Petroleum Experts

IPM

- GAP
- PROSPER
- MBAL
- PVTP
- REVEAL
- RESOLVE

ENGINEERING SOFTWARE DEVELOPMENT

Petroleum Experts have developed the Integrated Production Modelling toolkit (**IPM**) which models the complete production system from the reservoir to the surface network.

Integrating the tools of **GAP**, **PROSPER**, **MBAL**, **REVEAL** and **PVTP** to operate seamlessly, the engineer is able to design complex field models. The Reservoir, Wells and Complete Surface Systems model, having been matched for production history, will accurately optimise the entire network and run predictions.

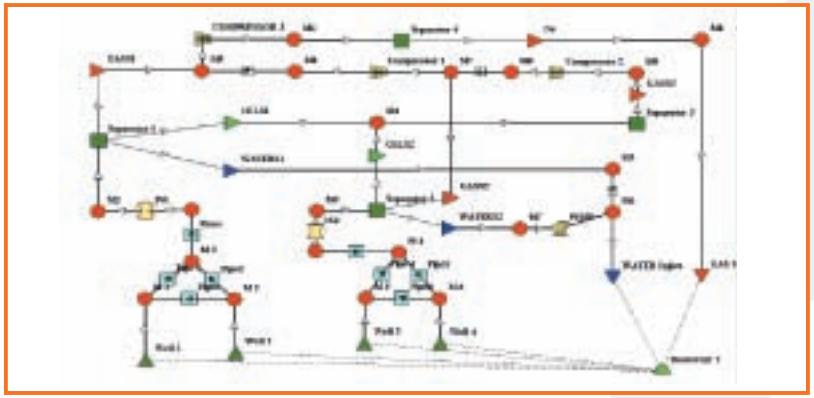
RESOLVE can extend integration, control and optimisation to full field models which include third party reservoir and process simulators.

The **IPM** suite is the leading Integrated Production Optimisation toolkit in the industry. It gives fast, reliable results and it is the industry standard with major operators worldwide. There are in excess of 180 oil and gas operators and service companies using the tools worldwide.

The easy use of **OpenServer** allows the **IPM** engineering software to be linked directly into a company or individual business processes. It has proven invaluable to many users and organisations in making their business integration workflows more efficient.

The **IPM** suite allows the user to work with one set of tools to model all common field production systems:

- Quick and reliable Optimisation and Forecasting of field production
- Single or Multi-tanks reservoir models, with inter tank communication
- Multi-Lateral and Horizontal well modelling accounting for pressure drops in the branches, including multi-layers and reservoir interferences between perforations sets
- Artificial Lift designs and diagnostics: including ESP's, HSP's, Gas Lift, PCP, Jet and Beam (Rod) Pumps
- Detailed pipeline design and performance: Flow Regimes, Slug Size and Frequency, Stability Analysis
- Surface Production Modelling of networks, pumps, compressors, multi-lines and looped gathering systems. There are no limits to the number of wells or reservoir tanks. Constraints can be included at each level in the system
- Modelling of Production through Hilly Terrain Surface Pipe Lines
- The Proprietary Correlations used are industry standards showing stability in some of the most challenging fluids
- The **IPM** suite allows the modelling of the most complex field designs
- Model can be Black Oil, Condensate, Gas or Fully Compostional



GAP-Looped network production and injection system

The package can run on a single PC or across a network.

The package is designed to work on Windows, NT, 2000 and XP.

The recommended minimum specification of PC is Pentium 1 GHz machine with 1 Gbyte RAM.

GAP IPM - Multiphase Network Optimiser Production Network Optimisation and Field Prediction

GAP is a multiphase optimiser of the surface network which links with ***PROSPER*** and ***MBAL*** to model entire reservoir and productions systems. **GAP** can model production systems containing oil, gas and condensate, in addition to gas or water injection systems.

GAP has the most powerful and fastest optimisation engine in the industry. Wellhead chokes can be set, compressors and pumps optimised, and gas for gas lifted wells, allocated to maximise oil production or revenue, while honouring constraints at any level. With ***MBAL*** field production forecast can be run.

GAP is part of the ***IPM*** suite, which allows the engineer to build complete system models, including the reservoirs, wells and surface system.

GAP features **OpenServer**.

APPLICATIONS

- Full field surface network design
- Field Optimisation studies with mixed systems (ESP, GL, Naturally Flowing, PCP, Jet and Rod Pumps)
- Multi-phase Looped Network Optimisation
- Advises on wellhead chokes settings to meet reservoir management targets
- Pipeline Flow Assurance studies
- Models full field injection system performance, using ***MBAL*** or ***REVEAL*** reservoir tank models
- Centrifugal and reciprocating compressor and Pump system modelling
- Production forecasting
- Programmable elements
- Fully Compositional from the Reservoir to the Process side
- Fast and robust Global Optimisation algorithm using Non-Linear Programming - NLP
- Easy to use graphical interface for drawing system network (using icons for separators, compressors, pipelines, manifolds and wells, inline chokes and reservoir tanks)
- **GAP** is unique in being able to model, optimise and run predictions of the entire production system, with ***MBAL*** and ***PROSPER***
- Naturally flowing, plus Artificial Lifted - gas lift, PCP, and ESP, etc. - wells can all be included in the same production system model
- **GAP** links to ***PROSPER*** (well models) and ***MBAL*** (tank model) to allow entire production systems to be modelled and optimised over the life of the field

GENERAL FEATURES

- Optimisation on Oil Production, Revenue, or Field Start-up
- Allows an unlimited number of wells, and tanks. (nodes)
- Production: gas and gas condensate wells and naturally flowing, gas lifted, Hydraulic Pump and ESP oil wells
- Injection: gas or water injection wells
- Automatic calculation of wellhead choke pressures to optimise production or injection
- Entry of constraints at well, manifolds, separator or system levels
- Links to ***PROSPER*** for generation of well performance responses and lift curves in batch mode (VLP/IPR)
- Pipeline pressure drop correlations can be matched to measured data and each pipe can use a different correlation
- Gas injection or water separation at common nodes
- Comparison of model and measured results to quality control the calculated well performance curves
- Flow Assurance: Pipeline stability studies, slug sizing.
- Flow correlations include the advanced mechanisitic model PE4, OLGAS 2-Phase and 3-Phase

OPTIMISATION

- Optimise production and injections system simultaneously. Systems can include ESP, Gas Lift, Compressors and Naturally flowing wells
- Optimise chokes anywhere in the system
- Full choke model implemented for inline chokes. Minimum and maximum choke diameters can be set to limit the optimiser search Optimise on maximum pipe line pressure if required
- Predictions can be made without optimisation
- Viscosities can be corrected for emulsion in pipeline calculations
- The IPR mobility correction can use its own set of relative permeabilities and the fluid mobility may be estimated using the same or different set of relative permeability curves
- In some special cases, for example for high gas coning wells, the left hand side (unstable) VLP/IPR intersection can be used instead of the right hand side (stable) solution

GENERALISED NETWORK SYSTEMS

- Multi-phase looped flow system modelling using fast solver and optimiser
- Complete Flexible network topologies
- Can include programmable nodes
- Flow direction calculation. Two arrows in the pipeline representation on the network plot to indicate the direction of the description on the pipe, i.e. the upstream to downstream direction
- The arrow in the blue square indicates the direction of the flow calculated during the last solver or prediction run

- Hydrate and wax warning (fully compositional mode)
- Annular flow for pipe elements
- Pipe element specific black oil PVT model selection

FLEXIBLE CONFIGURATION OPTIONS

- Sinks and Sources.
- Ability to route fluids in network after separation
- Connect Separators to High Pressure and Low Pressure line together
- Production and Injection systems are handled simultaneously
- Combine high and low pressure separation

COMPOSITIONAL MODELLING

Two Options:

a) Compostional tracking and flashing of the fluids throughout the network system using black oil PVT description for pressure loss calculations.

b) Fully comositional using characterised EoS. The composition may be entered at the well level if there are no reservoir models. In a prediction, evolving compositions are automatically passed to the **GAP** well level.

GAS CONING

- Gas coning at the reservoir can be modelled in **GAP**. This can be used in standalone networks or when linked with **MBAL** tank models

PERMEABILITY CORRECTION IN PREDICTION

- The change in tank permeability with pressure can be modelled

CROSS-FLOW INJECTIVITY

- Injection cross-flows into layers can be modelled with an injectivity index

ABANDONMENT CONSTRAINTS

Abandonment constraints can be set per-layer of multi-layer models, as well as for the entire model.

PROJECT ARCHIVING

GAP projects, including all associated files for the well and reservoir models, can be compressed and archived as one project file.

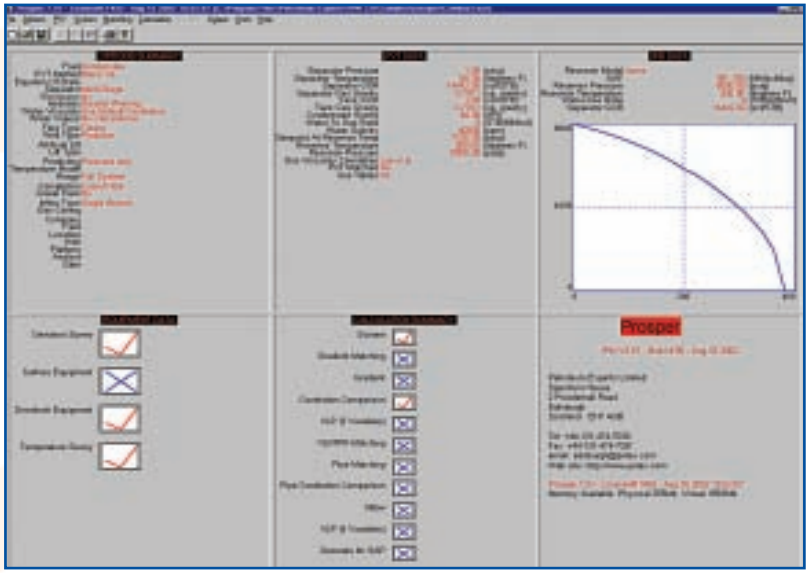
PROSPER IPM - Well Production Systems Analysis

PROSPER is a well performance, design and optimisation program which is part of the Integrated Production Modelling Toolkit (**IPM**). This tool is the industry standard well modelling with the major operators worldwide.

PROSPER is designed to allow the building of reliable and consistent well models, with the ability to address each aspect of well bore modelling viz, PVT (fluid characterisation), VLP correlations (for calculation of flow-line and tubing pressure loss) and IPR (reservoir inflow).

PROSPER provides unique matching features, which tune PVT, multiphase flow correlations and IPRs to match measured field data, allowing a consistent well model to be built prior to use in prediction (sensitivities or artificial lift design). **PROSPER** enables detailed surface pipeline performance and design: Flow Regimes, Pipeline Stability Studies, Slug Size and Frequency

PROSPER features **OpenServer**.



APPLICATIONS

- Design and optimise well completions including multi-lateral, multi-layer and horizontal wells
- Design and optimise tubing and pipeline sizes
- Design, diagnose and optimise Gas lifted, Hydraulic pumps and ESP wells
- Generate lift curves for use in simulators
- Calculate pressure losses in wells, flow lines and across chokes
- Predict flowing temperatures in wells and pipelines
- Monitor well performance to rapidly identify wells requiring remedial action
- Calculate total skin and determine breakdown (damage, deviation or partial penetration)
- Unique black oil model for retrograde condensate fluids, accounting for liquid dropout in the wellbore
- Allocate production between wells

INFLOW PERFORMANCE MODELS (IPR)

- Multilateral well models
- Single branch (Simple) inflows
- Several proprietary inflow models for various fluids
- Flux calculation module to calculate the flow velocity across the gravel pack completion (Vc : Vs)
- Compaction permeability reduction model
- Gravel Pack Beta factor calculated or entered, including a multiphase model

PRESSURE PREDICTION

- Predicts pressures only for various flow rates given the temperature profile along the flow path
- Predicts pressures as well as temperatures simultaneously

ENGINEERING APPROACH

INFLOW PERFORMANCE (IPR) MODELS

MULTILATERAL WELLS

- ***PROSPER*** has a rigorous approach to model the inflow into multilateral wells, accounting for the interference between individual branches and friction losses in the completion. This model is capable of performing and displaying detailed pressure and inflow profiles that can be used to diagnose what is coming from where in the multilateral completion
- Models intelligent well completions -SMART- with down-hole chokes, etc
- The model can handle Oil, Gas, and Retrograde Condensates
- Both injectors and producer with or without artificial lift, can be modelled

SINGLE BRANCH (SIMPLE) INFLOW

- ***PROSPER*** has a number of different inflow models for various fluids

FLUID PVT Models

- Black oil correlations for oil, gas and retrograde condensates
- Fully compositional model using Peng-Robinson EoS
- Convergence pressure method for retrograde condensates
- PVT handles up to 100% CO2 or N2 for injectors and producers
- Emulsion viscosity matching and viscosity corrections (for ESPs)
- Correlations can be automatically adjusted to match measured data
- Water vapour condensation correlation for gas condensate wells
- Water Viscosity Variation with pressure
- Boiling temperature column in EoS model
- Steam model for injection wells

COMPLETION METHODS

- Cased Hole
- Open Hole
- Gravel Pack (PVT for gravel pack calculated at correct pressure)

PREDICTION MODELS

- ***PROSPER*** can be used to predict pressures for various flow rates given the temperature profile along the flow path
- ***PROSPER*** has the capability of predicting pressures and temperatures simultaneously
- Temperature can be predicted using:
  - a simple approximation method based on overall heat transfer coefficient, accounting for Joules Thompson
  - Improved Approximation, which model various heat transfer co-efficients along the string; or a detailed model using a complete Enthalpy Balance approach. Conduction, forced convection, free convection and radiation are taken into account
  - Enthalpy Balance
- Insulation and burial depth of the pipeline are also considered
- For downhole equipment, the formation heat transfer coefficient is based on a transient model

LIQUIDS IPR MODELS

- PI Entry: constant PI, corrected for water-cut below bubble point
- Vogel
- Composite: Vogel + water cut
- Darcy
- Fetkovich: The reservoir pressure can be calculated from a multi-rate test.
- Jones

- Multi-rate Jones
- Transient IPR: for low permeability reservoir where deliverability changes with time
- External Entry (Import of externally generated IPR)
- Hydraulically fractured wells
- Horizontal Well - Bounded System and Constant pressure boundary models
- Horizontal Well - Friction dP: Allows entry of multiple zones and accounts for wellbore friction
- Horizontal well with transverse fractures – this model allows the entry of one or more transverse fractures along the horizontal well bore
- Multi-layered systems – with and without dP Loss in well bore: Network algorithm simultaneously solves inflow and layer pressure
- Multi-Lateral systems: A detailed model that accounts for the interference between individual branches. This can be used to model intelligent completions as well
- Naturally fractured reservoir systems
- Thermal Fracturing
- Error checking in IPR section

GAS AND RETROGRADE CONDENSATE INFLOW MODELS

- Jones
- Forcheimer
- Back pressure: C is calculated from permeability
- C & n are calculated from multi-rate data
- Multi-rate Jones
- Petroleum Experts: IPR using multi-phase pseudo pressures and non-Darcy coefficients. This model takes into account the condensate dropout and changes in water-to-gas ratio through use of multi-phase pseudo pressure for retrograde condensate systems
- Hydraulically fractured wells
- Horizontal wells: With & without Friction dP
- Horizontal wells with one or more transverse vertical fractures
- Multi-layered reservoirs: With & without dP loss
- External entry: user defined IPR model
- Naturally fractured reservoir IPR

FLUID FLOW MODELLING

PROSPER can be used to model any of the following flow geometries

- Tubing or Annular flow
- Tubing and Annular-simultaneous
- Producer or Injector
- Naturally flowing
- Artificially lifted wells
- Multilateral inflow accounting for branch effects
- Horizontal wells
- Simultaneous production through the tubing and annulus

The flow modelling in ***PROSPER*** is divided into two sections:

- Well bore or vertical lift flow
- Surface Pipeline flow

GAS CONING

The gas-coning model predicts a rate dependent GOR, based on the model developed by Urbanczyk and Wattenbarger. Alternatively, the model can be tuned using measured data.

DIETZ SHAPE FACTOR

A calculator is available which allows the user to calculate the factor for rectangular reservoirs with a well placed anywhere in the area.

SKIN

- This can be entered by hand or be predicted using perforation data.
- The mechanical and geometric skin can be calculated using: Locke's, Mcleod or Tariq's technique.
- The skin due to deviation and partial penetration can be computed using the model of Cinco-Ley model or Wong and Clifford model (point source solutions).

RELATIVE PERMEABILITY EFFECTS

The effects on IPR can be modelled: Water cut for test data points can be used to verify user entered relative permeability curves.

STANDING CORRECTION TO VOGEL IN IPR CALCULATIONS

VERTICAL LIFT CORRELATIONS:

- Duns and Ros (Modified for condensates)
- Duns and Ros Original
- Hagedorn-Brown
- Fancher-Brown
- Gray
- Orkiszewski
- Petroleum Experts.
- Petroleum Experts 2
- Petroleum Experts 3 (bio-degraded oils).
- GRE (modified by PE)
- Petroleum Experts 4 (Advanced mechanistic model for angled wells)
- OLGAS - Olga 2-phase and Olga 3-phase correlations

The Petroleum Experts' Correlations include internally developed flow regime maps and can be used in all flow regimes

PIPELINE CORRELATIONS

- Beggs and Brill
- Mukerjee-Brill
- Dukler-Flanigan
- Dukler-Eaton-Flanigan
- Fancher-Brown
- PE 4: Complex Terrain Flow Correlation
- OLGAS 2-phase and 3-phase Correlations

ARTIFICIAL LIFT

GAS LIFT DESIGN

- Casing, Tubing or Proportional Valves
- Automatic Valve Spacing
- Calculation of Valve Test Rack setting pressure
- Flexible design options for unloading valves allowing selection of Pvo or Pvc equal to casing pressure
- Real valve response modeling – Link to VPC database
- Thornhill – Craver valve de-rating model

PROSPER has a unique diagnostic tool to identify gas lift valves failure, point of gas injection and other operational problems

PROSPER re-checks the initial design to ensure that unloading can be achieved and that the well will flow at the maximum possible oil rate

Designs can also be run for wells with existing mandrel completions

ELECTRICAL SUBMERSIBLE PUMPS

- ESP design and diagnosis
- Design selects pumps, motors and cables from database
- Viscosity effects and temperature fluid rise across pumps handled
- PVT emulsion viscosity correction option
- Sensitivities can be run rapidly to check ESP design performance over life of well
- Calculation of ESP lift tables for simulators
- Down hole gas separation
- A comprehensive database of pump and motor performance characteristics is provided with the program

HYDRAULIC PUMPS

- HSP design and diagnosis
- Design selects pumps and turbines
- PVT emulsion viscosity correction option
- Sensitivities can be run to check HSP design performance over life of well
- Calculation of HSP lift tables for simulators

Progressive Cavity Pumps – PCP

- PCP Design: allows the user to select a suitable combination of pump and rods from a user-entered database

Jet Pumps

- Input Data and Pump Selection
  - Annular Injection – Tubing Production
  - Tubing Injection – Annular Production
- Power Fluid Properties
- Jet Pump Design

Rod (Beam) Pumps

- Design and Diagnostic Calculations

ADDITIONAL FEATURES

CORRELATION THRESHOLD ANGLES

PROSPER allows entry correlation threshold angles, which permits changes from vertical flow correlation to a pipeline correlation in the well bore based on the angle of the flow path with respect to the vertical. The same option is available for pipelines to change to vertical flow correlations based on angles with the horizontal.

- All gradient curves can be compared against measured data on a single plot
- Phase Densities, inter-phase IFTs, slug and bubble properties are displayed

- Flow Regime Plots can be displayed
- Erosional Velocity (C Factor) calculation is also displayed
- Facility to disable either the surface equipment or the down hole equipment during calculations

MODEL CALIBRATION AND QUALITY CONTROL

PROSPER allows the engineer to match different components of the model viz, PVT, flow correlations and IPR with measured data. The matching procedure is followed by quality checking options, on the basis of what is possible physically.

- PVT correlations can be matched to laboratory flash data
- Vertical lift and flowline correlations can be automatically tuned to match measured flowing pressure surveys
- Flow Correlations can be tuned to fit up to 10 tests simultaneously, using a multi-dimensional non-linear regression. This is achieved by varying independently the head and friction pressure loss components. The matching process is a powerful data consistency check

THERMAL FRACTURING

PROSPER models the combined effects of temperature, stress and fluid mechanics to predict the behaviour of the injectors.

SOLIDS TRANSPORT

Model predicting grain size that can be transported

HYDRATE FLAGGING

PROSPER will highlight areas that have a potential hydrates formation. The user enters a set of pressure-temperature tables for the fluid.

PROSPER SENSITIVITY

- Up to three sensitivity variables (four for lift curves) can be chosen and ten values may be entered for each. The program will run the sensitivity combinations calculating up to 1,000 solution-operating points

EXPORT LIFT CURVES

- Lift curves can be directly exported to Petroleum Experts' MBAL, GAP and most other reservoir simulators

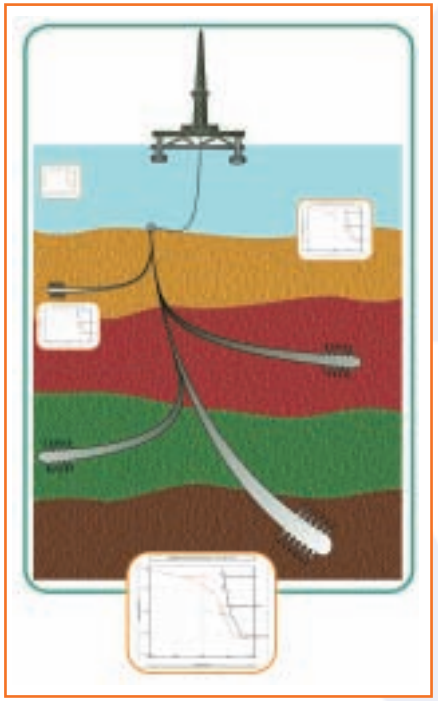
PROSPER CHOKE CALCULATOR

The choke calculator allows calculation of production rate, pressure drops or required choke sizes. The calculation solves the energy equation and can be used for both critical and sub critical flow.

GRADIENT CALCULATIONS

New variables are now displayed in gradient calculations.

- Oil Viscosity
- Oil Mass Flow Fate
- Water Viscosity
- Oil Formation Volume Factor
- Liquid density
- Gas Formation Volume Factor
- Total Mass Flow Rate
- Water Hold-up, etc



PROSPER - *Multilateral well model*

MBAL IPM - Reservoir Reservoir Engineering Toolkit

The **MBAL** package contains the classical reservoir engineering tool, which is part of the Integrated Production Modelling Toolkit (**IPM**) of Petroleum Experts.

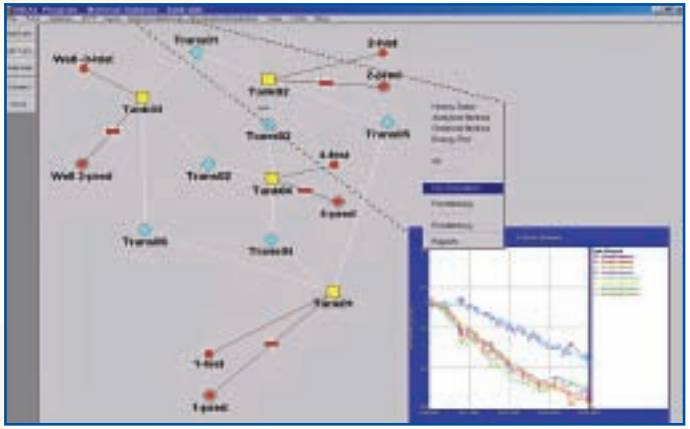
MBAL has redefined the use of Material Balance in modern reservoir engineering. **MBAL** has many innovations developed by Petroleum Experts that are not available elsewhere.

MBAL is the industry standard for accurate Material Balance modelling

Efficient reservoir developments require a good understanding of reservoir and production systems. **MBAL** helps the engineer define reservoir drive mechanisms and hydrocarbon volumes more easily. This is a prerequisite for reliable simulation studies.

For existing reservoirs, **MBAL** provides extensive matching facilities. Realistic production profiles can be run for reservoirs, with or without history matching. The intuitive program structure enables the reservoir engineer to achieve reliable results quickly. **MBAL** is commonly used for modelling the dynamic reservoir effects prior to building a numerical simulator model.

MBAL features **OpenServer**.



APPLICATIONS

- History matching reservoir performance to identify hydrocarbons in place and aquifer drive mechanisms
- Building Multi-Tank reservoir model
- Generate production profiles
- Run development studies
- Determine gas contract DCQ's
- Model performance of retrograde condensate reservoirs for depletion and re-cycling
- Decline curve analysis
- Monte Carlo simulations
- 1D flood front modelling
- Tight Gas Modelling
- Calibrate relative permeability curves against field performance data
- Control Miscibility
- Control recycling of injection gas
- Fully Compositional
- **MBAL's** logical and progressive path leads the engineer through history matching a reservoir and generating production profiles. The program is easy to use and fast to learn
- **MBAL** allows the engineer to tune PVT correlations to match with field data. This prevents data errors being compounded between modelling steps
- **MBAL**'s menu system minimises data entry by selecting only data relevant to the calculation options selected

MATERIAL BALANCE

Tank Pressures

- Average tank pressures calculated from well production histories using well rate weighted averaged pressures
- Voidage replacement (gas or water)
- Gas Cap gas production
- Gas re-cycling
- Inter tank transmissibility

Reservoir Types

- Saturated with gas cap
- Under-saturated
- Gas
- Retrograde condensate (suitable for very volatile oils)
- Separate Oil, condensate, and water PVT models. E.g. Oil and condensate models can be connected in the multi-tank
- Multitank reservoir system can be built with inter-tank transmissibility

Aquifer Models

Linear, Radial or Bottom Drive:

- Small Pot
- Schilthuis Steady State
- Hurst Simplified
- Hurst and van Everdingen
- Vogt and Wang
- Fetkovich Semi Steady State
- Fetkovich Steady State
- Carter- Tracy
- Multi-tank

Well Types

- Production
- Gas Lifted
- PCP
- Jet Pump
- Injector
- ESP
- HSP
- Rod Pump
- Gravel Pack

HISTORY MATCHING

Graphical Straight Line Methods

Oil	Gas and Condensates
+ Havlena - Odeh	+ P/Z
+ F/Et versus We/Et	+ P/Z (Over-pressured)
+ F/Et versus F	+ Havlena-Odeh (Water Drive)
+ F-We versus Et	+ Havlena-Odeh (Overpressured)
+ [F-We] / [Eo+Efw]	+ Cole (Strong Aquifer) versus Eg [Eo+Efw]

Aquifer size button simplifies graphical aquifer matching.

Analytical Method

- Main phase production from historical reservoir pressure data
- Automatic history matching using non-linear regression on aquifer & reservoir parameters

Reservoir Simulation

- Reservoir pressure and water influx from historical production data

PRODUCTION PREDICTIONS

Production profiles can be run for reservoir/well systems. The wells and reservoir interactions control the production rates

Main Prediction Options

- Reservoir pressure for a given Off take schedules (e.g. gas contract)
- Reservoir pressure and manifold pressure (requires well lift curves)
- Reservoir pressure and production rates (requires well lift curves and manifold pressure)
- DCQ prediction
    - Calculate the minimum number of wells required to achieve a production target

FIELD CONSTRAINTS

- Gas-lift gas and gas injection
- Manifold pressures
- Minimum or/and Maximum Flow rate
- Minimum or/and Maximum Pressure
- Breakthrough of water/gas and abandonment

WELL CONSTRAINTS

- Constant flowing bottom hole pressure, or tubing performance curves
- Breakthrough and abandonment saturations
- Minimum or/and Maximum Flow Rate
- Maximum Pressure Drawdown
- Producing BS&W and GORs
- Oil/water or Gas/Oil contacts
- Breakthrough constraints (effectively place completions with respect to fluid contacts)

PRODUCTION PREDICTION RESULTS

Extensive ranges of results are displayed by production prediction. **MBAL's** flexible plotting routines allows a wide selection of results to be cross-plotted.

Available reservoir parameters include

- Reservoir pressures
- Production rates and cumulative production
- Fluid saturations
- Aquifer influx
- and many more

Available well parameters include:

- FBHPs and FWHPs
- Well rates, BS&Ws and GORs
- Well cumulatives
- Timing of well liquid loading - validity of lift curves
- Gas contract DCQ accounting for swing (gas models)
- Instantaneous field potential (for gas and condensate reservoirs)

Fluid Models - PVT

- Black oil correlations for oil, gas and retrograde condensates. Condensate model handles liquid drop out, changes in produced gas gravity and condensate to gas ratio correctly
- Correlations can be automatically adjusted to match measured data
- Variable PVT
- Different PVT for each tank
- Based on well production, mixes in PVT are modelled from different tanks
- Fully Compositional - EoS model

WELL SCHEDULING

DATA IMPORT

- Flexible production history import filter for ASCII files, windows clipboard and ODBC compliant databases
- Import templates can be saved and recalled for instant data import

COMPOSITIONAL TRACKING

- **MBAL** can track a composition through a simulation or prediction. Compositions for each time-step are taken from the **MBAL** model, allowing the study of the evolution of the composition with time
- If **MBAL** is run through **GAP,** the fluid composition can be tracked from the reservoir, through the surface network

OIL BREAKTHROUGHS

- model for condensate wells.

TRAPPED GAS MODEL

- Model gas trapped behind aquifer. The effect of higher pressure drops due to water gradient is taken into account

RELATIVE PERMEABILITY

- Relative permeability curves can be assigned to a leak. These curves can be matched in Fw/Fg/Fo matching
- Option to calculate relative permeability tables from Corey exponents
- A separate set of relative permeability tables can be entered and used for the various mobility corrections for the PI
- Pressure dependant permeabilities. Changes in the tank permeability can handled in IPR calculations and transmissibility

GAS CONING

Gas coning can be modelled for oil tanks. This uses a gas coning model to calculate the GOR for each layer.

MISCIBILITY

- User can define percentage factor of gas re-dissolving into oil
- Model can handle super-critical fluids

RECYCLING of INJECTION GAS

- Injection gas is tracked as a separate phase
- Breakthrough saturations of the gas injection will determine when the gas is recycled

VOIDAGE REPLACEMENT

- Linked voidage replacement to injection wells

MULTI-LAYER

- This is a tool to allow calculation of a set of pseudo-relative permeability curves for a tank which is made up of a number of layers that are each described by their own relative permeability curve
- The multi-layer tool performs Stiles, Buckley - Leverett and communicating layers models

CROSS FLOWING PRODUCTION WELLS

- For multi-layer wells, an injectivity index can be entered for production wells to allow control of cross-flow

DECLINE CURVE ANALYSIS

Harmonic, Hyperbolic and Exponential.

- Single Well Production
- Total Reservoir Production

1 DIMENSIONAL WATER FLOOD MODELS

- Buckley Leverett

MONTE CARLO SIMULATIONS

- Statistical tool for estimating oil and gas in place

TIGHT GAS MODEL

- Tool to allow analysis of tight gas reservoirs
- History matching allows analysis of rate and Pwf history to determine Rd and K
- Allows prediction of rates using wells into the future
- Single phase

PVTP IPM – Fluids Reservoir Fluid Thermodynamics

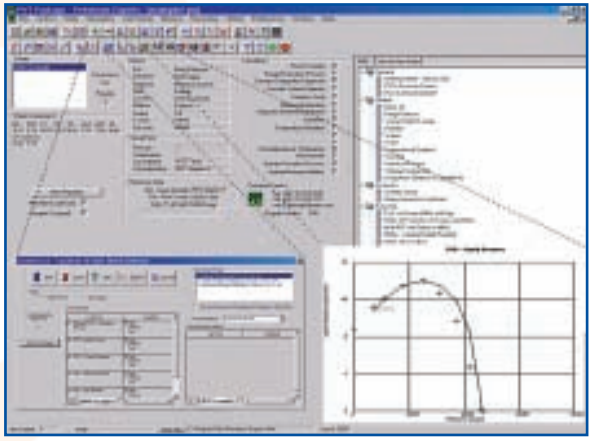
An understanding of **PVT** properties is fundamental to all aspects of reservoir, petroleum and production engineering.

PVTP allows tuning of Equations of State (EoS) to match laboratory data. The tuned EoS can then be used to simulate a range of reservoir and production processes, which impact equipment sizing and reservoir recovery.

Multiple Samples Reservoir information is handled in a unique project structure to allow the user to create a consistant picture of the reservoir system.

PVTP has been designed to lead the engineer logically through the fluid characterising process, which includes tuning EoS models to match measured laboratory data at both reservoir and process conditions.

PVTP can be used to generate tables of fluid properties, reduced compositions or matched parameters (T_c, P_c, ω, and Binary Interaction Coefficients) for applications such as reservoir simulation and nodal analysis. **PVTP** maximises the value of your laboratory **PVT** studies by minimising the amount of experiments required.



PVTP has been extended to include the modelling of solids viz. hydrates and waxes and includes calculations for hydrate formation pressure, hydrate inhibition, wax appearance temperature and wax dropout.

PVTP features **OpenServer**.

APPLICATIONS

- Characterisation of fluids
- Recombination of separator samples
- Determination of gas / oil contacts
- Separator train optimisation
- Phase behaviour prediction
- Swelling test simulation
- Solids (Hydrate and Wax Modelling)
- Generation of **PVT** tables for use in simulation
- Slim Tube Simulation
- Structured approach to sample decontamination, addressing an increasing problem of contaminated samples
- Recombination and **PVT** validation
- Simulation of lab **PVT** experiments
- Online Step-by-Step Help Guide takes the user through fluid characterisation
- Unique auto characterisation of heavy end fraction
- Simultaneously matches to reservoir and separator tests
- Tunes EoS for direct use in **PROSPER** well modelling systems analysis program
- Generates match data for black oil condensate model used in **MBAL** material balance program

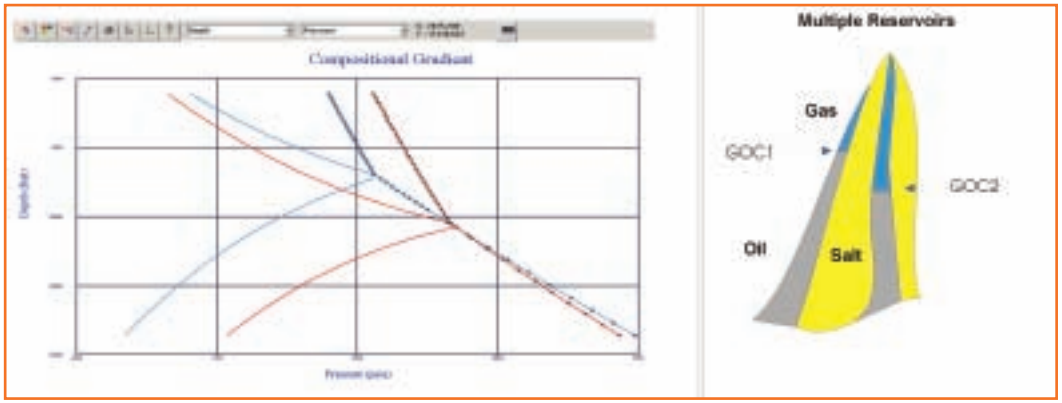
FEATURES

COMPOSITIONAL EQUATION OF STATE MODEL

- Peng-Robinson Equation
- Soave-Redlich-Kwong Equation
- Up to 200 components
- Advanced Splitting of Heavy End Pseudo components
- Automated Heavy End Characterisation including exponential and gamma function methods
- Advanced composition calculator with lumping splitters in pseudos, etc.
- Regression against Laboratory Data
- Multiple characterisations can be held as streams in one file allowing for complex analysis of difficult reservoir systems
- CCE experiments
- CVD experiments
- Differential liberation
- Phase Envelopes
- Separator test including chiller trains
- LNG calculations
- Compositional gradients
- Swelling tests
- Solids Modelling (hydrates and waxes)
- Recombination of samples
- User Database
- Mass Balance Calculator
- Joule-Thomson Effect Utility
- Allocation Calculation
- Whitson's method and best Alpha calculator
- Splitting preferences
- Steam calculations

BLACK OIL MODEL

- Oil, Dry and Wet Gas and Retrograde Condensates
- Matching against Laboratory Data



PVTP - *Variable PVT high relief reservoir.*

REVEAL IPM – Simulator Specialised Reservoir Simulator

REVEAL is a specialised reservoir simulator modeling near well bore effects including mobility and injectivity issues. Thermal and chemical effects are modeled rigorously. These effects can arise from injection of non-reservoir fluids at non-reservoir temperatures.

Injection of chemicals or fluids at non-reservoir temperature can have significant effects on fluid mobilities and therefore subsequent injectivity and oil production. Injectivity will also be dependent on perforation geometry, including the possibility of fracturing.

OpenServer has been implemented in **REVEAL**

SPECIFICATION:

MULTI-PHASE SIMULATOR

Thermal 3 phase Black Oil formulation for oil gas and condensates.

Implicit and IMPES solvers.

Grid refinement.

Multi-Lateral well capabilities with well bore friction and well-bore heating.

Thermal and chemical effects on mobility.

Analytical Carter Tracy aquifer.

4 phase (oil, water, gas, µ-emulsion)

Import: VIP, ECLIPSE and ASCII text data.

Import from PETREL formats

REVEAL RUNS ON A PC ENVIRONMENT

- There is a single interface to all functionality, including:
- data input and validation,
- post-processing,
- 3D graphical visualization,
- and export of results.

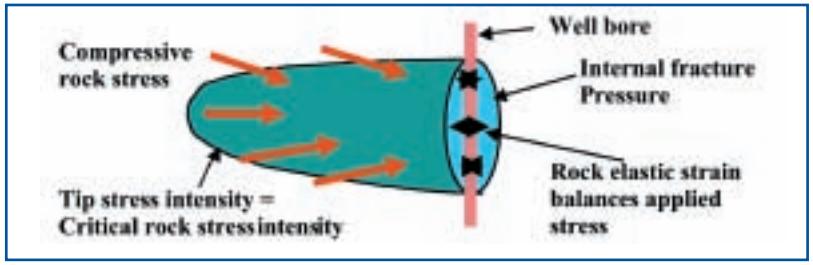
THERMAL AND HYDRAULIC FRACTURING

A numerical finite-element model for fracture initiation and propagation is directly coupled to the finite-difference 3D simulator.

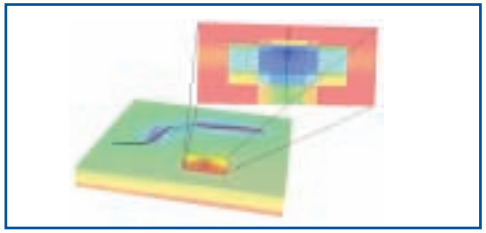
Thermal fracturing may increase injectivity, but the reduced mobility of water and reservoir oil resulting from lower injection temperature may reduce injectivity at later times or provide problematic flooding characteristics.

The model is based on the pressure balance within the fracture and the reservoir stress field, including poro-elastic and thermo-elastic stress reduction effects.

The elasticity of the rock determines the internal shape of the fracture, while the shape of the fracture near its tip determines the ability of the fracture to propagate by overcoming the critical stress intensity (strength) of the rock.



Flow within the fracture and leak-off are also modeled, resulting in a fully consistent dynamic model of thermal and hydraulic fracturing.

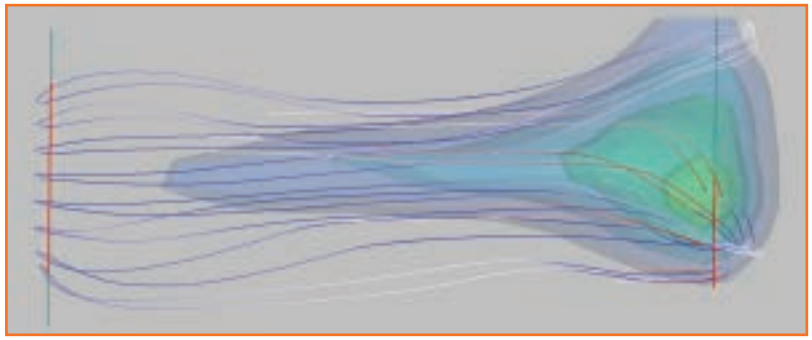


Thermal fracture calculation within refined region (pressure on Full Reservoir and temperature in Blowup)

STEAM

A fully implicit steam injection model is present to model 'huff &puff', cyclic steam injection of SAGD geometries.

Vertical steam flood with water and steam streamlines



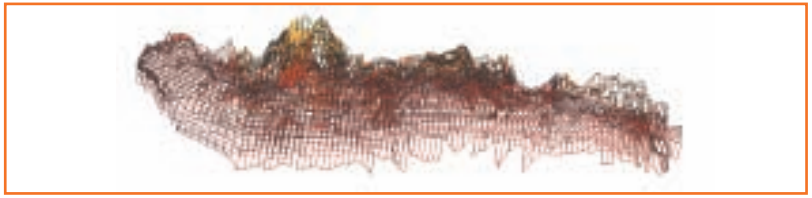
SOLIDS

Wax and asphaltene precipitation and consequent permeability reduction is modeled by defining solubility characteristics and plugging effects within the reservoir.

A compressible filter cake model (reducing the filter cake porosity and permeability as the pressure drop across it increases) is present to model injection damage arising from solid particulate present within at an injector. This model is available with both unfractured and thermally fractured wells.

A solid transport, trapping and permeability reduction model is also present for injectors and producers. For producers this model includes formation failure and sand production.

LARGE GRID WIRE FRAME



MOBILITY CONTROL

Thermal viscosity effects are important for water injectivity and the resulting relative mobility of cooled water and oil.

Gel, polymer, chelating agent, cross-linker and foam mobility control of the aqueous phase is modeled to improve water flooding or reduce water breakthrough.

Non-Newtonian oils are modeled, where the apparent viscosity reduces with applied shear stress.

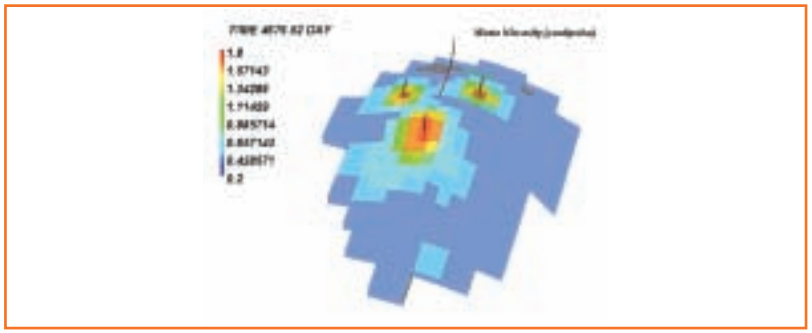
Phase desaturation, resulting from changes in interfacial tension can be modeled as a function of capillary number when surfactants or when a wetting agent is added and also as the fluid interfacial tensions change with temperature, pressure or Rs.

Relative permeability hysteresis is available for modeling cycling injection strategies.

Dispersion and diffusion models are available for trace component tracking.

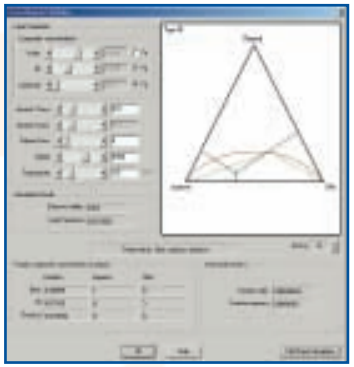
A well-bore heating model is present to model increased productivity near a well, heated by microwave or electrical heater.

Water Viscosity (cp) for thermal water injection



PHASE EMULSIFICATION

If a surfactant is injected, the interfacial tension between the water and oleic phases will reduce and an intermediate phase (μ-emulsion) may be generated. This may favorably increase the mobility of heavy oils.



This is modelled in **REVEAL** by calculating an effective salinity resulting from concentrations of the surfactant, polymer, alcohols, temperature and equivalent alkane number (EACN), then using a ternary diagram to calculate the phase saturations and concentrations of all components within the phases.

Ternary diagram for surfactant model - data input screen

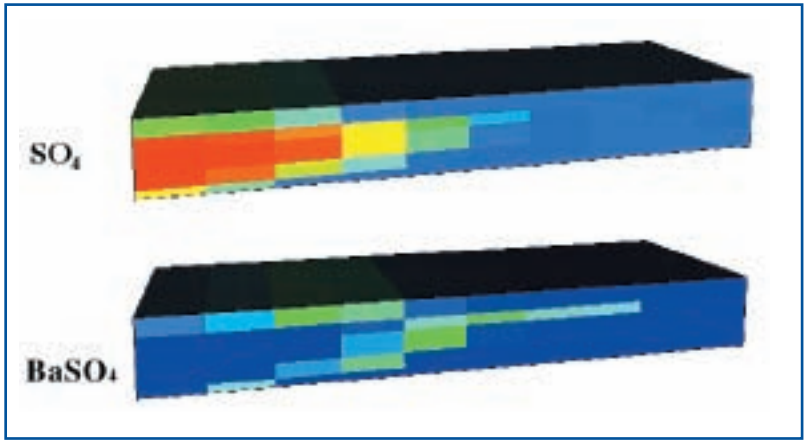
SPECIALISED MODELS - WATER CHEMISTRY

The mixing of incompatible waters following an injection strategy may result in scale or souring.

REVEAL has a comprehensive water chemistry capability with a large database of reaction species and reaction pathways. The prediction of solid precipitation and dissolution is modelled as the chemical species are transported within the reservoir. Scale inhibitor and reversible/irreversible adsorption models are also

present to model the behaviour of precipitates. A souring model, catalysed by bacterial action is present, with partitioning of H2S between the aqueous and oleic phases.

Sulphate ions in injection water react with Barium ions in reservoir water to precipitate Barite. Precipitated Barite is transported with the injected water and is concentrated at the flood front.



RESOLVE IPM - Controller Link and Interface Between IPM and Third Party Software

Petroleum Experts was the first company to present a fully integrated reservoir, well, and surface network modelling and production optimisation system – the Integrated Production Modelling Toolkit (**IPM**).

RESOLVE takes integration to move a step further. It allows the industry to connect, run, control and optimise multi-vendor engineering models. Through **RESOLVE**'s open and flexible architecture the dynamic links between proprietary software models as well as multi-vendor commercial software models tools is now practical. **RESOLVE** is the corporate standard with international majors.

RESOLVE is essentially a master controller, which allows software applications to be connected together and controlled centrally. While each application runs autonomously, **RESOLVE** takes care of synchronisation, data transfer, scheduling, reporting, data gathering and global optimisation. Models can be run on computer clusters or distributed machines.

RESOLVE can be used as an open framework for users to develop dynamic connections to other proprietary models. This work has been carried out successfully by several companies who wanted to connect their proprietary reservoir simulators to **GAP**. In doing this, the engineer gains access to the other connections offered through **RESOLVE** (e.g. the connection to HYSYS, Eclipse, etc.). The current set of commercial connections (those modules that are released with **RESOLVE**) includes:

- **GAP, REVEAL, MBAL** and the other **IPM** tools (**PROSPER** and **PVTP**).
- Process Simulators: UniSim, HYSYS
- Eclipse 100 and 300
- Tempest/More
- Excel – Economics packages

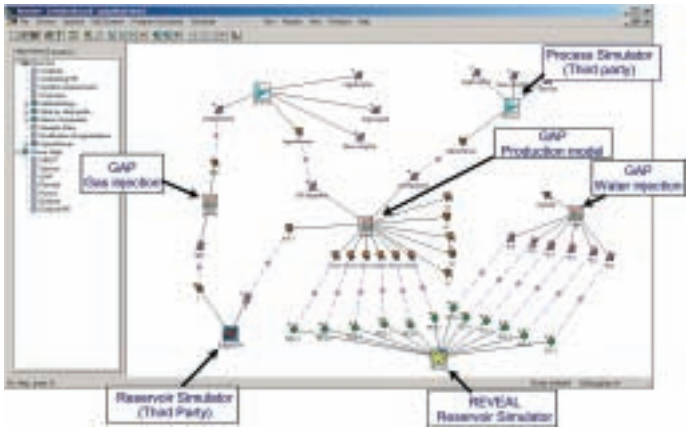
Further connections are under development, notably between **IPM** and:

- Transient pipeline models
- Proprietary reservoir simulators
- **RESOLVE** supports **OpenServer**

AN EXAMPLE OF A RESOLVE SYSTEM

The screen shot above illustrates how **RESOLVE** can be used to connect several disparate applications together to create a model of a field from the reservoir to the sales line

RESOLVE IPM – Controller Link and Interface Between IPM and Third Party Software



This model consists of:

- 3 reservoir models: Eclipse300, **REVEAL**, MBAL
- 3 **GAP** models (production, water injection, gas injection)
- 2 process models (HYSYS)

All the individual models can be distributed on remote computers. This is particularly useful in the case of reservoir simulators where the simulations can be distributed over a network and run in parallel.

RESOLVE – Features - Main

- Application to connect and run integrated models comprising an unlimited number of applications
- Hyper-threaded
  - Strong parallelisation of solver algorithm wherever this is possible
  - Makes use of local (multi-processor) and network (remote machine) resources
- Any topography of connected system is allowed
  - No fixed concept of upstream or downstream
- Entirely open architecture
  - User connections can be developed (many examples of this)
  - The application as a whole can be controlled from an external controller
  - In addition to our optimisers, users can use their own external optimiser (see below)
- Models can be run predicatively or at a snapshot in time

RESOLVE – Reservoir Coupling

- Petroleum Experts-developed algorithm for improved coupling stability
- Non-iterative – good performance
  - default scheme does not use Newton coupling (although available as an option)
  - iteration between reservoirs and GAP is possible, but is rarely required with the default algorithm
- Tested extensively on fields throughout the world
- Adaptive time-stepping also available
- Improved IPR models to address limit in most reservoir simulators IPR
- Implementation of MPI communication protocol in Windows and LINUX

RESOLVE – Surface Network Implementation

- ***RESOLVE*** is set up to take full advantage of the features of Petroleum Experts **'GAP'** software
  - optimisation
  - connection to material balance (**MBAL**)
  - production AND injection systems in a single license
  - distribution of network models and parallel optimisations over a network

RESOLVE – PVT

- Thermodynamic consistency between applications in an integrated model is ensured Black-oil models can be mixed with fully compositional models

***RESOLVE* - Event/(well) management**

- Comprehensive event / well management scheme
  - entirely open-ended
- Any variable of any application in an integrated system can be interrogated to perform (if … then … action) directives
  - An action does not have to apply to the application in which the event took place
- Actions can be complex e.g. well ranking based on an associated variable (e.g. water cut, potential, revenue calculation)
  - e.g. switching from HP to LP separation while simultaneously changing compressor curves
- This is all available through a simple user interface
  - Very complex management can be performed through a VBA script, hence the management is completely open ended
- Schedules embedded in the client applications will be honoured in a Resolve run

RESOLVE – Optimisation

- Two levels of optimisation
  - Non-linear optimisation in **GAP**
  - Successive linear optimisation in Resolve
- Optimisation problems can be distributed over ALL applications in an integrated model
  - ***RESOLVE*** determines most efficient iteration scheme to calculate derivatives
  - Tested extensively on real-field cases

RESOLVE – version control

- Tight integration with Petroleum Experts Model Catalogue.
- ***RESOLVE*** models can be checked in and out
  - All associated models from the client applications are also checked in and out

RESOLVE – link to Excel

- Dynamic linking (drag and drop) to Microsoft Excel for:
  - Calculation
  - Reporting
  - Stream splitting / manipulation

RESOLVE – GUI

- All application 'instances' can be added to the framework through a simple 'drag-and-drop' interface
- Wizards are available for common tasks, e.g.
  - Voidage replacement
  - Configuration tasks
- Run-time data from client applications (e.g. diagnostics) is channelled through the ***RESOLVE*** GUI

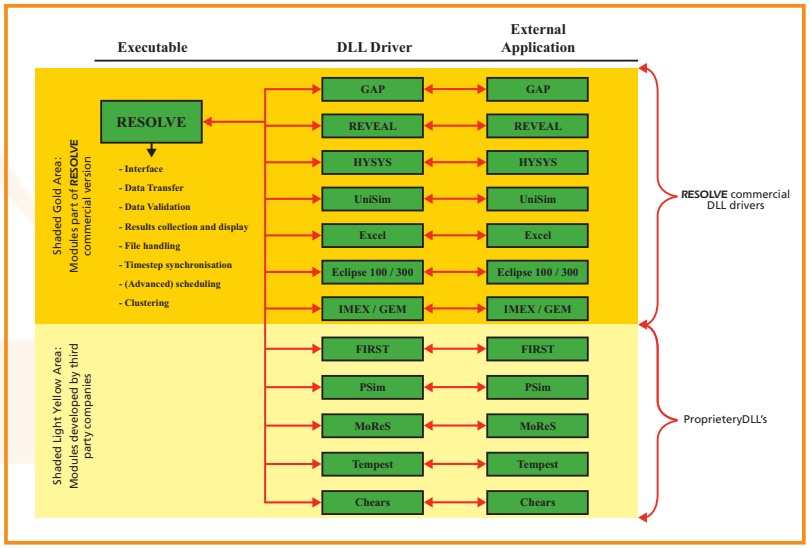
RESOLVE – Reporting

- Comprehensive and dynamic
  - Results appear dynamically during the run, allowing instant access to the results and improved trouble-shooting
  - Optimisation and loop iteration results are stored separately at every timestep
  - Any variable of any client application can be added to the 'standard' variables always displayed by ***RESOLVE***.

RESOLVE AS A CONNECTIVITY TOOL

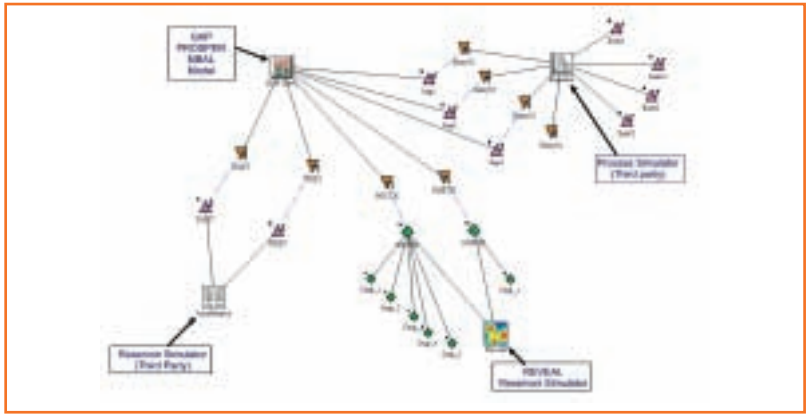
RESOLVE can be used as an interface to connect customer applications together or the ***IPM*** suite. To explain further, we need to examine the architecture of the application.

is an application that connects to a set of 'software drivers', as shown in the diagram below. The drivers are dynamic link libraries (dlls) that are programmed to communicate with ***RESOLVE***.



COMPUTER CLUSTERING

- Px Cluster – Windows clustering
- Open interface for other clustering tools
- Supports platform LSF



CURRENT COMMERCIAL DEVELOPMENT LINKS TO "DLL" RESOLVE

HYSYS	–	Aspentech Process Simulator
UniSim	–	Honeywell Process Simulator
REVEAL	–	Petex specialised reservoir simulator
ATHOS	–	Reservoir Simulator of IFP
PSim	–	Reservoir Simulator of ConocoPhillips
ECLIPSE	–	100 and 300: Reservoir Simulator of Schlumberger
TEMPEST	–	Reservoir Simulator of Roxar
IMEX/GEM	–	Reservoir Simulator of CMG
MoRES	–	Reservoir Simulator of Shell
POWER	–	Reservoir Simulator of Saudi Aramco
CHEARS	–	Reservoir Simulator of Chevron

OpenServer Connection to Third Party Software

OpenServer is designed to provide an Open Architecture for all the Petroleum Experts products. This will allow the programs to be directly accessed and be driven by other third party programs.

Applications for **OpenServer** are in Connections to:

- Third Party Reservoir Simulator
- Process Simulators
- Economics Packages
- Database
- Field Control System
- Inhouse and Proprietary Applications

Specifically, the **OpenServer** allows other programs (such as Excel or programs written in Visual Basic) to access public functions in Petroleum Experts' programs. An external program, in an automated procedure, can then access the Petroleum Experts' products.

The **OpenServer** can be used to run the **PETEX** programs in conjunction with other software applications and exchange data between them. For example, a visual basic program or batch file could be used to successively:

Potential Uses: Some ideas of the possible uses of the **OpenServer** are summarised below. It is by no means an exhaustive list.

- Running **PETEX** programs with other engineering software applications
- Batch Runs

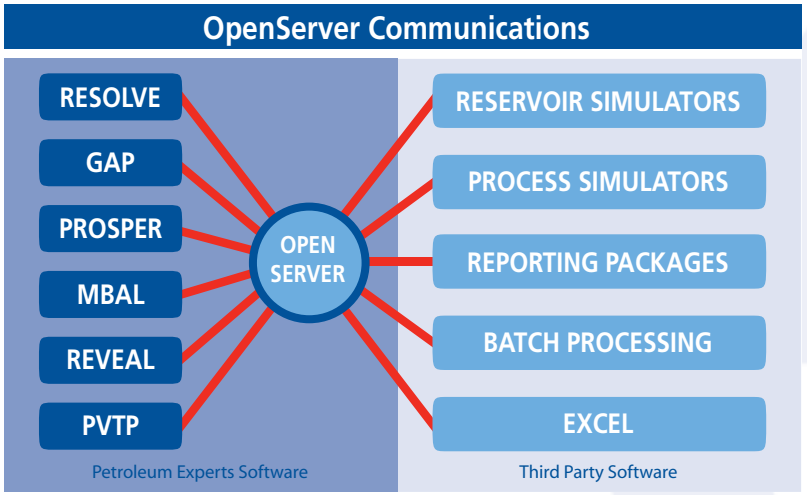
It is now possible to generate a set in-house Reports format and populate the reports directly. A VBA macro within Excel can be written to query the required values from a **PETEX** product and then write these values in the required format to a spreadsheet.

- Data Import/Export

The **OpenServer** can be used for transferring data between a database and **PETEX** programs.

The client program can use any technique to access the values in the database (e.g. ODBC, DAO, SQL) and then transfer them with **OpenServer**.

Using the **OpenServer** for **GAP**, the prediction can be run a step at a time. This means that values can be changed during the prediction. For example, you could write a VBA macro to change the PI when an acid job has been performed on a well.



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