C. Develop reduced-order models (ROMs) that rapidly reproduce component model predictions



D. Link ROMs via integrated assessment models (IAMs) to predict system behavior; calibrate/validate using lab/field data

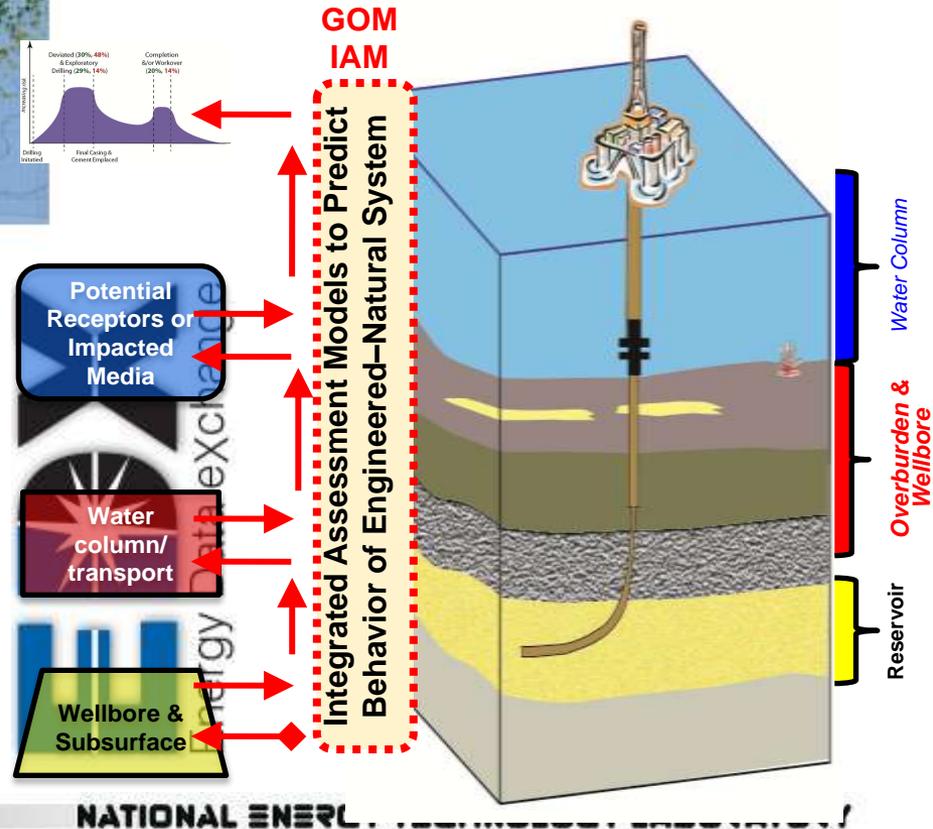
**Will result in data (field, laboratory, numerical) & IAM tools needed to conduct rapid response & predictive risk models**

# Geospatial Evaluation of the Deep/"Frontier" Offshore – Assessing Social, Environmental, and Risk Factors



When released **GOM IAM will be the 1st coordinated platform** and tools (EDX and IAM) to allow for independent, rapid science-based prediction of UDW hydrocarbon risks & assessment of spills

- NETL deepwater risk and environmental impact assessments:**
- Energy Data eXchange (EDX), provides a focal for rapid access to key data needs, coordination/collaboration tool
  - Developed preliminary GOM plume model
    - Full version forthcoming in FY13
    - Novel, multi-phase modeling approach
  - Contributor to LANL/NETL UDW wellbore systems model/risk assessment in support of Spill Prevention Subcommittee
  - Finalizing GOM IAM and EDX tools, initiating adaptation for Arctic IAM/EDX tools



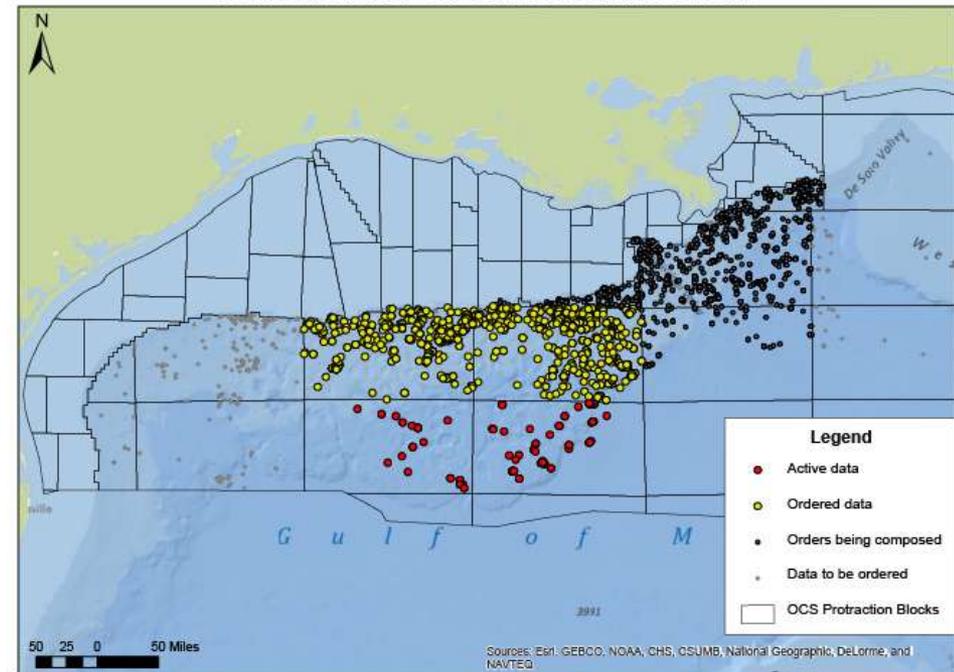
# Geospatial Evaluation of the Deep/"Frontier" Offshore – Assessing Social, Environmental. and Risk Factors

## Geospatial Data Framework:

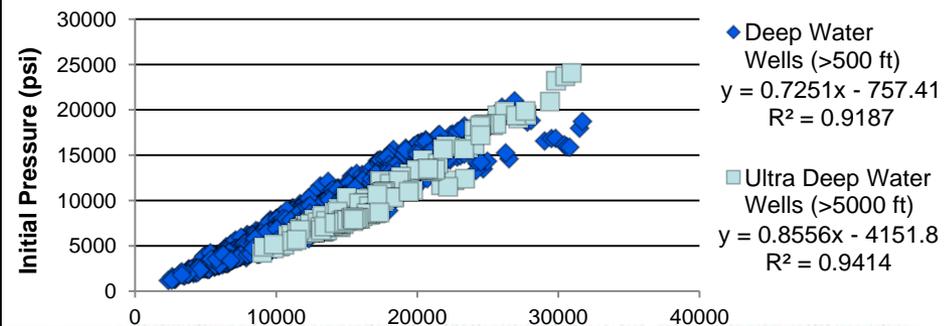
- BOEM/BSEE Atlas of Gulf of Mexico Gas and Oil Sands Data provides data on reservoir sands.
  - Data tables from 1999 to 2008 were released in 2011.
  - [http://www.data.bsee.gov/homepg/data\\_center/gandg/gandg.asp](http://www.data.bsee.gov/homepg/data_center/gandg/gandg.asp)
- Compiling GOM subsurface properties data including:
  - Oil and gas estimates including proved and unproved resources, cumulative produced
  - “Reservoir” characteristics
  - Pore-filling media characteristics including GOR, oil API gravity, volume, density
- **Performing analysis of data (both statistically and spatially) to identify patterns to assist with future interpolations**
- **Continuing collection/interpretation of deep offshore wells to integrate with geostatistical framework**

*Preliminary Results*

Data Collection for Gulf of Mexico Boreholes 9/2012



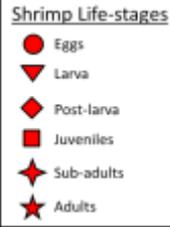
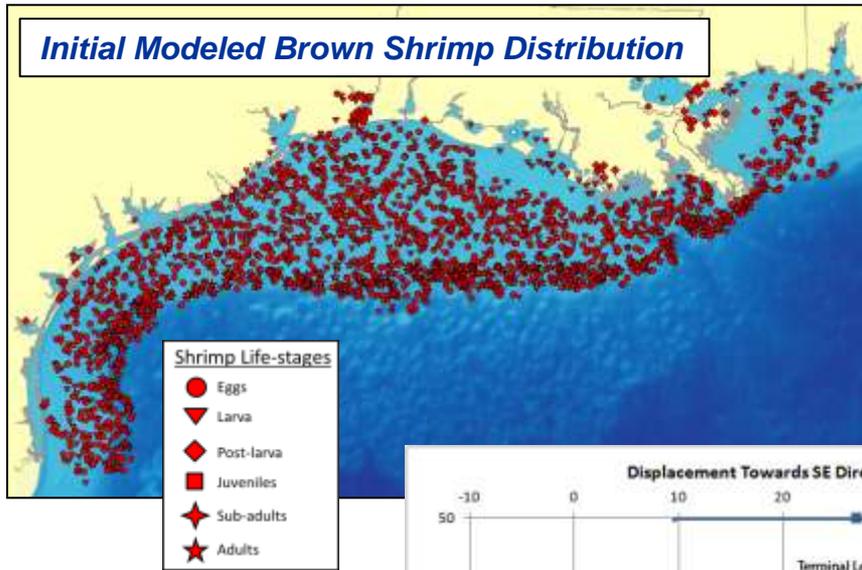
**Comparison of Pressure versus Subsea Depth for Deep and Ultra-deep Water Wells in the Gulf of Mexico**



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# Geospatial Evaluation of the Deep/"Frontier" Offshore – Assessing Social, Environmental, and Risk Factors - Water Column & Impacts Modeling

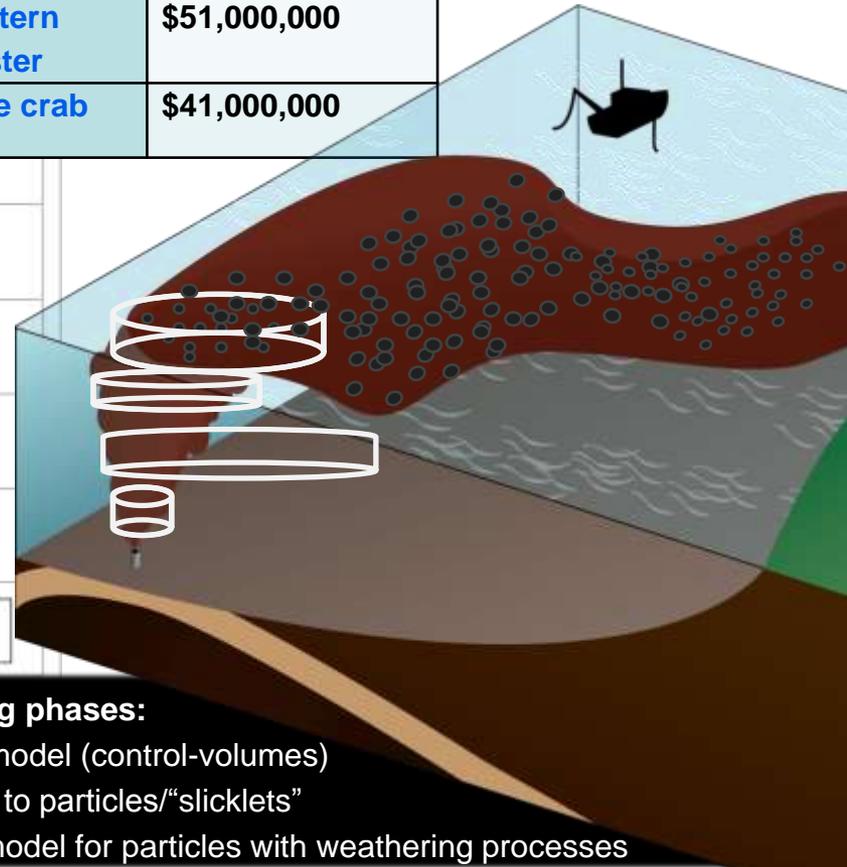
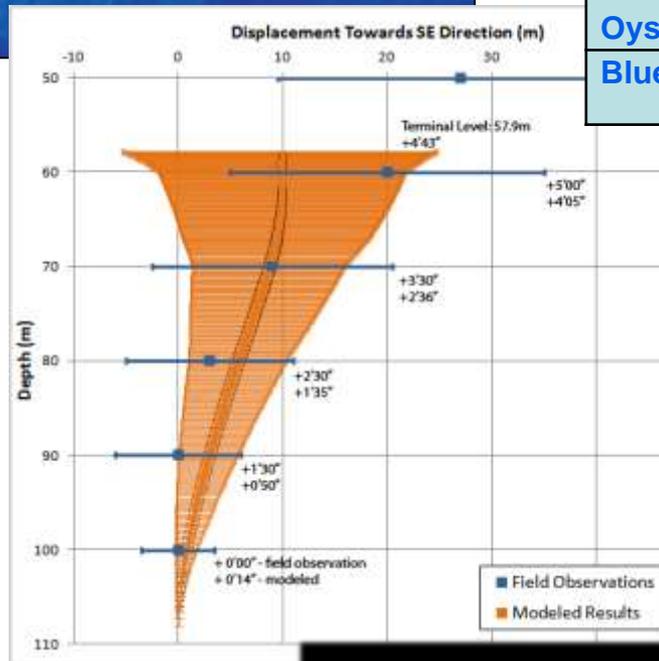
Initial Modeled Brown Shrimp Distribution



Gulf of Mexico top commercial species by value (1991-2010 annual average)	
Brown shrimp	\$205,000,000
White shrimp	\$167,000,000
Gulf menhaden	\$60,000,000
Eastern Oyster	\$51,000,000
Blue crab	\$41,000,000

Five species account for about 70% of the total value (\$525 million)

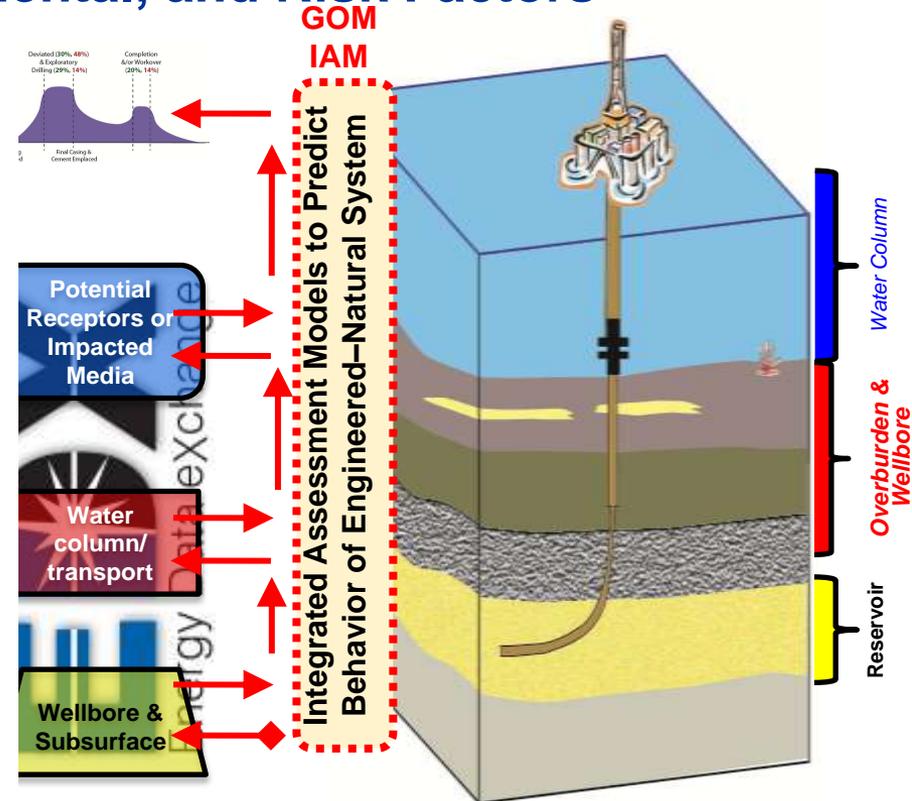
- Transport model has advection and horizontal diffusion in place
  - Incorporating evaporation next
- Conversion model from plume to transport is finished,
  - Now working to integrate gasses/hydrates into plume model



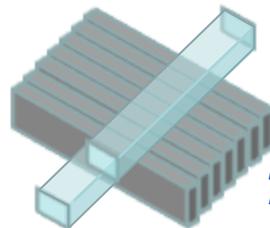
- **3-major modeling phases:**
  - Plume/Jet model (control-volumes)
  - Conversion to particles/"slicklets"
  - Transport model for particles with weathering processes

# FY13: Geospatial Evaluation of the Deep/"Frontier" Offshore – Assessing Social, Environmental, and Risk Factors

- **Finalize GOM databases** for subsurface, wellbore, and water column properties, deploy via EDX
- Develop & deploy EDX geospatial tool/viewer for GOM offshore datasets
- Finalize beta component models for GOM IAM
- Test integrated assessment model for a hypothetical spill events in the GOM
- **Delivery of IAM tool for GOM**
- **Preliminary assessment of general trends across the GOM related to impacts associated with potential hydrocarbon releases**
- **Initiate adaptation of GOM IAM for Arctic IAM**



Gulf of Mexico Boreholes



Multiple EDX Data Sets

# GOM IAM Papers in Preparation

- **An Environmental Comparison of the Exxon-Valdez and the BP-Deepwater Horizon Oil Spills** - This report examines the Exxon Valdez and the Deepwater Horizon spills by looking at the environmental impacts to the land and fisheries as well as the response and cleanup efforts at the two spill locations.
- **Researching Potential Impacts of Oil Spills in the Gulf of Mexico - Spatial Data Report** -This report is a review of the spatial datasets needed for conducting risk analysis and modeling of potential impacts associated with fossil fuel exploration and production in the Gulf, including both existing datasets and those developed by the NETL-ORD group. These datasets span the subsurface through the water column and when complete will be the most comprehensive set of data available for the GOM
- **Blowout and Offshore Spill Occurrence Model: Plume Model and Initial Validation** - This paper describes the deepwater oil plume model under development by the NETL-ORD group, including the major equations and concepts behind the model and an initial validation of the model against existing experimental data.
- **A Spatially Explicit Population Model for Brown Shrimp (*Farfantepenaeus aztecus*) in the Gulf of Mexico** - This paper describes the brown shrimp model under development by the NETL-ORD group for the Gulf of Mexico, which will be used for impact studies. The model attempts to reproduce the broad-scale dynamics of shrimp growth and movement for all life stages, including spawning over the continental shelf, movement of the young to coastal bays and estuaries, and movement of adults back to spawning depths.
- **Geologic overview of the Gulf of Mexico** -This paper summarizes the paleogeography, depositional history, structure, deformation, and the oil/gas system for the GOM using literature related to the topic. The paper is framed around how this geologic background is important to assessing risks associated with deepwater drilling.

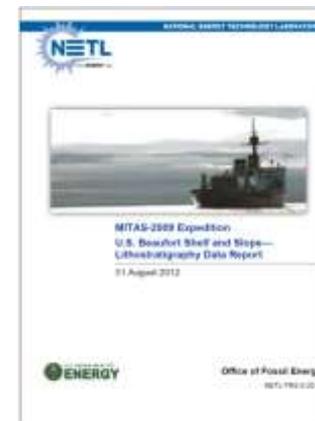
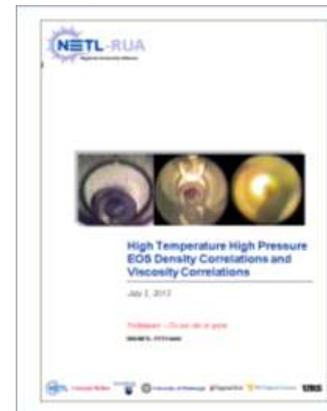
# Related Items

- **AAPG session in Theme 7 : Energy and Environment**
  - Pittsburgh AAPG, 19-22 May 2013
  - <http://aapg2013ace.abstractcentral.com/>
    - **Offshore Drilling and Marine Ecosystems: assessment of ecological impacts and recovery from the Gulf oil spill, lessons learned, new risk assessments for deepwater offshore and frontier drilling**
    - Session chairs: Kelly Rose, DOE, and Michel Boufadel, NJIT
- **NETL-ORD project selected for new BSEE Award**
  - Real-Time In-Situ Monitoring and Early Detection of Corrosion Damage in Risers and Structures
- **NETL-ORD Technical Report Series**
  - High temperature high pressure EOS density correlations and viscosity correlations, **released July 2012**
  - *MITAS-2009 Expedition, U.S. Beaufort Shelf and Slope—Lithostratigraphy Data Report*, **released September 2012**
  - An Assessment of Research Needs Related to Improving Primary Cement Isolation of Formations in Deep Offshore Wells, **anticipated October 2012**
  - An Assessment of Current Deepwater Drilling and Production Equipment Failure Issues Related to Metallurgical Failure, **anticipated October 2012**

**NETL TRS available at:**

[http://www.netl.doe.gov/onsite\\_research/index.html](http://www.netl.doe.gov/onsite_research/index.html)

**EDX available at:** <https://edx.netl.doe.gov>

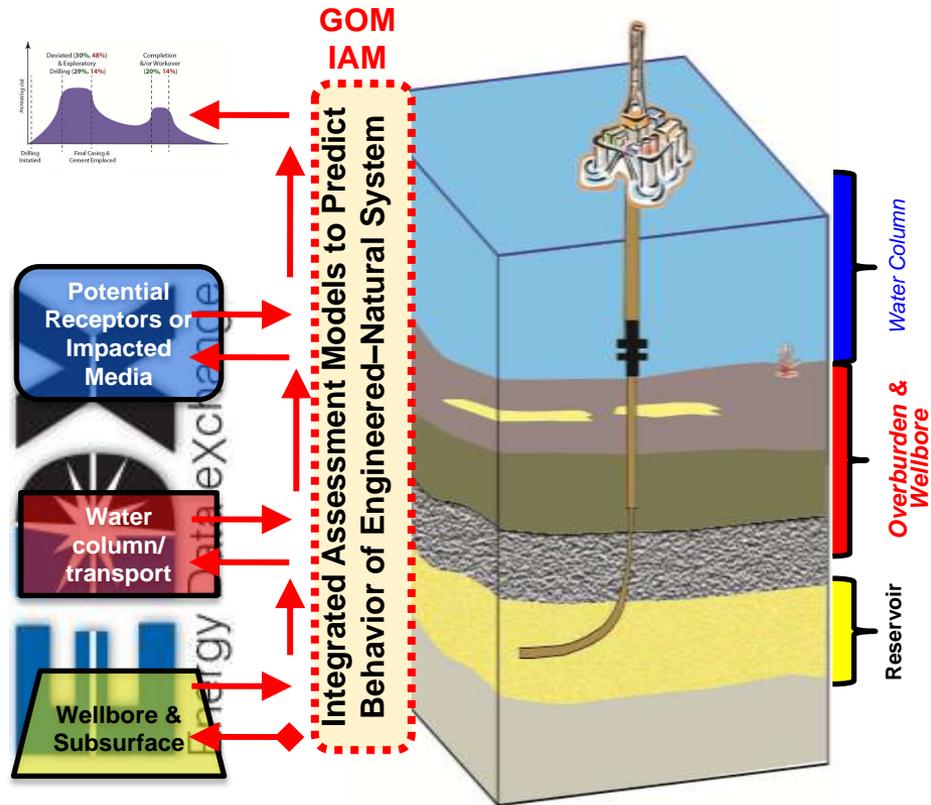
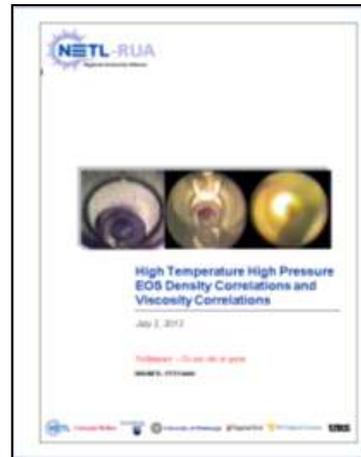
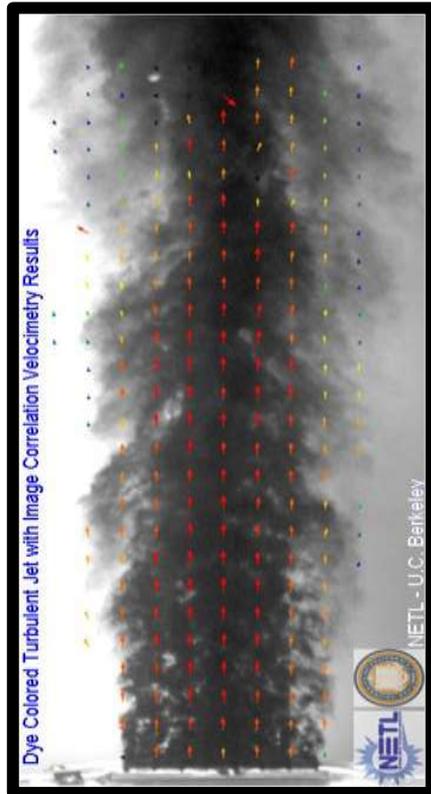
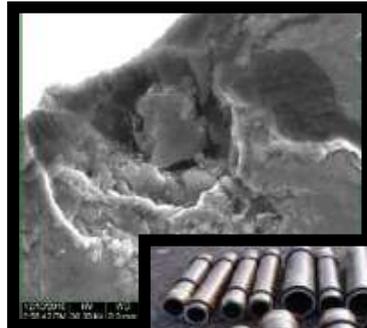
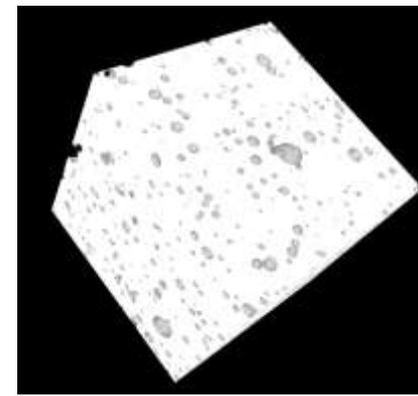


## Potential Synergies – NETL Comp Program & RPSEA Efforts

- **NETL:** Characterizing the behavior of metal-based systems used for control devices in extreme environments
  - **RPSEA:** Brine Chemistry Solutions; Schlumberger DBR Technology
- **NETL:** Deepwater cement barriers
  - **RPSEA:** CSI, University of Houston
- **NETL:** Quantifying complex fluid-phase properties at high pressure / high temperature (HPHT)
  - **RPSEA:** Brine Chemistry Solutions
- **NETL:** Improving deepwater drilling safety through enhanced understanding of multiphase flow dynamics of hydrocarbon mixtures
  - **RPSEA:** Brine Chemistry Solutions; Colorado School of Mines; Lockheed Martin
- **NETL:** Geospatial Evaluation of the Deep/"Frontier" Offshore – Assessing Social, Environmental, and Risk Factors
  - **RPSEA:** Chevron/MIT plume study and deepwater currents

# Thank you!

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# Data Exchange for Energy Solutions

- **R&D coordination & collaboration tool**
- **Share information across networks**
  - **Rapid access through one site**
  - **Online access for historical data**
  - **Venue for newly released datasets**
- **Security, database design, and structure leverage DHS system**
- **Built to accommodate both open access and restricted access data**
- **Role-based security allows for groups or “communities” within the system**
- **Future FY13 roll outs will incorporate spatial/mapping tools, displays and other opportunities**

## More information on EDX:

<http://www.netl.doe.gov/publications/factsheets/rd/R%26D184%20.pdf>

The screenshot shows the EDX website interface. At the top, there is a header with the NETL logo and the text "National Energy Technology Laboratory". A warning message states: "Attention: Test Data has been rolled back. Search results will be temporarily affected." Below this is the EDX logo and the text "Data Exchange for Energy Solutions". There are links for "Anonymous", "LOGIN", "JOIN", and "FEEDBACK", along with a search box and a "Search" button. A navigation bar contains links for "Home", "About", "Search", "Contribute", "My EDX", "Contact", and "FAQ". The main content area features a large image of a field with an oil rig in the background. To the right of the image is a "Welcome to EDX" message, followed by a description of the system and a search bar. Below the search bar are links for "Data", "News", "People", "Organizations", "Images", and "Video". A "Latest News Items" section is visible, featuring a news item about Shell's Arctic oil spill training. At the bottom, there is a footer with various government and organizational links, a "Rate and contribute data Join Now" button, and the NETL logo.

## Designed for:

- **Fossil & renewable energy researchers**
  - **Policy makers**
  - **General public**

NATIONAL ENERGY TECHNOLOGY LABORATORY

Now available at: <https://edx.netl.doe.gov>