Skoltech Center for Hydrocarbon Recovery

Partnership Program

is the most effective way
for institution to grow up from the scratch
and start to conduct research, education and innovation
in the field of exploration and production of hydrocarbons
on a world level with significant value and impact in a few years

Spasennykh M.Yu. <M.Spasennykh@skoltech.ru>
May 18, 2016
Skoltech, Moscow
## Partnership with Universities: strategy

### Stage 1 – Quick start /2015-2017

<table>
<thead>
<tr>
<th>Category</th>
<th>Activities</th>
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<tbody>
<tr>
<td><strong>Education</strong></td>
<td>• Development and delivery of MS courses</td>
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<tr>
<td></td>
<td>• Student internship</td>
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<tr>
<td><strong>Experimental facilities</strong></td>
<td>• Recommendations on research equipment and procedures</td>
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<tr>
<td></td>
<td>• Development and launch of research equipment</td>
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<td></td>
<td>• Joint R&amp;D in partner lab, training Skoltech personnel</td>
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<tr>
<td><strong>Research and innovation</strong></td>
<td>• Launch of Skoltech R&amp;D projects on partner facilities</td>
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<td></td>
<td>• Joint grants (replacement of Skoltech funds)</td>
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<tr>
<td><strong>Collaboration with industry</strong></td>
<td>• Development and delivery of trainings for RF industry</td>
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<td>• Start R&amp;D with industry (replacement of Skoltech funds)</td>
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### Stage 2 – Mutually beneficial partnership/2017-2018

<table>
<thead>
<tr>
<th>Category</th>
<th>Activities</th>
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<tbody>
<tr>
<td><strong>Education</strong></td>
<td>• Double MS diploma</td>
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<td></td>
<td>• Joint PhD programs</td>
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<tr>
<td><strong>Experimental facilities</strong></td>
<td>• Joint experimental research in Skoltech and partner lab</td>
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<td></td>
<td>• Support of lab operations in Skoltech</td>
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<tr>
<td><strong>Research and innovation</strong></td>
<td>• Joint R&amp;D projects</td>
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<td></td>
<td>• Executing joint grants (replacement of Skoltech funds)</td>
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<tr>
<td><strong>Collaboration with industry</strong></td>
<td>• Creation of research consortia</td>
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<td></td>
<td>• Joint trainings for industry</td>
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<td></td>
<td>• Participation in joint R&amp;D with Industry (replacement of Skoltech funds)</td>
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<tr>
<td>Discipline</td>
<td>University Partner</td>
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<td>Enhanced oil recovery</td>
<td>University of Calgary</td>
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<td>BSU, Ufa</td>
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<td>Mining University</td>
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<td>Geomechanics</td>
<td>INGG RAS, Novosibirsk</td>
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<td>Lausanne university</td>
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<td>Shale oil</td>
<td>IPE RAS</td>
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<td>BSU, Ufa</td>
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<td>Moscow State University</td>
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<td>Gubkin University</td>
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<td>Kurchatov Institute</td>
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<td>Gas Hydrates, Arctic shelf,</td>
<td>Heriot – Watt University</td>
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<td>Permafrost</td>
<td>Moscow State University</td>
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<td>Advanced reservoir modeling</td>
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<td>Advanced reservoir modeling</td>
<td>Texas A&amp;M University</td>
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<td>MIPT</td>
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<td>MIT</td>
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**Research consortium on Bazhenov**

- **MSU**
- **Gubkin University**
- **MIT**
- **Kurchatov Institute**
- **Surgut University**
- **Unil**
- **UNIL | Universite de Lausanne**
- **Universitetet i Stavanger**
- **Skoltech**
- **Geomechanics**
- **Basing modeling**
- **Chemical EOR**
- **Digital rock**
**700-MRA Project 1**

**Project:** Methods of well thermometry (thermal logging) for unconventional reservoirs  
**Partner:** Bashkir State University, Russia  
**PI:** Prof. Valiullin R.A.

**Goal:** Modern theory, research methodology and interpretation of thermometry applied to unconventional reservoirs.

**Work plan:**
- Describe physical basis of thermometry for unconventional reservoirs;
- Study horizontal wells;
- Study watered and low-yield wells;
- Study multilayer wells;
- Develop diagnostics of hydraulic fracturing completion;

**Application in industry:**
- Methodology on defining most promising reservoirs based on thermometry logging data;
- Methodology on defining water leak based on thermometry logging data;
- Multilayered reservoir diagnostics during the development and production of wells by thermohydrodynamic simulator;

Shale oils in Russia

Well logging
Project: Study of surface relief, mechanical properties and wettability of porous materials at micro and nano scales

Partner: Bashkir State University, Russia

PI: Batyrshin E.S.

Goals:
- Method to measure mechanical properties of shales at micro- and nano-scale
- Method to measure wettability and surface morphology of shales at micro- and nano-scale

Shale rock model composed of:
- Pyrite, Carbonates,
- Quartz, Kerogen+Pores

Shale rock model composed of:
- Connected pores,
- Isolated pores

Surface of rock sample

Wettability map of rock sample

Work plan:
- Study rock mechanical properties at micro- and nano-scale;
- Study rock wettability at micro- and nano-scale;
- Study of physical and chemical interaction of rock and fluid at micro- and nano-scale
- Validate of Atomic Force Microscopy approach;

Application in industry:
- Extended “Digital rock” model;
- Completion design;
- EOR design;
700-MRA Project 3

**Project:** Study of hydrodynamic flow in porous microstructures based on physical and chemical changes

**Partner:** Bashkir State University, Russia

**PI:** Musin A.A.

**Goal:** Develop methods of experimental studies and mathematical model of fluid flow in samples of low-permeability reservoirs with physical and chemical changes of the filtering continuum

**Work plan:**
- Experimental setup construction and microchannel samples fabrication;
- Experimental study of flow in microchannels;
- Mathematical modeling of flow in microchannels with physical and chemical changes;

**Application in industry:**
- Enhanced oil recovery design;

![Pore types in shale rock](image)

![Lab-on-chip: microchannels](image)
Project: Methods of electromagnetic influence on bottomhole formation zone
Partner: Bashkir State University, Russia
PI: Prof. Kovaleva L.A.

Goal: Create a modern mathematical model that takes into account the processes of heat and mass transfer in a non-isothermal filtration of heavy hydrocarbon liquid in a porous media under the influence of high-frequency electromagnetic radiation.

Possible technological solution

Work plan:
- Develop initial mathematical model based on published data;
- Develop laboratory setup and methodology;
- Conduct experimental research;
- Develop modern mathematical model;
- Validate modern mathematical model on laboratory setup;
- Verify modern mathematical model by comparing predictively with widely used commercial simulators on field data;
- Create research simulator;

Application in industry:
- Methods for stimulation of high-viscosity oils and bitumen production and enhanced oil recovery

Tests in labs

- $f = 10$ MHz, $T = 90^\circ$C, $P = 41.4$ kPa
- $f = 10$ MHz, $T = 90^\circ$C
- $T = 23^\circ$C, $P = 41.4$ kPa

Time, hours

Oil recovery factor, %
**Project:** Geomechanic modeling of hydraulic fracture growth and its connection to microseismicity

**Partner:** Institute of Petroleum-Gas Geology and Geophysics, Russia

**PI:** Stefanov Yu.P.

**Goal:** Develop technology of numerical modeling hydraulic fracture with different growth mechanisms

**Work plan:**
- Develop model of seismic waves generated by fracture growth;
- Analyze possible mechanisms of fracture growth;
- Develop numerical model and computational algorithms for modeling fracture advancement accounting to its orientation and medium structure;
- Assess impact of inelastic deformation and pore pressure change on the growth of hydraulic fracture

**Application in industry:**
- Technology of hydraulic fracturing (HF) control;
- Technology of assessing feasibility and effectiveness of HF;
- Reducing costs and risks of contamination during HF.
Project: Microseismic Monitoring Techniques for Hydrofrac Monitoring and Field Development

Partner: Institute of Petroleum-Gas Geology and Geophysics, Russia

PI: Duchkov A.A.

Goal: Develop technology of using microseismic monitoring for detecting positions, mechanisms and types of hydraulic fracture propagation

Work plan:
- Develop and implement microseismic data processing graph in application to hydrofrac monitoring;
- Refine medium parameters from microseismic monitoring data and cross-well seismic tomography;
- Define relation between microseismic source mechanisms and hydraulic fracture development;
- Develop microseismic monitoring technology for assessing hydrofrac geometry and development mechanisms.

Application in industry:
- Technology of data processing and analysis for microseismic monitoring of hydraulic fracturing;
- Technology of seismic velocity model building from microseismic data suitable for application hydraulic fracturing in unconventional reservoirs (characterized by strong seismic anisotropy);
- Technology of calibrating geomechanic models of fracture growth and reservoir production using microseismic monitoring.

Microseismo gramm
**Project:** Theoretical and experimental rock physics for unconventional hydrocarbon resources exploration and recovery

**Partner:** Institute of Physics of the Earth, Russia

**PI:** Tikhotsky S.A.

**Goal:** Develop model of the behavior of elastic properties and mechanical sustainability of reservoir rocks under different stress-strain conditions

**Lab plastic-brittle data**

**Rock mineral composition (scale: 40 µm):**
1 — pyrite, 2 — apatite, 3 — kerogen

**Work plan:**
- Carry out lab high-pressure experiments studying mechanical properties of samples;
- Study microstructure, mineral, fluid and chemical composition of the reservoir rocks;
- Develop homogenization and simulation methods;
- Develop inversion methods.

**Application in industry:**
- methods and software for the localization of the unconventional oil-bearing formations and accurate determination of their effective transport and oil-bearing properties from well logs and field data;
- Methods and algorithms for the estimation of the quasi-static elastic moduli and non-elastic rheology of rocks for geomechanical modeling of the oil fields. The latter is important for the optimal drilling design, drilling risks lowering, prevention of drilling accidents and optimal design of the oil recovery, including hydrofracturing and recovery regime.
711-MRA Project 2

**Project:** Geophysical methods for exploration of hydrocarbon fields on the Russian shelf and assessment of related geological risks

**Partner:** Institute of Petroleum-Gas Geology and Geophysics, Russia  
**PI:** Tokarev M.Yu.

**Goals:**
- Develop method for the hydrocarbon reservoir defining at sea shelf areas
- Develop method for estimation mechanical properties of non-consolidated sediments from seismic data

**Work plan:**
- Develop joint inversion method of multi-type geophysical data for sea shelf studies;
- Develop model of gas hydrates reservoir formation and evolution;
- Study low-consolidated sea shelf sediments properties;
- Develop method of ecological risks evaluation and mitigation for hydrocarbon exploration and recovery;

**Application in industry:**
- Technology of investigation geological structure and oil-gas-bearing capacity of reservoirs external and internal Russian seas;
- Technology of assessment of geological risks associated with the hydrocarbon recovery at sea shelf.
- Geophysical methods for defining mechanical properties of near-bottom sediments with applications for drilling design and mitigation of construction risks.

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Permafrost soils in Russia  
Core from subaquatic permafrost  
Seismic image of the scattered gas in sediments
**Project:** Methane recovery from gas hydrate reservoirs by nitrogen/flue gas injection

**Partner:** Heriot-Watt University, UK

**PI:** Prof. Bahman Tohidi

**Goal:** Develop physical and chemical bases for technology of methane recovery from methane hydrate deposits by injection of nitrogen and flue gas

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**Work plan:**
- Study kinetics of the decomposition of methane hydrate and the formation of carbon dioxide hydrate in the pore space after the injection of flue gas;
- Investigate how methane recovery factor depends on permeability, porosity, mineral composition of rocks and composition of the flue gas;
- Estimate CO$_2$ hydrate formation in reservoirs and shift in geomechanical properties of sediments.
- Develop a physicochemical model for the effectiveness of methane recovery from hydrate-saturated deposits by injection of flue gas.

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**Application in industry:**
- Technology of methane recovery from methane hydrate deposits
- Technology of utilization of flue gases from large industrial facilities in permafrost collectors;

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**Distribution of organic carbon in Earth (10^{15} tons of carbon)**

**Replacement of CH$_4$ by CO$_2$ in hydrate structure**

**Possible technology**
742-MRA Project 2

**Project:** Geomechanical, geophysical, geothermal properties of gas hydrate-bearing permafrost sediments

**Partner:** Heriot-Watt University, UK

**PI:** Prof. Bahman Tohidi

**Goal:** Study physical, mechanical, acoustic and thermal properties of frozen soils containing gas hydrates

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**Work plan:**

- Study influence of temperature and pressure on geomechanical, geophysical and thermal properties of frozen and/or hydrate-containing rocks;
- Estimate salinity effect on the properties of frozen and/or hydrate-containing rocks;
- Develop model for diagnosing and quantification of gas hydrate content in permafrost.

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**Application in industry:**

- Identification of gas hydrate accumulations in the permafrost zone;
- Estimation of geological risks due to gas hydrate in permafrost;
- Prediction of properties of gas hydrates in cryolitozone;
- Estimation of porous medium physical properties of the bottom-hole zone during hydrate formation.

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Influence of gas hydrates on geomechanical properties of frozen rocks. Sh – hydrate saturation, vol%; Si – ice saturation, vol%
Project: High Performance Simulation in Conventional Reservoirs

Partner: Texas A&M University, USA

PI: Prof. John Killough

Goal: Develop complex multi-porosity simulation model

Comparative Study: Production Results in 2,000 days

- 36,080 Grid Cells
  - Simulation Time: 2 Minutes

- 1,021,750 Grid Cells
  - Simulation Time: 3 Hours

Work plan:
- Develop Prototype of Multiple Porosity Model;
- Develop Multiscale and Upscaling Techniques;
- Carry out Numerical Simulations to Match Field Data and Determine Model Predictability;
- Enhance Simulator Efficiency for Large-Scale Applications;

Application in industry:
- Model capable of handling multiple porosity scales simultaneously interacting with one another;
- Technique for handling the many scale levels from pore-level to large-scale fractures;
- Technique for enhancing simulator efficiency to extend beyond single wells and into full-field simulation capabilities to allow economic evaluation of oil reservoirs.
Project: Predictive Models for Hydrocarbon Phase Behavior and Fluid Properties in Hydrocarbon Reservoirs
Partner: Texas A&M University, USA
PI: Prof. Yucel Akkutlu
Goal: Develop laboratory methods for the PVT study of hydrocarbons produced from organic-rich resource rocks and to predict the hydrocarbon fluid phase behavior and their transport properties in reservoirs under the reservoir conditions

Methane-ethane mixture in slit-pore

Phase diagrams of n-octane in graphite slit-pores

Work plan:
• Estimate effective pore size for the condensate system.
• Develop pore-size adjusted phase diagrams for the hydrocarbons, water, CO₂, N₂;
• Develop pore-size adjusted multi-component phase diagram for the reservoir fluid;
• Develop mixing rules suitable for the reservoir fluid under confinement;
• Develop single-well history-matching case studies.

Application in industry:
• Predict producing gas-oil ratios and reserve accurately by taking in account how important the confining effects are for the organic-rich shale system.
Project: Fast Multiscale Model Reduction-Based Methods for Reservoir Simulation and Optimization
Partner: Texas A&M University, USA
PI: Prof. Eduardo Gildin
Goal: Develop reliable and efficient model of complex large-scale geosystems, amenable for fast simulation in uncertainty quantification, parameter estimation and optimization applications

- Which model should I work with?
- How to measure my approximation/error within and among each tier?
- How to add Uncertainty?
- What about complexity?

Model reduction techniques

Understanding “complexities” in reservoir models

Work plan:
- Understand complexity in porous media flow by the analysis of system-theoretical properties;
- Develop local-global model order reduction algorithms for flow in porous media;
- Interplay between multiscale methods and model-order reduction by means of the development of error estimators;
- Develop realistic test-bed for implementation of reduced-order models in porous media flow.

Application in industry:
- Multiscale model reduction of large scale dynamical systems
- Conventional and unconventional reservoir simulation and optimization;
- Closed-loop reservoir management.
746-MRA Project 4

**Project:** Real Time Data Assimilation Accounting For Multi-Physics Reservoir Processes

**Partner:** Texas A&M University, USA  
**PI:** Prof. John Killough

**Goal:** Develop reliable and efficient model of complex large-scale geosystems, amenable for fast simulation in uncertainty quantification, parameter estimation and optimization applications

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**Conventional reservoir model:**
- spatial properties;
- Dimension is defined by size and complexity of the reservoir.

**Flow network model:**
- Relationship between wells
- Dimension is defined by number of wells

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**Work plan:**
- Assimilate data and estimate parameter of multi-physics reservoir attributes;
- Evaluate reservoir performance uncertainty using computationally efficient schemes;
- Implement data assimilation and uncertainty quantification in parallel architectures;
- Develop real time data assimilation and feedback control of oil recovery process.

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**Application in industry:**
- Data assimilation and techniques for fast quantification of uncertainty in reservoir modeling, data assimilation, feedback control of enhanced recovery processes.
745-MRA Project 1

**Project:** High Pressure Air Injection (HPAI): Physical Modeling Matrix for HPAI Feasibility Assessment, Field Design and Kinetic Parameters

**Partner:** University of Calgary, Canada  
**PI:** Prof. Raj Mehta

**Goal:** Designing experiments which generates ‘meaningful’ data for evaluation of process performance, obtain field design parameters and oxidation reaction kinetics data for numerical simulation

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**Work plan:**
- Develop matrix for systematic screening/evaluation of target reservoirs for High-Pressure Air Injection (HPAI)-based oil recovery processes using elemental physical modeling at reservoir conditions;
- Develop methodology for the relevant experiments for physical simulation of the HPAI-processes in the laboratory;
- Design and carry out experimental programs.

**Application in industry:**
- Reservoir screening, field design parameters and process performance monitoring for implementation of the HPAI-based oil recovery processes;