ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO
DEPARTAMENTO DE ENGENHARIA DE MINAS E DE PETRÓLEO

# PETROLEUM ENGINEERING RESEARCH PROJECTS

## DEPARTMENT OF MINING AND PETROLEUM ENGINEERING

**Escola Politécnica da Universidade de São Paulo**
Departamento de Engenharia de Minas e de Petróleo
www.pmi.poli.usp.br

# Universidade de São Paulo USP

- Established in 1934 (80th anniversary)
- State University (no tuition fee)
- Most prestigious Brazilian University
  - ✓ The Times Higher Education
  - ✓ Webometrics Ranking of World Universities

#1 LatAm University Rankings

#120 QS World University Rankings

#10 BRICS Rankings

QS Ranking

QS WORLD UNIVERSITY RANKINGS TOP 50 UNDER 50

- Budget of about R$ 4 billions
- Over 200 undergraduate programs
- Campus: 8 campi

USP 80 1934 2014

www.usp.br

# Escola Politécnica (Engineering School)

- Established in 1893 (122nd anniversary)
- 15 Departments
- 457 professors
- 4500 undergraduate students (17 programs)
- 2500 graduate students (11 programs)

www.poli.usp.br


# Department of Mining and Petroleum Engineering

#36 world

QS Ranking

- 75 years of excellence in engineering education, research and consultancy
- International reputation
- Complete infrastructure for scientific and technological research
- Updated library with thousands of books and scientific journal access
- SPE Student Chapter – **Gold Standard Award**
- Petroleum Engineering – since 2001 São Paulo and 2012 Santos

SPE International
SPE Student Chapter USP


www.pmi.poli.usp.br

# SPE Student Chapter

The student chapter supports the networking among Petroleum Industry professionals and students through SPE events and discussions

The student chapters organize several events: workshop, field trips, conferences and foruns.

USP/SP

Unicamp/SP

UFRJ/RJ

The students can participate in several academic competitions: Paper conterst, PetroGames, Petrobowl, etc.

# Department of Mining and Petroleum Engineering

## Petroleum Engineering Research projects

- Multivariate analysis for data prediction by Self Organizing Maps
- Digital core analysis and flow simulation
- Semi-Automated Mud Logging
- Chemist applied to Petroleum sciences
- Ultrasound in the breakdown of water and oil emulsion
- Autonomous Inflow Control Devices for Horizontal Wells
- Numerical Methods and simulation
- Logistics and optimization in Oil Industry
- Applications of ROVs to the Oil industry
- Mineral & Petroleum Economics and Public Policies

Research at PMI

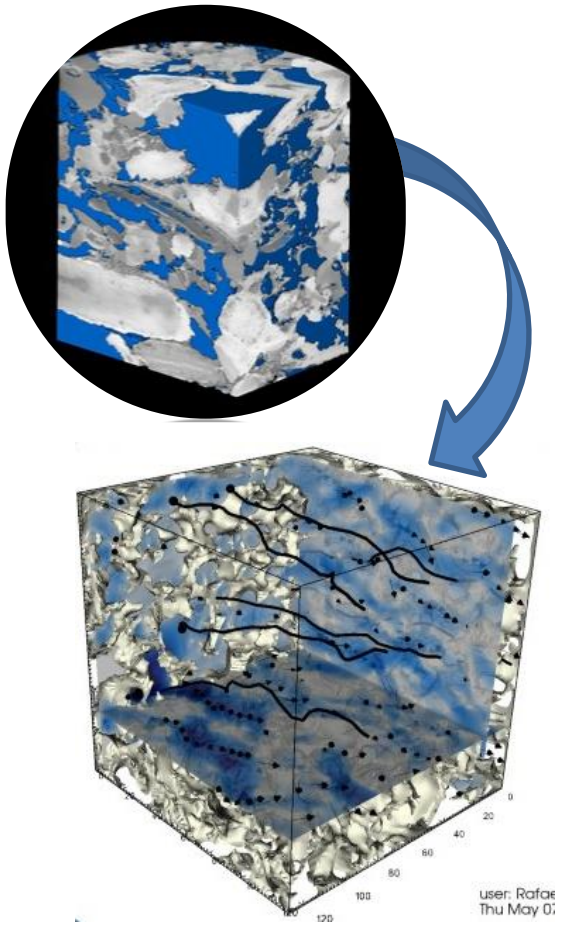
http://www.pmi.poli.usp.br – Pesquisa

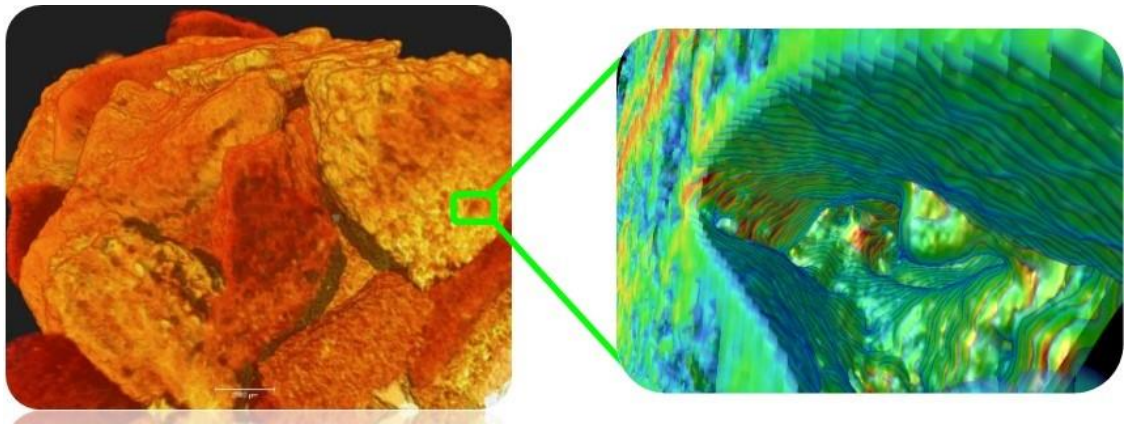
http://www.pmi.poli.usp.br – Pós Graduação

**Master, Doctorate, Pos doctorate**

# INTEGRATED RESERVOIR ROCKS CHARACTERIZATION (IRC)

- Integrating knowledge for reservoir characterization
- Focus on the interface among different knowledge areas
- Multivariate analysis for data prediction by Self Organizing Maps
- Digital core analysis and flow simulation
- Semi-Automated Mud Logging
- Interaction rocks-fluid





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Prof. Cleyton Carneiro, PhD
Prof. Jean Ferrari, PhD
Prof. Márcio Yamamoto, PhD
Prof. Rafael Gioria, PhD
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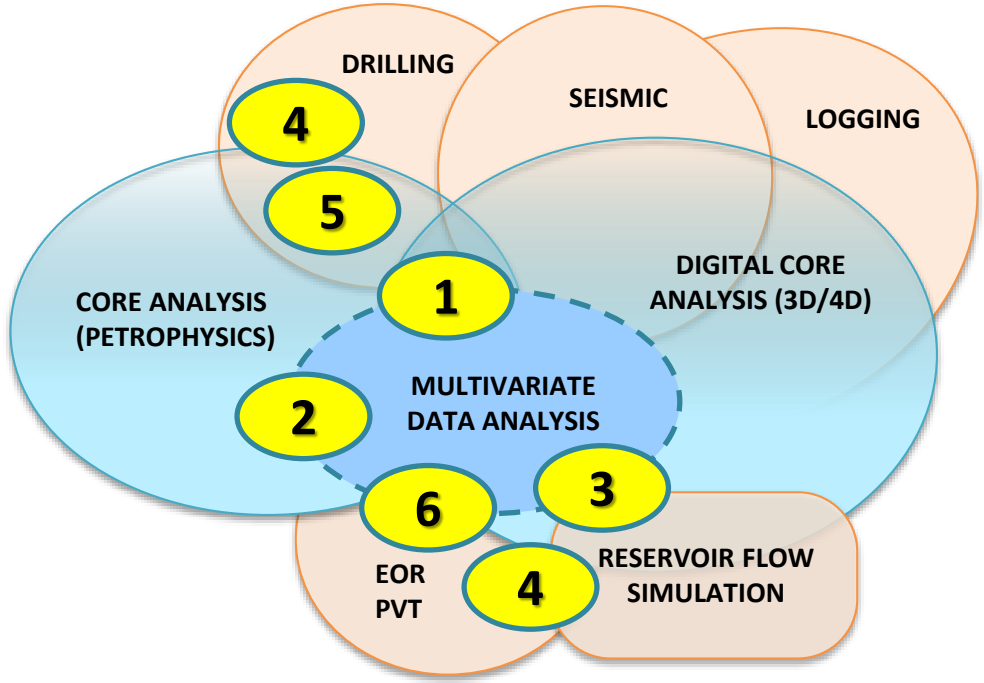
# INTEGRATED RESERVOIR ROCKS CHARACTERIZATION (IRC)

## IRC: *Focus on the interface among different knowledge areas*

1. Multivariate analysis for data prediction by Self Organizing Maps (SOM)
2. Porosity and permeability measurement and prediction
3. Digital core analysis and flow simulation
4. EOR/IOR e PVT
5. Semi-Automated Mud Logging
6. Reservoir simulation

IRC
Integrated Reservoir Characterization

*"From gap to overlap"*



# INTEGRATED RESERVOIR ROCKS CHARACTERIZATION (IRC)

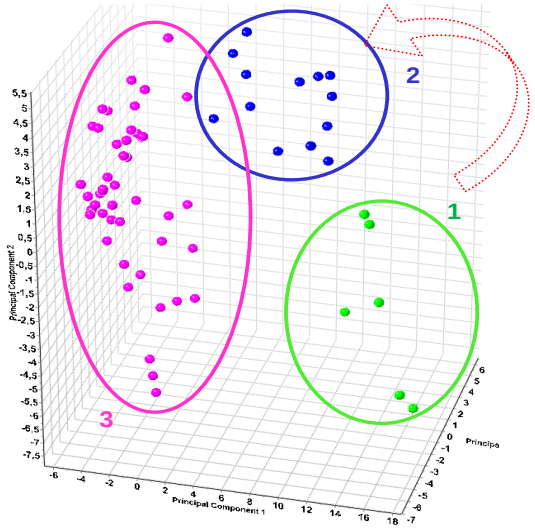
## Semi-automated mud logging

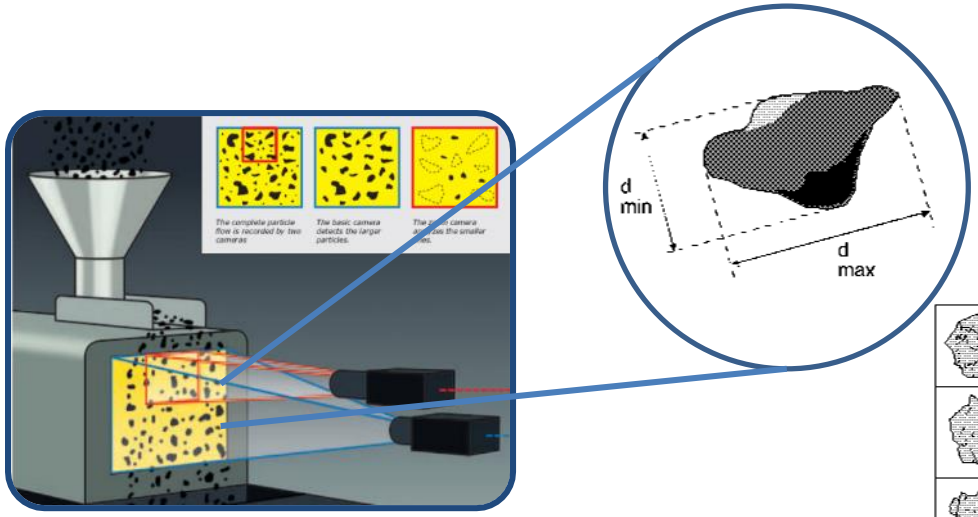
- XRD cluster: mineralogy by semi-automated system

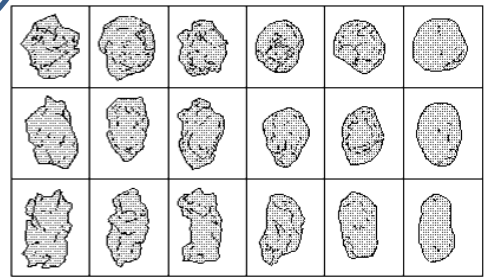
  Time reduction, increase precision on mineralogy interpretation

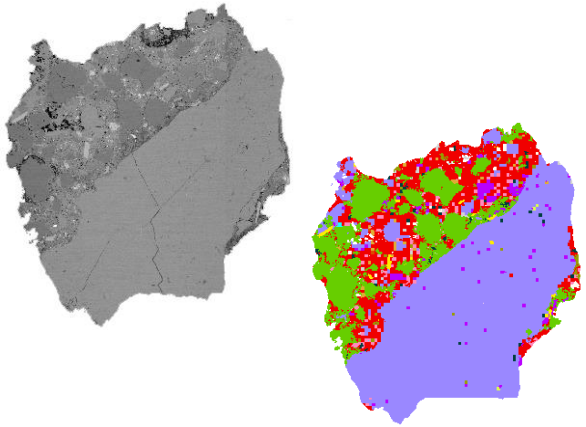
- Dynamic Image Analysis: particles size and morphology

  Rocks cuttings morphology x lithology



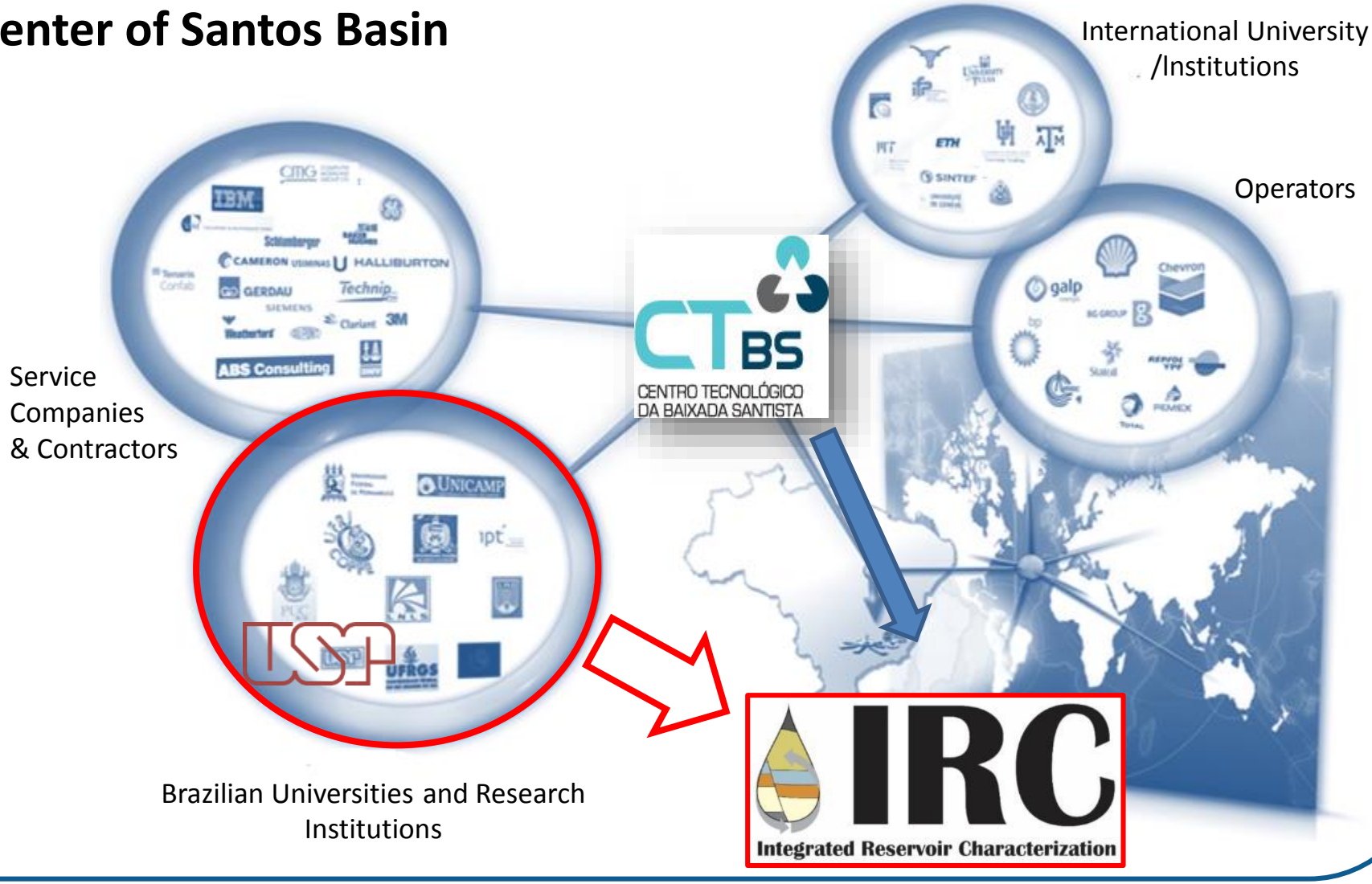





Automated mineralogy and clustering

# INTEGRATED RESERVOIR ROCKS CHARACTERIZATION (IRC)

**CTBS – Technological Center of Santos Basin**
**Place for integration**




**IRC structural project at CTBS**

# MULTIUSER FACILITY – CHARACTERIZATION

## Technological Characterization Laboratory

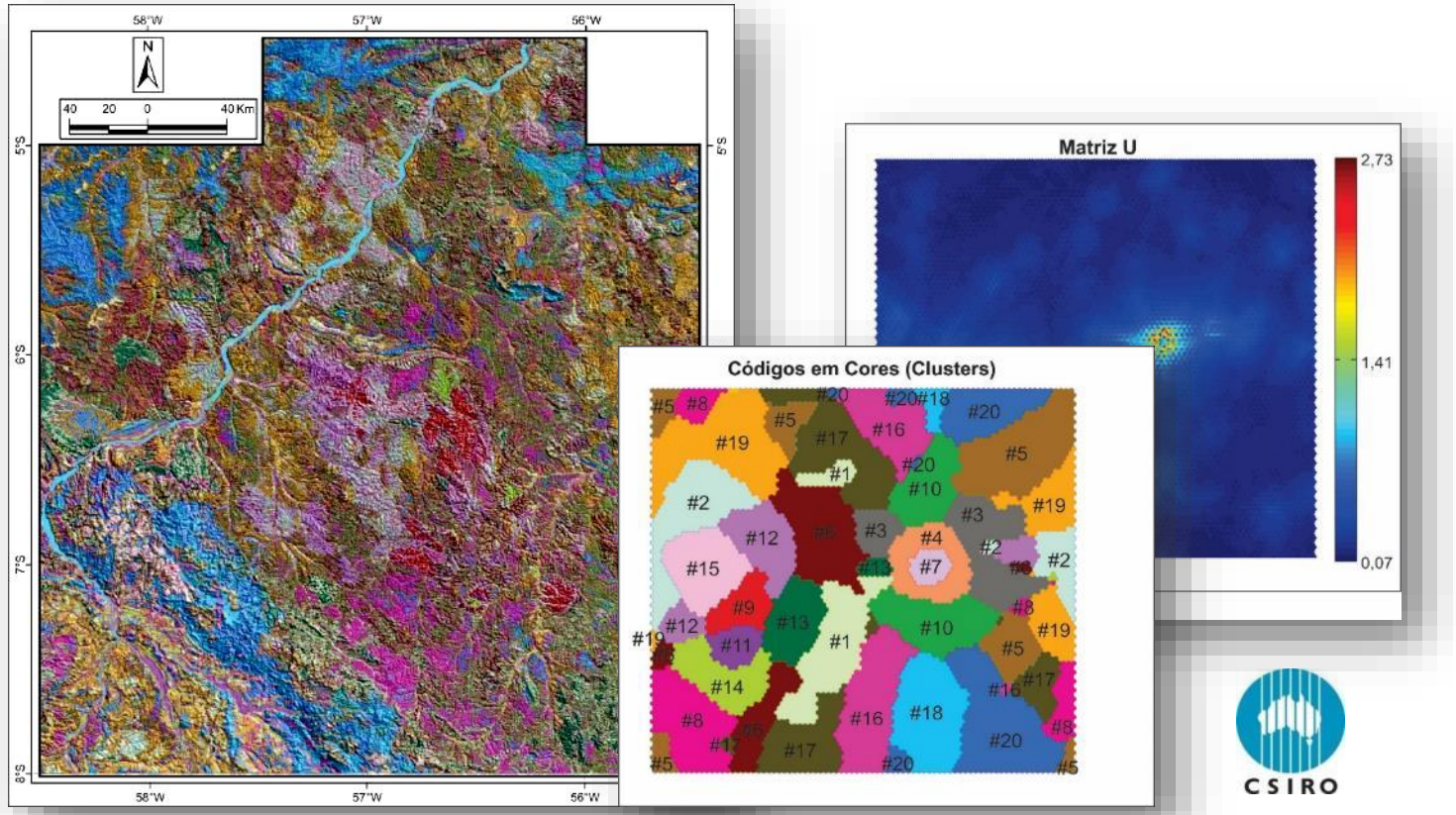
- Ore characterization and **geometallurgy**: quantitative mineralogy by automated image analysis: P, Zn, Pb, Ni, iron ore, bauxite, gold, rare earth
- Characterization of products from mineral and metallurgical processing
- 3D characterization by **µ-tomography** (reservoir rocks, ore, concrete, materials)
- Particle characterization: size, shape, porosity, composition, phase's associations
- **Materials characterization** (ESEM, SEM, MLA, XRD, XRF, ICP, MIP, 3D-XRM, LAS)


Laboratório de Caracterização Tecnológica

www.lct.poli.usp.br

# MULTIVARIATE DATA ANALYSIS - SELF ORGANIZING MAPS (SOM)

***Vector quantization in n-dimensional space to generate maps and predict values in multivariate data***




**Self-Organizing Maps (SOM):**

*"Tool for analyzing and visualizing data in a high-dimensional space, based on vector quantization (Kohonen 2001)*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# MULTIVARIATE DATA ANALYSIS - SELF ORGANIZING MAPS (SOM)

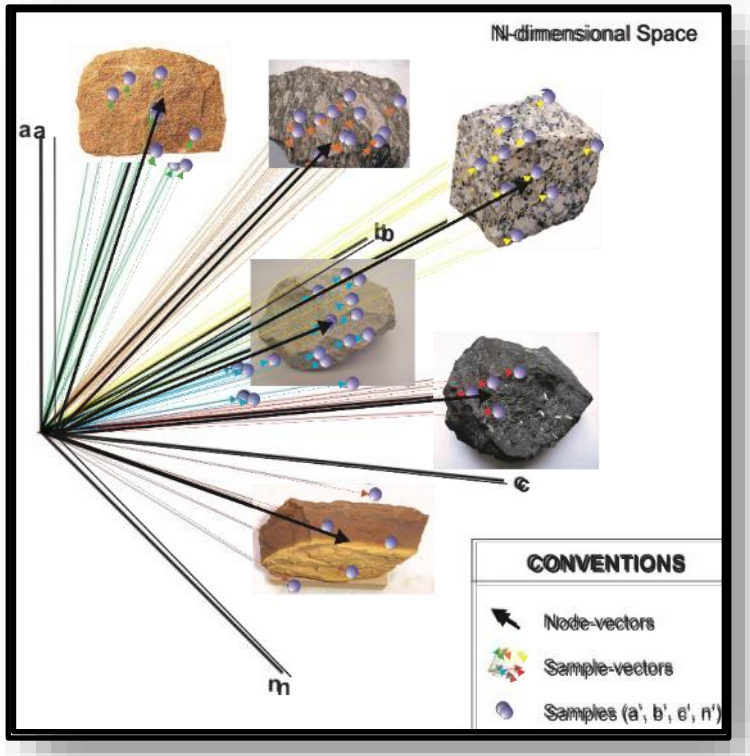
Samples can be considered as vectors based on the contributions of the various constituent components;

Considere um agrupamento de amostras semelhante e relacionadas no espaço nD;

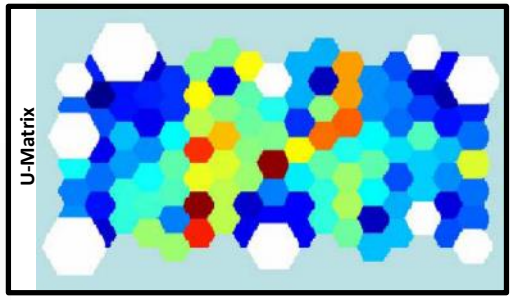
In a multi-population data set, SOM finds the “medium-vector” of each population or cluster;

Coloured vector are population;

Black vectors are the SOM “node-vectors”;




Then displays them as a “map”, so thar topology (relationships) is maintained.




**Ongoing projects**

- Semi-Automated Geological Maps;
- Chemical predictions in bauxites;
- Variable predictions in takeoff and landing variables of aircrafts

**Other projects in analysis**

- Pore pression prediction;
- Analysis of velocity in fluids.

# MULTIVARIATE DATA ANALYSIS - SELF ORGANIZING MAPS (SOM)

## SOM for Rock Properties Prediction

SOM has the ability to visualize multidimensional data in a two dimensional way as well as to cluster and classify them. Predictions can be done by supplying a priori known information (e.g. porosity, permeability) to a trained SOM and get the prediction of other analytical data for reservoir (e.g. pore pressure).

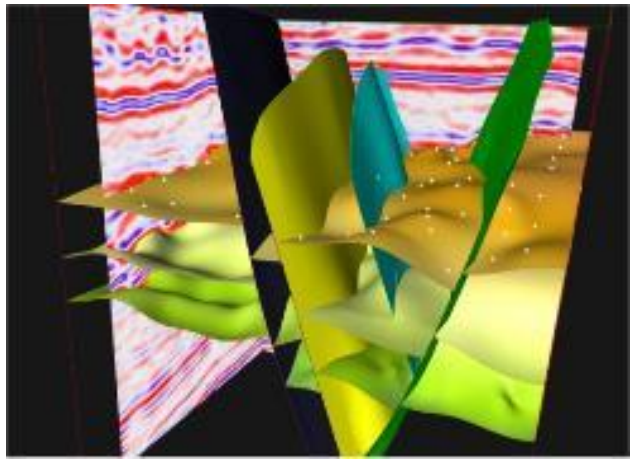
## Noise attenuation of Seismic Attributes

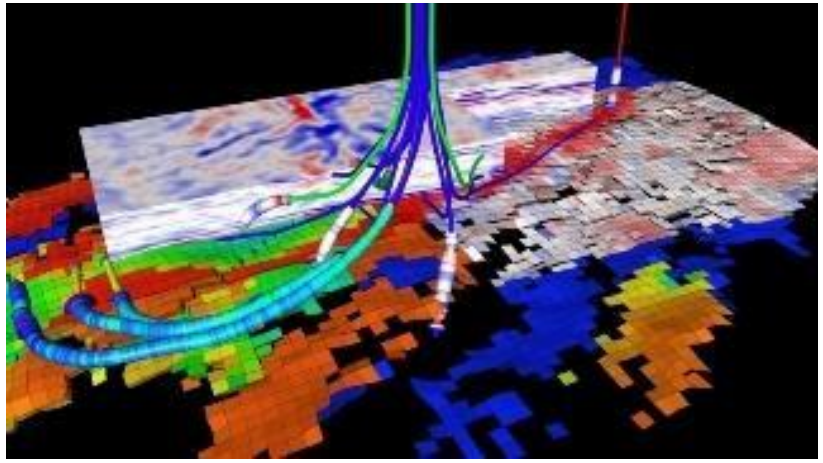
Using multivariate analysis, where the variables would be represented by seismic attributes, noises would be replaced by more representative samples constructed from the Self-Organizing Maps.

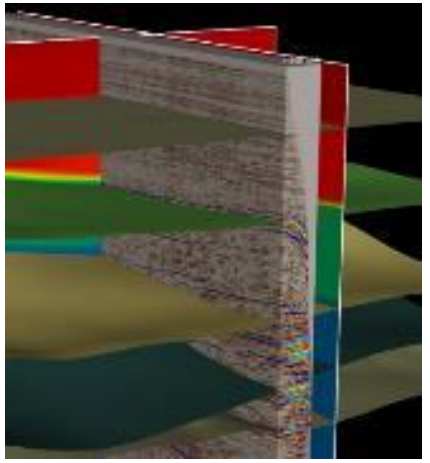
# MULTIUSER FACILITY – RESERVOIR MODELLING

LISTEC
Laboratório Integrado de Simulação Tecnológica

- Software *"Reservoir Management Software (RMS)"*







roxar
MAXIMUM RESERVOIR PERFORMANCE

EMERSON
Process Management

***US$ 14 732 578***

- Xeon with 08 cores;
- Frequency 2,4GHz;
- Cache 20MB;
- QPI System Bus 8,0 GT/s;
- *16 GB (expansable* up to 64GB);

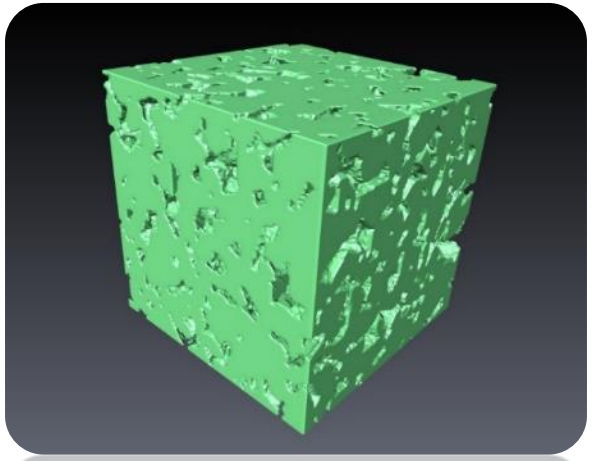
- Video board Nvidia Quadro 2000:
  a. 256 cores CUDA;
  b. 2048 MB of memory GDDR5;
  c. 256-bit memory interface;
  d. Memory band of 89.6 GB/s

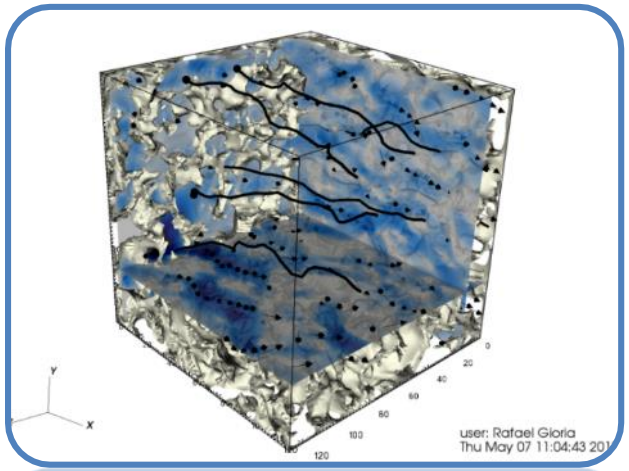
# NUMERICAL METHODS AND SIMULATION

## PERMEABILITY SIMULATION AT PORE SCALE

### Lattice-Boltzmann method

- Geometric boundary conditions:  digital core analysis images
- Pore scale flow numerically computed using Lattice-Boltzmann method
- Permeability estimation from flow data
- Validation using experimental data



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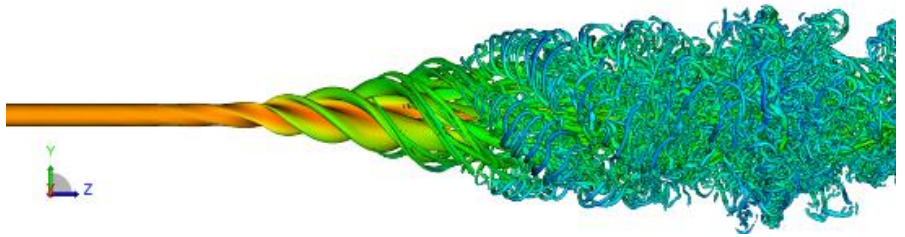
# NUMERICAL METHODS AND SIMULATION

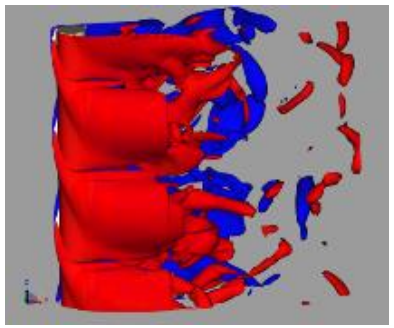
## FLOW STABILITY AND CONTROL

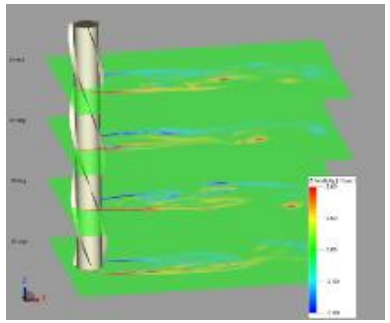
- Focused on transition to turbulence and flow control
- Stability and transition analysis
- a deeper look into fluid flow physics



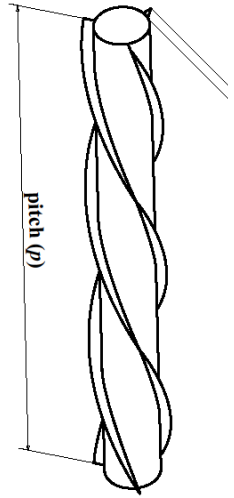
## FLOW CONTROL / FLUID STRUCTURE-INTERACTION

- Using Stability analysis and knowledge of flow physics
- Adjoint models employed to choose and quantify flow control



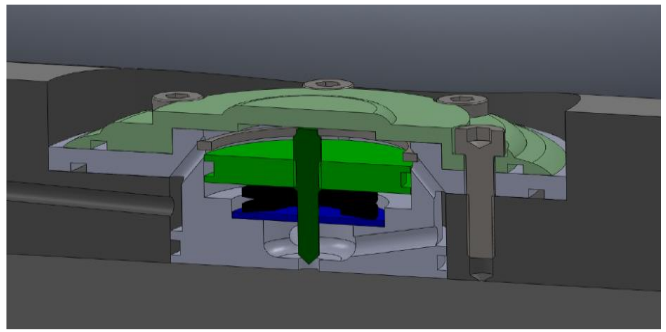


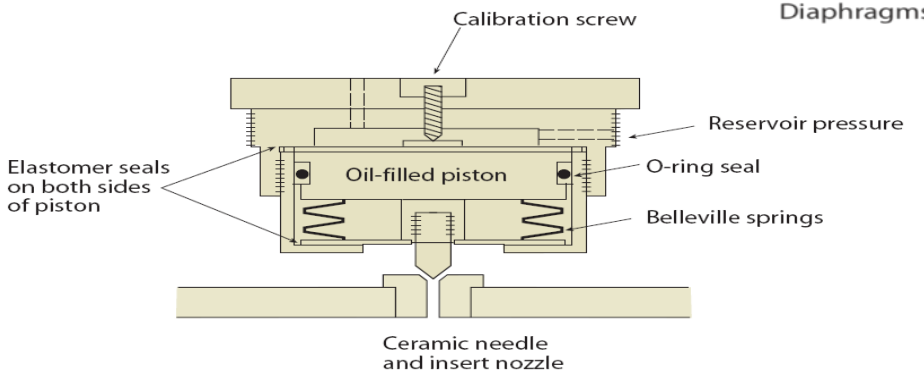
Simulated flow around cylinder with strakes

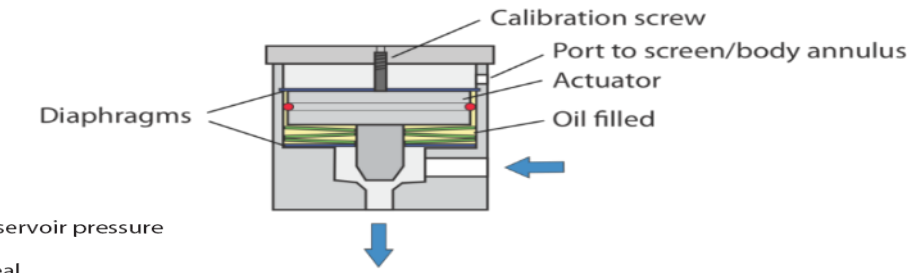


# RESERVOIR-WELL INTEGRATION

- Closing the gap between the well and the reservoir
- Research on oil and gas exploration and production, including: characterization of reservoir rocks and fluids, well geometries and trajectories, intelligent wells, production optimization, and improved oil recovery (IOR)
- Example of a recent study: Autonomous Inflow Control Devices (AICD) for Horizontal Wells, with Prof. Aadnoy, from Norway (figures below)
- When the fluid passes through the AICD, the flow rate won't change, no matter the changes in reservoir pressure



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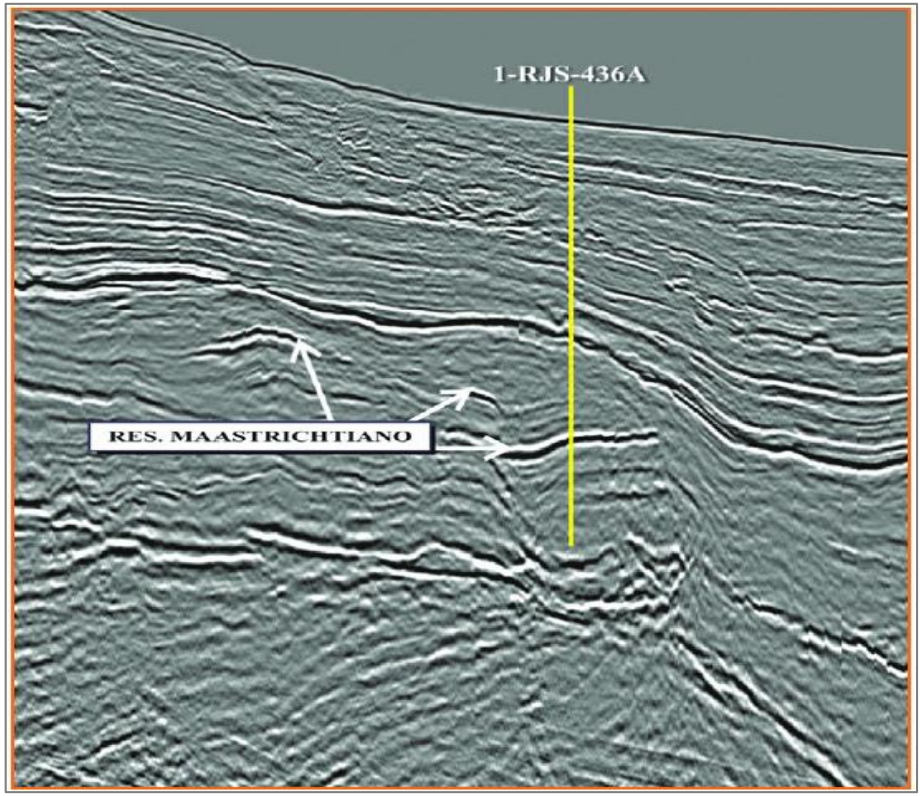
# OIL AND GAS EXPLORATION

## Research Line

Research on the methods required to define and evaluate hydrocarbon deposits, including potential and seismic methods of acquiring, processing and interpreting geophysical data. The objectives are to get information on the structure and composition of the subsurface rocks, seeking to define the location of pioneer wells.

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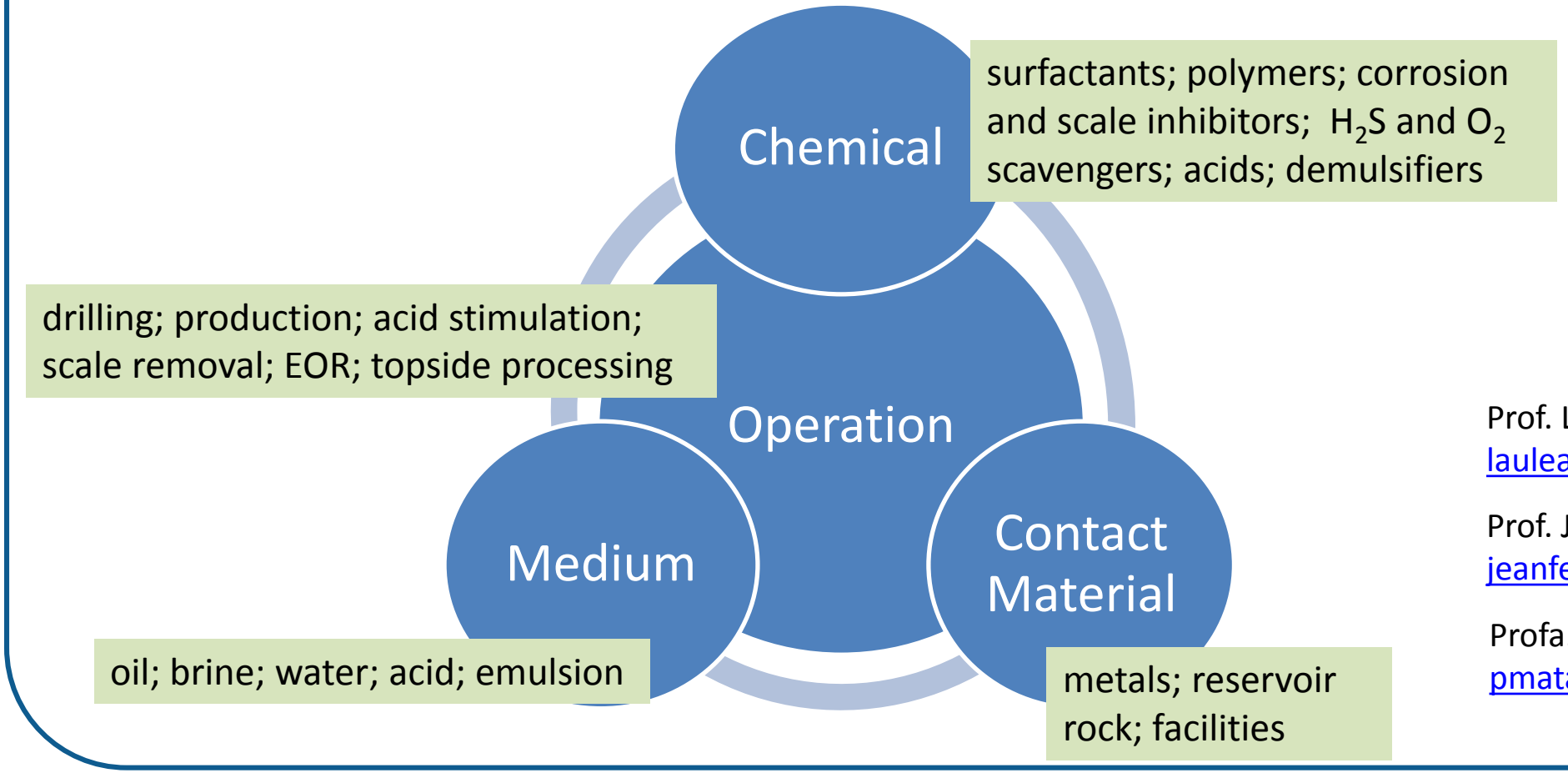
# CHEMICALS FOR OIL UPSTREAM INDUSTRY

Evaluation, developing and selection of chemicals solutions for oil *upstream* industry (*offshore and onshore*), from downhole to topside facilities, including compatibility issues with mediums, operations and contact materials





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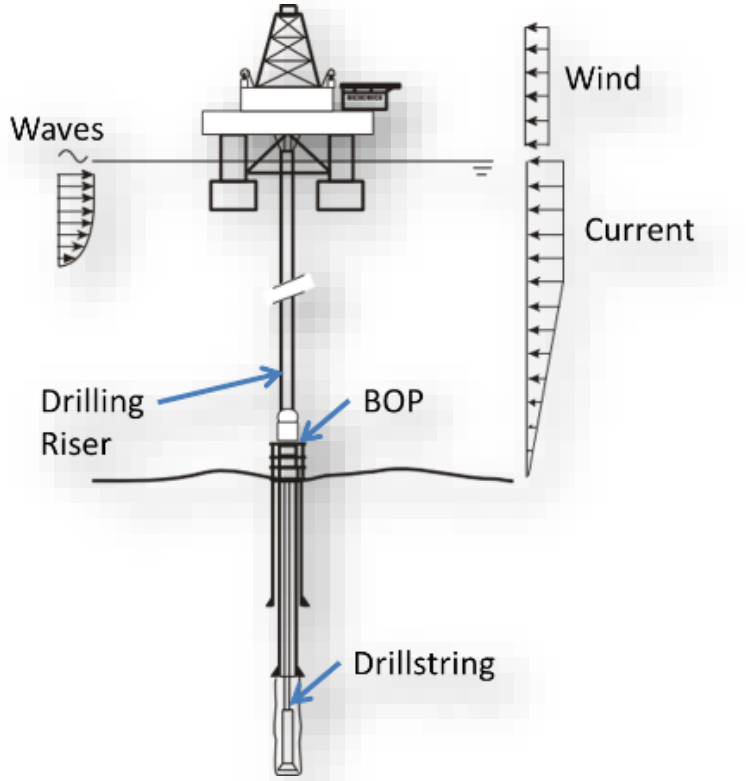
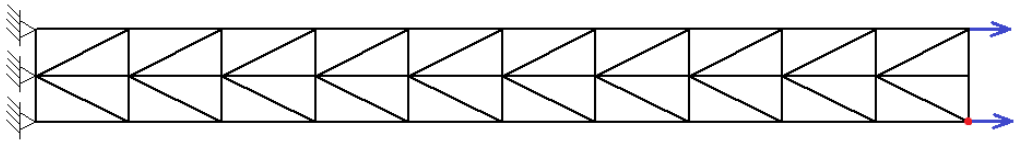
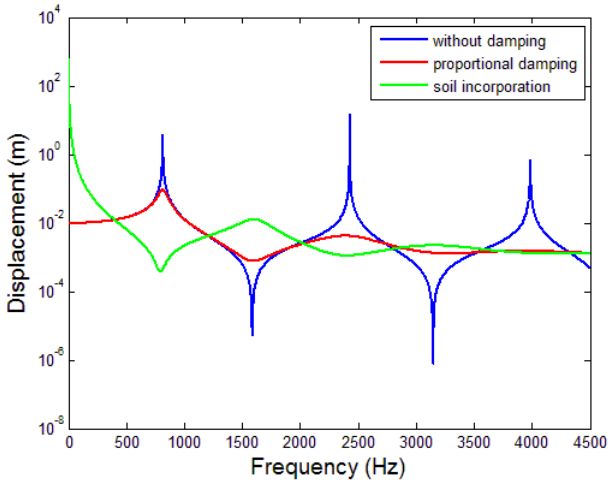
# NUMERICAL METHODS AND SIMULATION

## DYNAMIC BEHAVIOR OF DRILLSTRING

### Finite elements method



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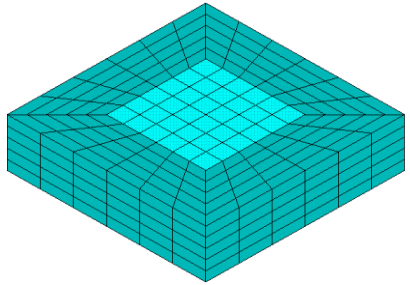
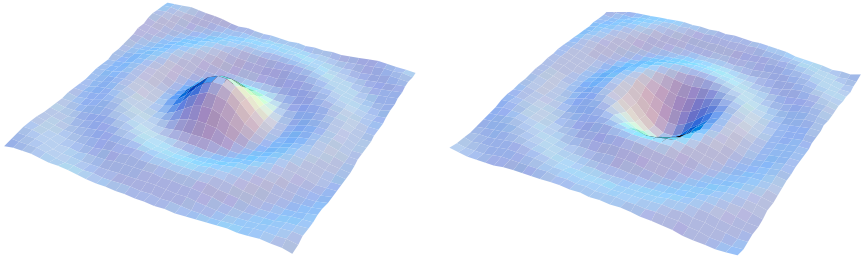
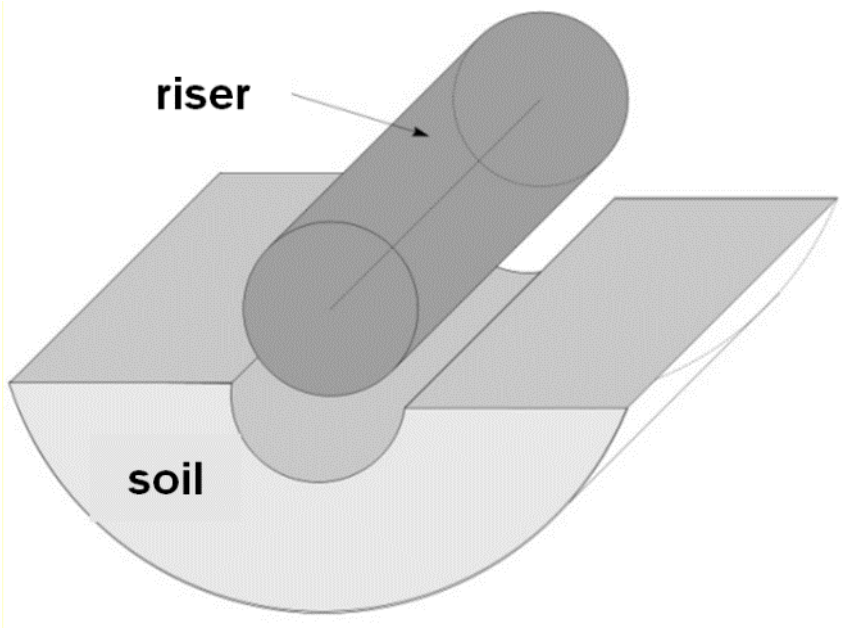
# NUMERICAL METHODS AND SIMULATION

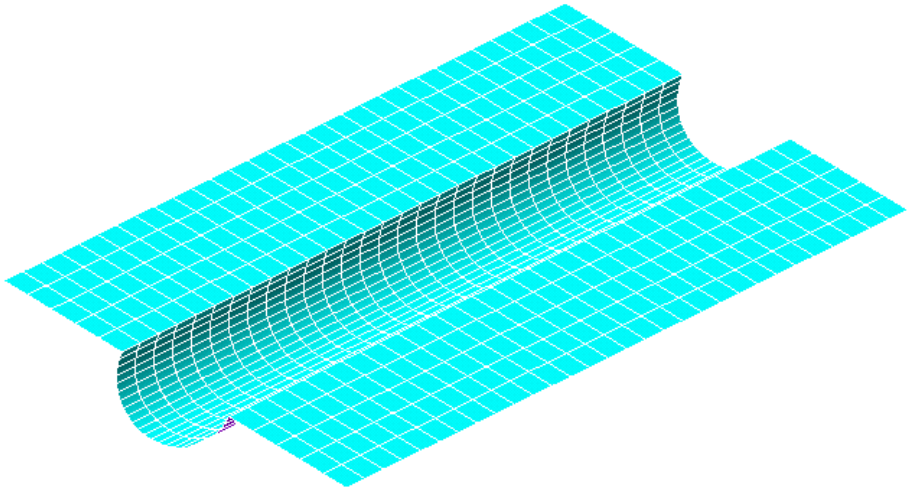


## DYNAMIC SOIL –STRUCTURE INTERACTION

### Boundary Elements Method

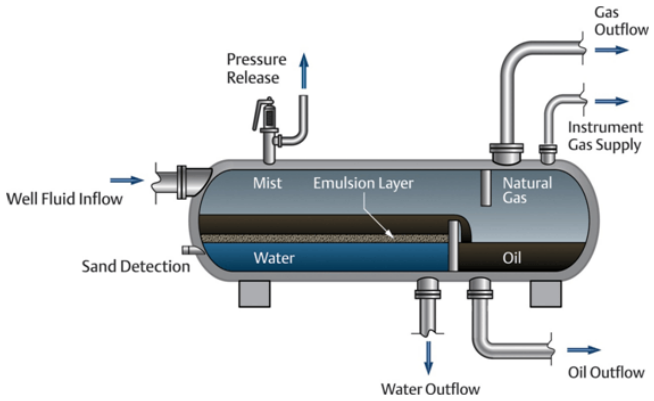




# PROCESS AUTOMATION AND CONTROL

- Simulators
- Process optimization
- Control and remote operation of offshore industrial plants
- Development of teaching platforms of oil production processes (small oil-water separation plant )
- Promote education and training in modeling, instrumentation, control and automation of oil production processes

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# POWER SYSTEM AUTOMATION

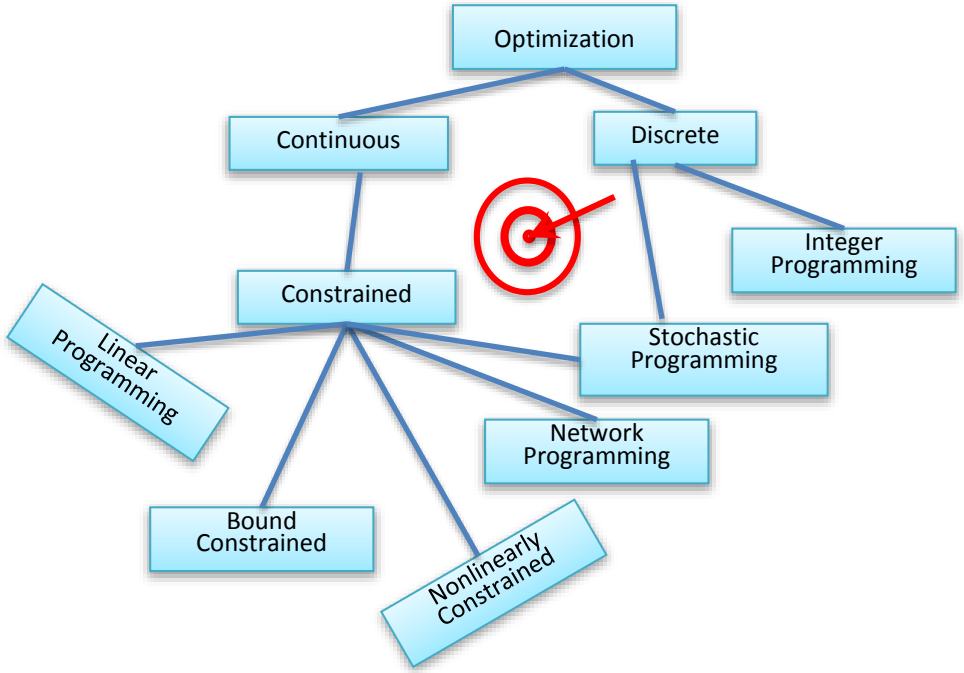
- Support regulatory guidelines for electrical installations projects
- Evaluate power supply alternatives to offshore platforms (onshore network integration, HVAC / HVDC, or renewable sources)
- Explore possibilities of IEC 61850
- Evaluate performance of protection systems in industrial onshore and offshore plants
- Assess the impact of power management and load selective cutting systems
- Develop infrastructure for simulation of power system in real time

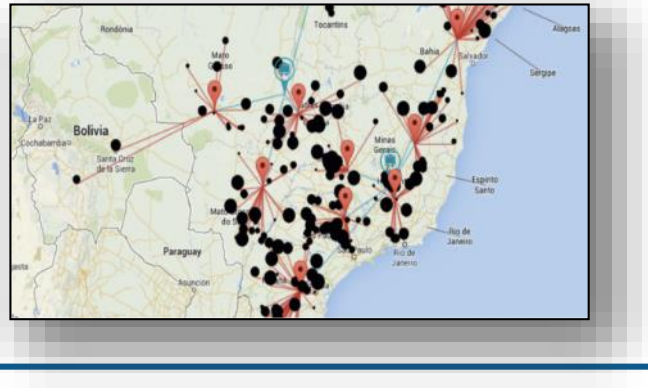
# PERSONAL SKILLS IN EXPLOSIVE ATMOSPHERES

- Promote training for carrying out activities (area classification, equipment selection and repair, installation and inspection of facilities) in explosive atmospheres
- Developing infrastructure for training in explosive atmospheres
- Support regulatory guidelines for design of electrical installations and safe operation of existing industrial plants

# OPTIMIZATION AND LOGISTICS IN PETROLEUM SUPPLY CHAIN

- Geographical Location of Facilities
- Supply Scheduling
- Parts and Components Planning and Scheduling
- Storage, Handling and Packing Methods
- Modal Definition
- Vehicles Routing and Scheduling
- Integration of  Logistics Concepts and Optimization Techniques

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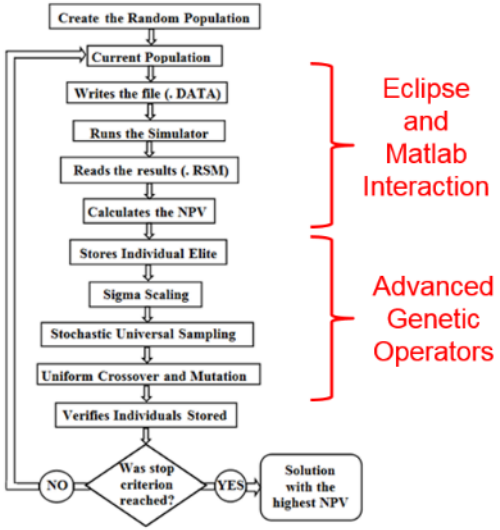
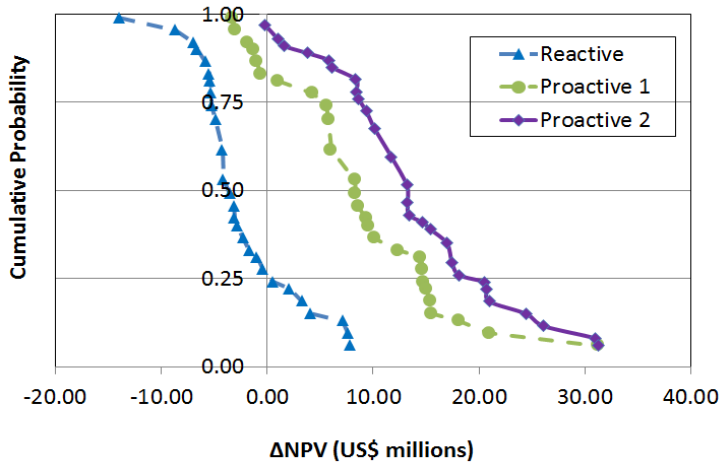
# RESERVOIR SIMULATION AND MANAGEMENT

## OPTIMIZATION FOR LARGE SCALE PROCESS

### Derivative-free optimization

- Genetic algorithms (GA) and simultaneous perturbation stochastic approximation (SPSA)
- Optimization under uncertainties: geological, economic and technical

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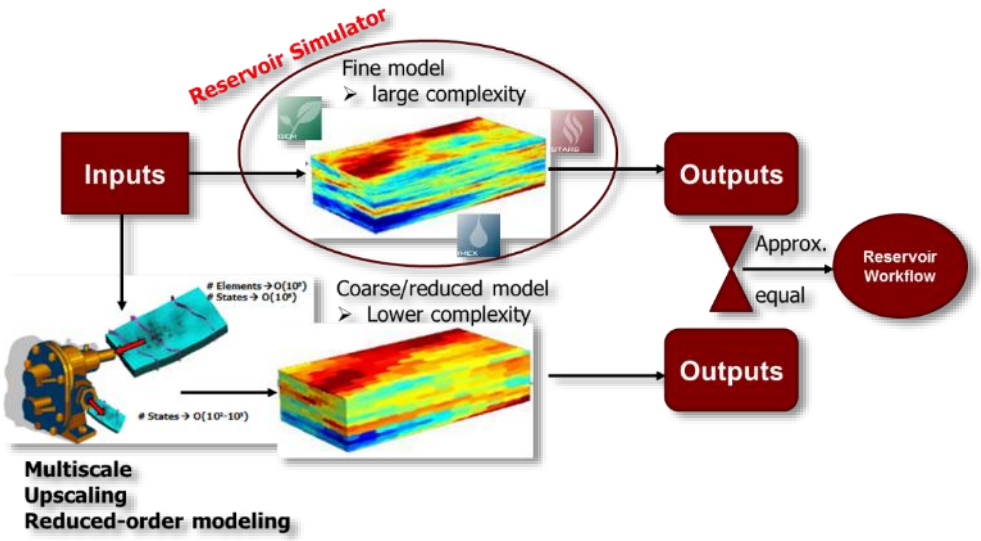
# RESERVOIR SIMULATION AND MANAGEMENT

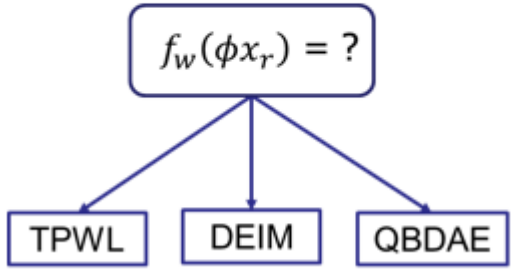
## SPEED UP SIMULATION TIME

- Surrogate models:  experimental design and neural networks
- Model order reduction: proper orthogonal decomposition (POD) and trajectory piecewise linear (TPWL)




$$R(x) = x - s_w^n - A\, f_w(x)$$

$$J(x) \triangleq \frac{\partial R}{\partial x} = I - A\, f_w'(x)$$

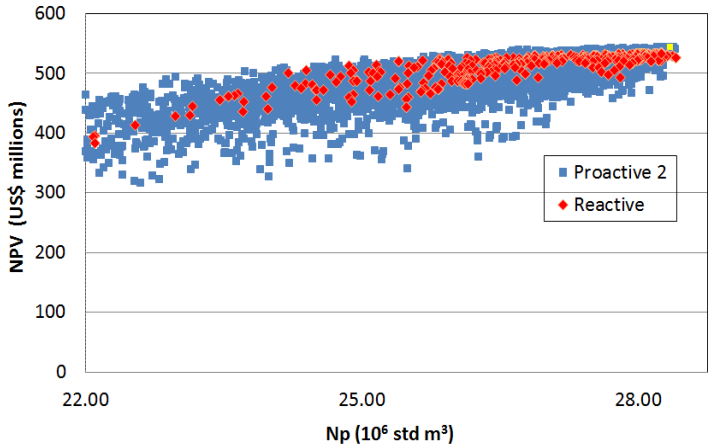


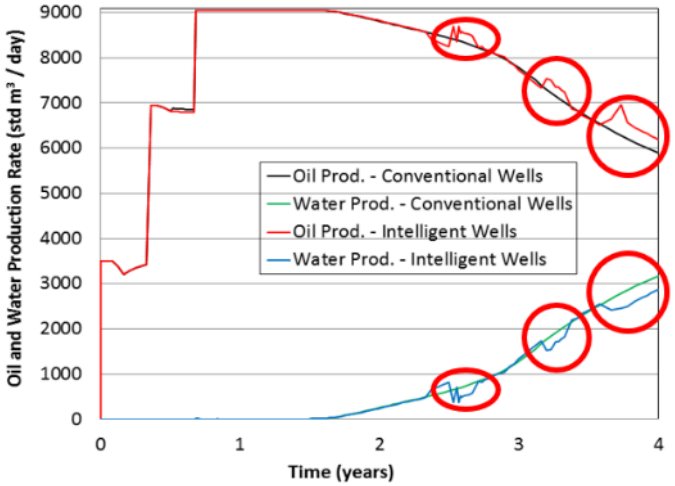
# RESERVOIR SIMULATION AND MANAGEMENT

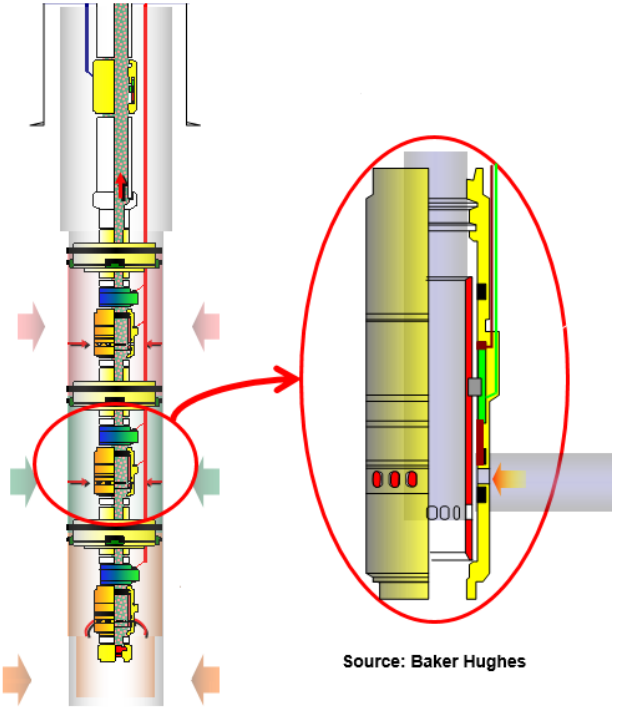
## APPLICATION OF INTELLIGENT WELLS

### Recovery in heterogeneous reservoirs

- Number and placement of wells and valves
- Control valves operation



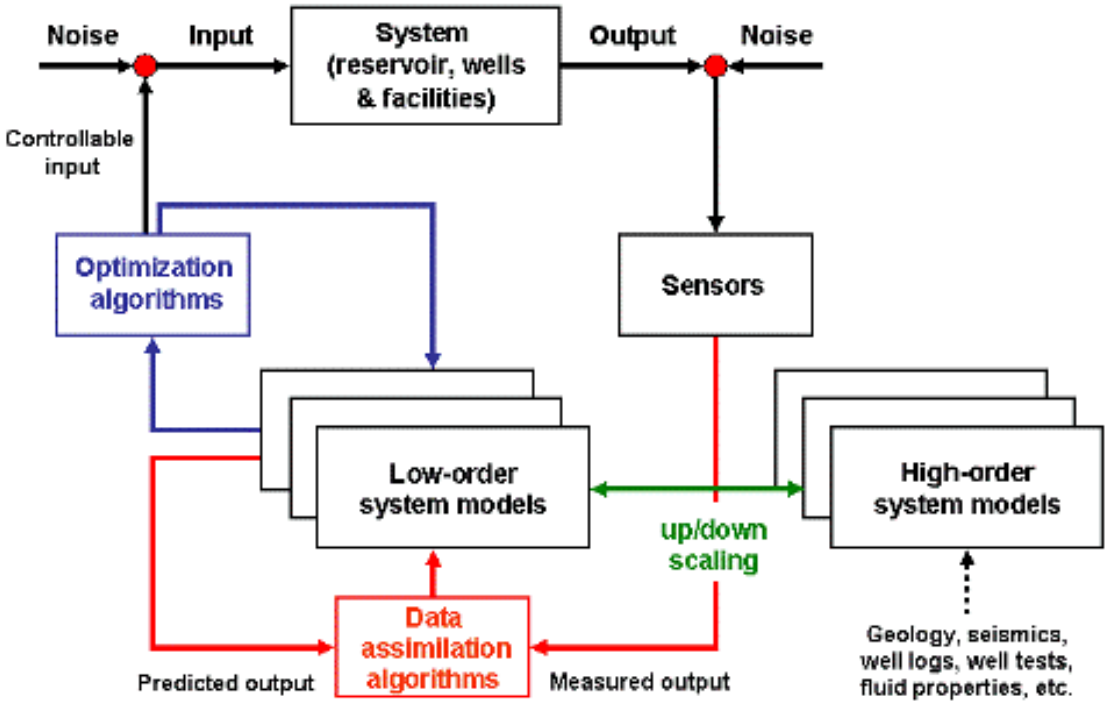



Source: Baker Hughes

# RESERVOIR SIMULATION AND MANAGEMENT

## RESERVOIR MANAGEMENT

- Short and long-term;
- Closed and open-loop;
- Real-time reservoir management;
- History matching using the Kalman filter




Source: Jansen et al., 2004

# APPLICATIONS OF ROVs TO THE OIL INDUSTRY

- Best practices in ROV operation and maintenance;
- Use of ROVs for observation and inspection;
- Inspection process analysis and improvement;
- Applications to rig structure and pipeline inspection
- Research and development of new ROV tools
- Simulation and work practice

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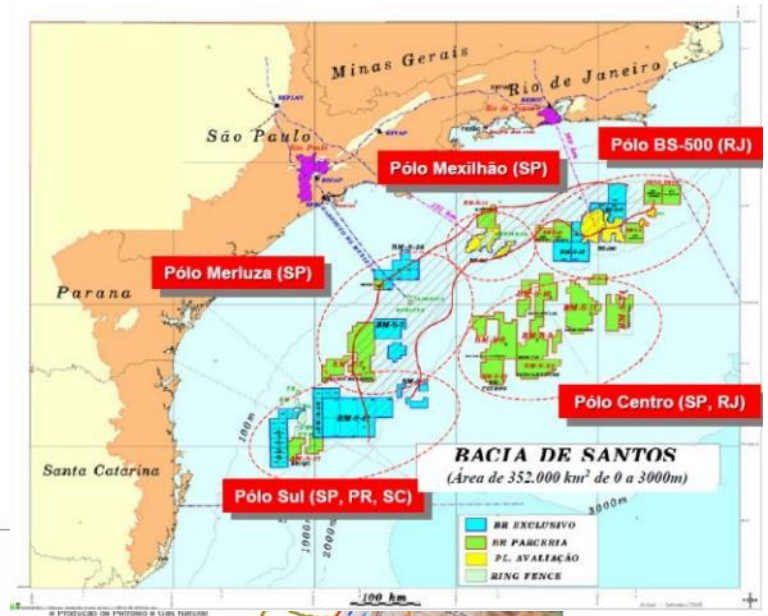
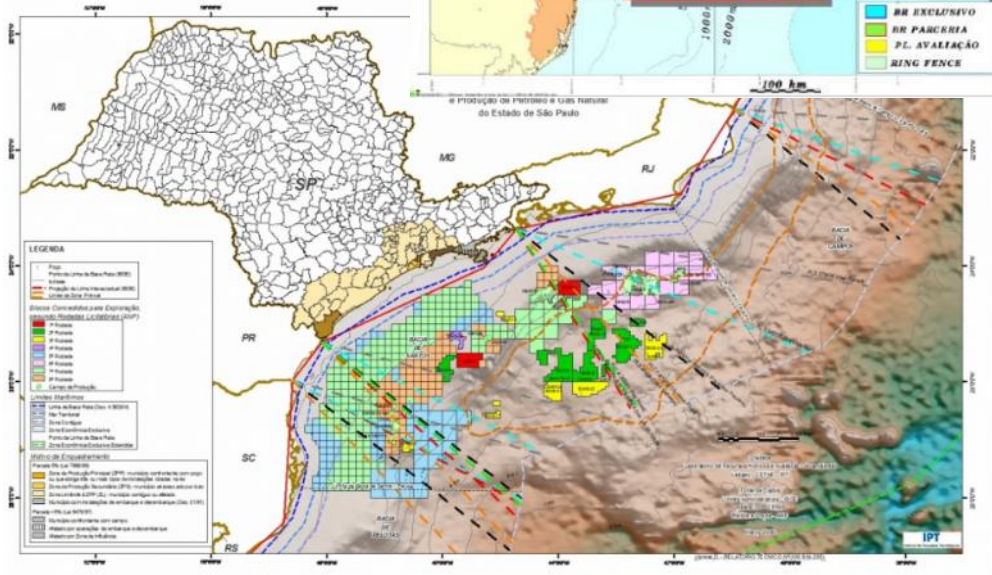
# MINERAL & PETROLEUM ECONOMICS

## SUPPORT TO PUBLIC POLICY

- Study of the main drivers, restrictions and controls in the production and consumption of oil and mineral commodities in the State of São Paulo
- This research area supplies guidelines and information to support public policies and government actions for the oil sector in São Paulo and Brazil.

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