Reservoir Imaging in Challenging Environments

(Output from ITF Technology Challenge Workshops)

A Collaborative Approach to Investment in Technology

The Industry Technology Facilitator (ITF) is a not for profit organisation owned by, and with access to funds from major oil and gas operating and service companies that comprise its membership. ITF has an impressive track record in delivering finance to help develop new initiatives for oil and gas technologies from early stage joint industry projects (JIPs) through to field trials and commercialisation. Since 1999, ITF has supported more than 150 projects worth in excess of £45 million in funding. ITF's key objectives are to identify technology needs, foster innovation and facilitate the development and implementation of new technologies.

A fundamental element of ITF's role as an internationally recognised champion for facilitating research, development and deployment of technology innovation within the upstream oil and gas industry is to engage with key industry sources. ITF uses a proven process, working in collaborative participation with both its Members and industry to identify technology needs and potential solutions.

The ITF process, illustrated below as a step-by-step course of actions, endeavours to bridge the gap between the industry's large global players and development community with the ultimate aim of implementing new technology solutions:

STEP 1 - Understand and Identify Technology Needs
STEP 2 - Engage the Development Community / Invite Proposals
STEP 3 - Evaluate Proposal Submissions
STEP 4 - Secure Funding
STEP 5 - Assist the Launch of JIPs
STEP 6 - Facilitate the Implementation of Technologies

ITF has contractual confidentiality arrangements with all its Members and will enter into a parallel agreement with all developers submitting proposal applications. Proposals will be submitted to our Members only for the purpose for which they are provided, i.e. assessment for funding support and implementation.

Proposals submitted under this Technology Challenge Program will be reviewed for financial sponsorship by **all ITF Members** therefore this is an excellent opportunity to gain access to a global audience in seeking support for your technology. The focus of all ITF themes is to identify technologies which bring clear benefits to sponsors but which require assistance in **research, development, and / or field trial.**

For details of ITF's full Portfolio of Members, please visit our Website - www.oil-itf.com

Background to the Theme

This Call for Proposals is the collective output of various ITF "Reservoir Imaging in Challenging Environments" events; a workshop held in Aberdeen on the 5th of October 2009 and two full Technology Challenge Workshops held in Houston and Aberdeen on the 29th of October and the 26th of November respectively in recognition that technology in relation to reservoir imaging needs to be developed further to help overcome the specific problems associated with complex geological environments.

All the events included intensive, facilitated workshops which brought together ITF Members, Operators, Service Companies, Small and Medium-sized Enterprises and research and academic players. The output of these discussions has formed the basis of this Call for Proposals.

Program Timeline

Each ITF Theme follows a nine month timeline from the Technology Challenge Workshop to Program Completion. The following list of tasks describes the key milestones and their associated date:

Technology Challenge Workshop	Nov 2009
Call for Proposals Issued	Jan 2010
Deadline for Receipt of Proposals	***Mar 2010***
Publish to Members for Review	Apr 2010
Member Review and Voting	May 2010
Technical Clarification Meeting	Jun 2010
Members finalise commitment to sponsor	Sep 2010
Program Complete	Sep 2010

An Open Invitation to Global Technology Developers

This document aims to stimulate high quality proposals from global development expertise which meet the specific requirements for reservoir imaging in challenging environments. ITF and its Members will jointly assess all submitted proposals and our Members will potentially fund those proposals of greatest interest.

ITF and its Members will not prescribe specific technology solutions, but instead use the output gathered from the Theme Day to stimulate innovative proposals that offer potential solutions to identified needs. Key technology drivers, as identified by ITF Members, are the desire to produce fields in a more cost effective and efficient manner.

This is an open invitation to any organisation seeking sponsorship for innovative technologies in the oil and gas industry to submit proposals for research, development, and / or field trial in the following areas, associated with the identified needs of the ITF Reservoir Imaging in Challenging Environments Technology Program:

- **Imaging Problem Layer and Below It**
- **4D Imaging**
- **Reservoir Characterization and Integration**
- **Fracture Imaging**
- **Borehole Geophysics**
- **Other**

It is recognised that much work is being undertaken in these areas and that many valuable developments are being worked on around the world. The purpose of this call is to add to this body of work by challenging the development community to think beyond the current limits and propose projects which will significantly improve the industry's ability to image reservoirs in geologically complex environments.

The list of detailed technology challenges are identified within each area that are of explicit interest to ITF Members in the 'Specific Technology Requirements' below. This information highlights key elements required but allows for innovation and flexibility in interpreting the most appropriate technical solutions.

The method for submitting a proposal is described later in this document but you can also learn how to submit a proposal by going to our website www.oil-itf.com

Specific Technology Requirements

(Any submitted proposal **must** address one or more of the following identified requirements)

IMAGING THE PROBLEM LAYER AND BELOW IT

Background:

The industry is looking for different ideas and thoughts that can improve the imaging of and below what has been defined as problem layers. The defined problem layers correspond to those of high impedance such as salt, basalt and chalk and low impedance such as gas and glacial channels.

The output of the research should produce improved images of these layers and of the sediments below them.

Requirements:

- *High Resolution Velocity Models.* Deep targets can be structurally complex, and in many places are overlain by high velocity lithologies such as chalk or salt thus reducing the angle of wavefield coverage that can be recorded from limited offset streamer surveys. This reduces the resolution of the velocity field that can be inverted from the recorded wavefield. Below are the specific requirements related to higher resolution Velocity Models:
    - Full waveform inversion to be used as an advanced tool for velocity estimation.
    - High resolution spatial 3D Pore Pressure Distribution. The lack of resolution in deeper velocity fields is reducing the ability to accurately estimate pore pressure from velocity. In deep high pressure wells unexpected pressure variations can have a very large impact on well operating costs which are already high.
    - Overburden/underburden. There is a need to better understand near surface geology and its effects on imaging (subseismic and seismic scale). The velocity distribution in the overburden is generally more complex and a better understanding of the changes in compaction gradient could solve the problem of wrongly interpreting them as changes in reflectivity or be mistaken by apparent anisotropy.
    - Improved Cycle Times/accuracy/resolution. A need to build velocity models in a fast cycle time.
    - Joint Inversion. Structurally complex velocity anomalies have significant uncertainty in their spatial extent. This is partly due to poor sampling of the complex seismic wavefield and poor inversion of the complex anisotropic velocity field. Limited resolution the inversion of seismic data can lead to velocity models that can be unrealistic.

      Failure to be able to reliably invert for density reduces ability of seismic inversion to discriminate pore fluids. Also surface based resistivity measurements do not currently have required high spatial resolution at depths greater than 3km and do not account for anisotropy in 3d EM wavefields.

- Focusing of events. A higher resolution power of the recorded wavefield is needed to increase special extent of the focus.

- *Noise Attenuation*
  - Random/Coherent. Although there are a number of techniques that have been developed to attenuate it, coherent noise is a persistent problem in seismic imaging as well as random noise that can disguise subtle structural or stratigraphic features.
  - Multiples attenuation (including intra-salt). There is a specific need to increase the ability to predict salt-related multiples.
  - Improved resolution of final images. The Lack of resolution from reflection wavefield at depth (greater than 4km) caused by attenuation and interbedded multiples needs to be addressed.

- *Seismic data correction for uneven illumination*. There is a need for a better illumination compensation to overcome the effects of different factors (limited acquisition geometry, the complex overburden structure, and the reflector dip angle etc) on the subsurface target to avoid a distorted image caused by the uneven illumination.

- *Shallow Gas Characterization* (resource and hazard). Rapid vertical changes in velocity at shallow depths (less than 2km) reduce angle coverage for targets just below them. Shallow gas has an impact on the host rock and the seafloor acoustic properties. There is a need to confidently interpret shallow gas.

- *Characterization of High/ Low Impedance layers.* High impedance: salt, basalt, chalk. Low impedance: gas, glacial channels.
  - Outcrop + Borehole Characterization of complex layers for forward modelling. Need for combination of outcrop and borehole data together with forward modelling for prediction purposes.
  - Characterization of fault damage zones
  - Salt tectonics. Better understanding of what a salt body can/can't do and build into velocity models.
  - More accurate interpretation and positioning of events (sub-salt, flanks, etc)
  - A more accurate salt definition is needed (shape and position)
- *Algorithms*. New adaptable to resolution algorithms are required to reduce speed and cost of seismic processing.
  - Fine tune models (forward seismic models)
  - Use of complex acquisition models
  - Recognized velocity algorithms
  - Time 2D processing.

- *Understand the scattering effect of salt on the wavefield*. Upgraded and new modelling (Forward, Velocity Analysis), interpretation (Structural Geology and Stratigraphy) and Imaging (Processing, Migrations, and Acquisition) techniques are required to enable a better knowledge of the salt effect on the wavefield. In order to achieve this there needs to be a better understanding of the following:
    - Salt Geometry(ies) (i.e. Top and Base of Salt, overhangs, sutures, etc)
    - Intra-Salt complexities (Physical properties – velocity, rheology, sed. rafts)
    - Salt/Sediment Interface (carapace, rafted terrain, etc)
    - Energy Partitioning (Mode conversion, attenuation, focusing, multiples)

  The scattering effect of salt also presents processing challenges of how to cope with all the different azimuths and anisotropy and these are not currently fully solved.

4D IMAGING

Background

Time-lapse geophysical measurements are powerful techniques for monitoring subsurface flow processes including the enhanced recovery of oil and gas and CO2 Storage.

There is a need in the industry to increase the ability to interpret the different velocity changes that can occur as a result of fluid migration, substitution and composition and also resulting from changes in total stresses during depletion.

Requirements:

- Use of complimentary techniques (non-seismic) for 4D Imaging such as Gravity, EM, Borehole, CSEM. Other techniques such as passive seismic (LOFS, Borehole) are also required for the interpretation of micro seismic field and detection and positioning of events.
- 4D for Gas Saturation & Pressure Changes
    - Non-Seismic methods are required for the determination of gas saturation and pressure changes within the reservoir.
    - Density from Seismic/Potential Fields. Amplitude does not change much for a range of gas saturation so can we use density from seismic inversion or potential fields?
    - Integration. Some work has been done in trying to get back to the depositional model but further development is required.

- Q Attenuation. New methods and tools are required to better define P- and S-wave seismic attenuations (Q factors) to improve fluid and lithological interpretations.
- Geomechanics. Geomechanical changes in the subsurface can occur due to depletion of the reservoir. These changes can induce changes in reservoir permeability, subsidence and formation compaction and well as fault reactivation. There is a need to understand what is happening between the individual areas to overcome the risks associated with geomechanical changes across the field.
- An additional challenge would be the inverse problem when pushing gas into the reservoir (CO_2 Storage)

- Sub-salt 4D. New technology is required to overcome the effects of salt attenuation in 4D Imaging
- Reducing Acquisition Costs.
  - Integrate VOI (value on investment and upgrade the cost of the final data)
  - Streamer, OBC, OBN
  - Gravity Gradiometry.
  - Random AUV recording.
  - Satellite
  - Nano Technolgy
- Best Practices/Workflow Updates to generate Static/Dynamic Model from 4D.
- Interplay between Reservoir Engineering and G&G disciplines
- Smarter devices for smaller and smarter acquisition and recording. For 4D monitoring there is a need to record a lot of information smartly, to come up with new recording devices that would benefit the whole industry.

RESERVOIR CHARACTERIZATION AND INTEGRATION

Background

One of the big challenges today is still the characterization of reservoir connectivity and how to relate large scale properties with detailed characterization.

Requirements

- *Static Properties.* There is a need for a better mapping of carbonate properties and a better characterization of faults and fractures- How to image them? is it fracture/fault or high non-brittle strain?-anisotropy, density.....
- *Integrating wells and seismic (& more modelling tools).* There is a need to improve well imaging and measurements (logging techniques) and develop a better borehole resolution to help in the interpretation and integration of well data to seismic data. A need for a less convoluted model as a whole. The reservoir model must be coherent with the seismic volumes, wireline logs, core plug analyses and well production data, which are the response of the same subsurface.
- *Process and workflow.* What do we need in terms of processing to lower the uncertainty of the models and quantify the uncertainty? There is a need for better and improved existing modelling tools and finding new ways to utilize those tools.
- *Cross-scaling.* There is a need to go across all the scales from rock physics to reservoir scale and a need for a workflow to support this. A shared earth model derived from seismic that will reduce the cycle time is needed.
- *True amplitude presentation after migration.* There is a need for a focused structural image of the subsurface that could be used for AVO studies. New technologies to reduce time and cost of this high computational effort will be of great value.
- *Integration of pre-stack data.* Important hydrocarbon information can be missed in stacked sections but this can be uncovered by the use of prestack seismic data. Although significant advances have been made in the integration of pre-stack data with well data some further developments are required to open this specialized analysis to a wider range of interpreters.
- *Carrying uncertainty through model and quantifying uncertainty of seismic*. There is a need for an integrated uncertainty analysis, a model that describes the uncertainty in the different disciplines involved to gain a better decision basis.

FRACTURE IMAGING

Background

Our members feel that in order to better image fractures the development community should focus on new technology, either seismic or non-seismic in order to better image fracturing and not seek evolutionary improvements in current seismic technology. The effort should be focused on fractures that impact permeability, at any scale from pore scale to reservoir scale. A new technology that has a great improvement in production and recovery to be used for smarter well placement and that carries less development cost is needed.

Requirements:

- *Resolution*; increased resolution of fractures with non-seismic methods.
- *Connectivity*; a better understanding on how the fractures connect.
- *Understanding of the geophysical signature of fractures* (e.g. shear wave splitting, anisotropy); a better understanding of fault and fractures indirect evidence. Seismic fracture detection, Seismic fracture-directional anisotropy. There is a need for new tools to accurately measure the microseismicity during hydraulic fracturing and to map fracture orientation and extent in the borehole conditions.
- *Integration of data across the range of scales*

BOREHOLE GEOPHYSICS

Background

Borehole geophysical methods have been used since the beginning of exploration seismology. These methods are used for surface seismic calibration, imaging and prediction as well as for reservoir characterization and monitoring.
It is widely recognized that major advantages have been made in the field of borehole geophysics such as 4C / 3D / 4D surveys, microseismicity, SWD (Seismic while drilling) and resolution enhancement but there are still some specific challenges that the industry wants to address.

Requirements:

- *Drill ahead seismic*; real time data and forward looking from bit.
- *Seismic Imaging below gas pockets*. There is also a need to reduce cost and time.
- *Imaging natural or hydraulic fracturing around wellbore using injected fluid/ slurry.*
- *Increased and improved communication between drill bit and the surface to extract more information on formation changes.* There is also a need for filtering acoustic noise.
- *Transmitter processing at bit* (processing/size data transmission) Confirm progress of the bit. Data sent while drilling. Real time information such as weight on bit and speed of rotation.
- *Permanent and continuous monitoring.* New acoustic technology in the form of a new downhole seismic tool. There is also a need for new tool development is this area.
- *Increased resolution of fractures around the borehole*
- *Use of Borehole seismic for specific imaging purposes such as 4D imaging underneath gas clouds and imaging below salt overhangs*
- *Use of geometry to overcome difficult layers.* New migration techniques to mitigate migration smears at the edge of data is required as well as anisotropy estimation (AVO/AVA) as borehole seismic for anisotropy is not used as fully as it is desired.

OTHER

HOW DO WE KNOW OUR IMAGE IS RIGHT?

Decisions are being made based on "Reservoir Images" but one of the biggest questions that arise is: How good in the information we are basing them on?

There is a big uncertainty as decisions are subject to data at different scales:

1. Exploration/Structural
2. Reservoir Scale (container size/shape, reservoir properties)
3. Borehole Scale-> Rock Physics

There are some challenges to be addressed such as the non-uniqueness of the calibration, the noise adequacy of Physics and the bias on the adequacy of the model approximation.

If these issues are solved it will be possible to quantify the value of the existing data and additional data/work, to take more informed decisions, to understand the upside and downside risk and to prioritize resources.

JOINT INVERSION ISSUES

Joint inversion of CSEM, MT, Seismic and gravity data is already being done with beneficial extents. However our members would like to encourage further developments in this area to full integration of all techniques, to maximize the use of the complementary information. There is a need for:

- Complete, Consistent model of the subsurface/Reservoir (structure/Fluids/Reservoir Parameters, etc) -> available to all. Used by different disciplines.
- Resolving the computational burden of combining discrete and diverse data types.
- Combine datasets with different resolutions. Pulling together data that has different resolution. How do you link different data types? Uncertainty? How to handle uncertainty in rock physics model->reservoir parameters you want to invert on.
- Best practice for 2D inversion-workflow developing techniques

DATA INTEGRATION

Multiple interfaces linking the different data types cause a great deal of complexity to users and IT departments unless common data standards are utilized.

Enabling technologies should be crafted for all the applications to fit (or adapt) into a common data standard in order to make (new and current) data integration and associated workflows easier, cheaper to perform and maintain resulting in faster, better

operational and business decisions at ideally lower cost.

ACQUISITION

Current seismic recording systems do not scale to recording more of the wavefield, without significant increases in cost and HSE exposure.

A more commodity scaleable system is required that records just the pressure field and part of the EM field. This also applies to OBC node acquisition needing lower costs of deployment and the ability to record lower frequency data with an acceptable signal to noise ratio.

Process for Submitting a Proposal

1. **Register Interest with ITF**
   Register your interest as early as possible by sending an email to Cristina Puig at c.puig@oil-itf.com

2. **Visit the ITF Website -** www.oil-itf.com
   On the ITF Home page, click on the "How to Submit a Proposal" button or follow this link to access all the information required to submit a proposal.

3. **Read the 'Project Application Guidance' Document**
   This document is available to view or download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website. Reading this document prior to submitting a proposal is essential. If you require further clarification or are unsure if your proposal is suitable for submission, please call ITF (ITF Contact Information appears later).

4. **Download and Complete the 'Project Application Form'**
   This form is available to download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website.

5. **Download and Complete the 'Project Presentation Template'**
   This template is available to download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website.

6. **Email the Completed 'Project Application Form' and 'Project Presentation Template' to ITF**
   Email the Completed 'Project Application Form' in Microsoft Word format (not PDF) and the 'Project Presentation Template' in Microsoft PowerPoint format (not PDF) to Cristina Puig at c.puig@oil-itf.com by **no later than 15th March 2010**. Proposals received after this date may not be processed.

Qualifying Technologies

In order to qualify for potential sponsorship, technologies submitted in response to this Call for Proposals must:

- be applicable to at least one of the identified requirements
- be novel or innovative
- demonstrate a clear business case for support
- have a clear and demonstrable path to commercialisation and implementation

Note: Proposals submitted to any other ITF Call in the past nine months or any previously unsuccessful applications should not be resubmitted without first consulting ITF (contact information provided later in this document).

Qualifying Organisations

Proposals are invited from any organisation including SME's, academia, research institutions, large organisations, consortiums or alliances. Proposals may be submitted by a national or international organisation, and equal opportunities will be extended to all proposers. Please keep in mind however that should your proposal be taken forward, you will be required to participate in meetings and make presentations to interested parties in the UK and in the English language (teleconference and video conference are acceptable).

ITF Contact Information

If you would like to discuss any matters related to this call or any other issue related to ITF, please contact any of the following people:

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For more information on ITF please visit the ITF Website - www.oil-itf.com