STAR – A Smart Technology for Maximizing the Value of Heavy Oil Reservoirs*

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Abstract

In Situ Combustion (ISC) is a very effective process for recovering mobile heavy oils, especially under conditions of a water drive, or high water saturation, where steam injection may not be feasible. It also allows for the use of large well spacing. But, on the basis of nearly 250 field projects of ISC, process control is the main problem that made many of these projects unprofitable even when most of them produced 20-50% incremental oil.

Process control, using Pacific Rubiales STAR™ (Synchronized Thermal Additional Recovery) technology, involves several actions: (1) Sensing the combustion zone advance in different directions in real time and distance, and correcting, (2) Integrating production and injection rates, simulation results, geomechanical measurements, 4-D seismic, and downhole temperature and pressure data, for optimum performance, and (3) foreseeing and correcting reservoir problems before they occur. This article discusses the implementation of STAR technology as being applied in the Quifa ISC project. Although it could be readily applied to other thermal recovery methods, such as steam injection. Well design and elements of STAR technology are discussed. Project design, laboratory work, numerical simulation, and field implementation are described. Also mentioned are the potential problems that may occur and how the STAR technology addresses them.

Application of STAR technology in the Quifa pilot project involves two sets of wells: four instrumented internal wells called STAR synchronizing wells, and four instrumented outside main production wells. These are equipped with short inclined segments pointing away from the air injection well situated equidistant. The overall pattern size is 21 acres, where a high recovery factor is expected in a very short term. The project is in the start-up phase.

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Pacific Rubiales Energy

CONTENT

- Who we are - Our Heavy Oil Exploitation Strategy
- STAR Technology Fundaments
- Estimated Value Creation by STAR

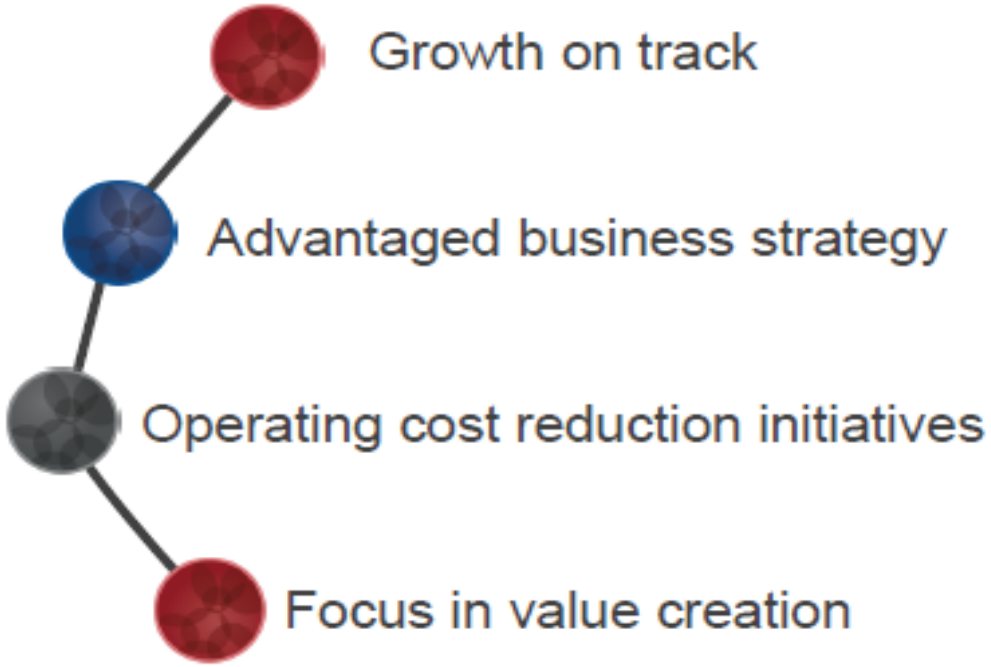
WHO WE ARE

Pacific Rubiales is a public company listed on the Toronto and Colombian stock exchanges. The Company is the largest independent oil and gas exploration and production company in Colombia. We owns 100% of Pacific Stratus and Meta Petroleum Limited, two Colombian oil & gas operators which operate and own interests in, amongst others, the Rubiales and Piriri oil fields in Colombia's Llanos Basin and the La Creciente natural gas field in northern Colombia.

The Company is focused on identifying growth opportunities in almost all the hydrocarbon basins in Colombia, as well as in eastern Peru, and Guatemala. The Company has a strong and growing reserve base, and is maximizing future production prospects through its exploration activities.

OUR HEAVY OIL EXPLOTATION STRATEGY

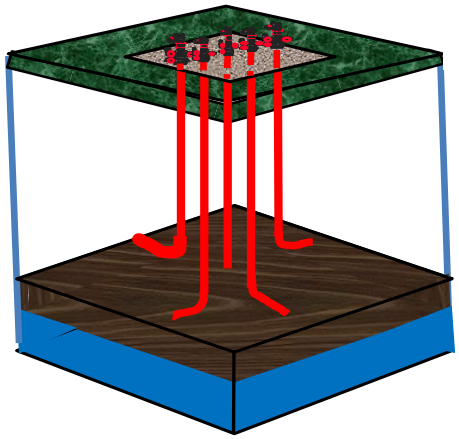
Main Focus on ……



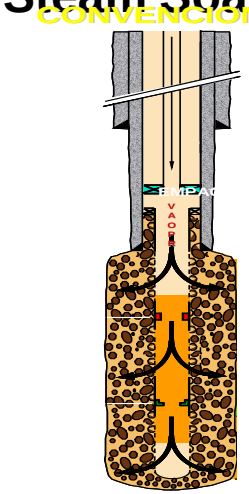
The Company aims to enhance shareholder value through the acquisition, exploration, and development of prospective oil and gas exploration assets and areas. The Company continues to apply the right technology in the right field.

CURRENT TECHNOLOGIES

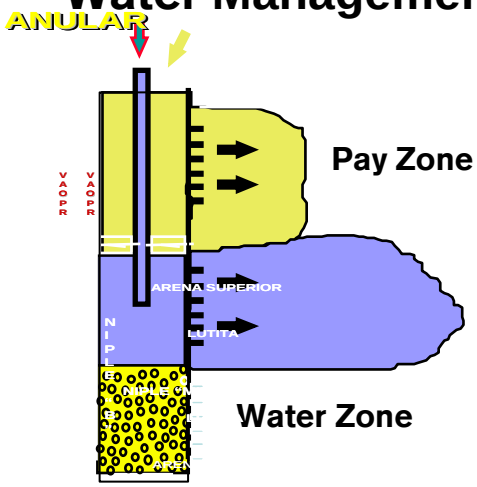
Drilling Clusters



Steam Soaking

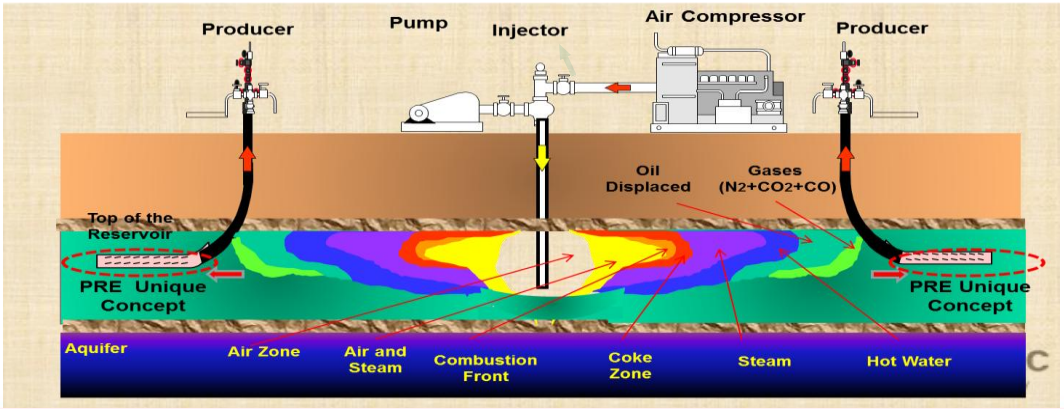


Water Management



LLanomulsion

Synchronized Thermal Additional Technology STAR



WHAT IS STAR TECHNOLOGY

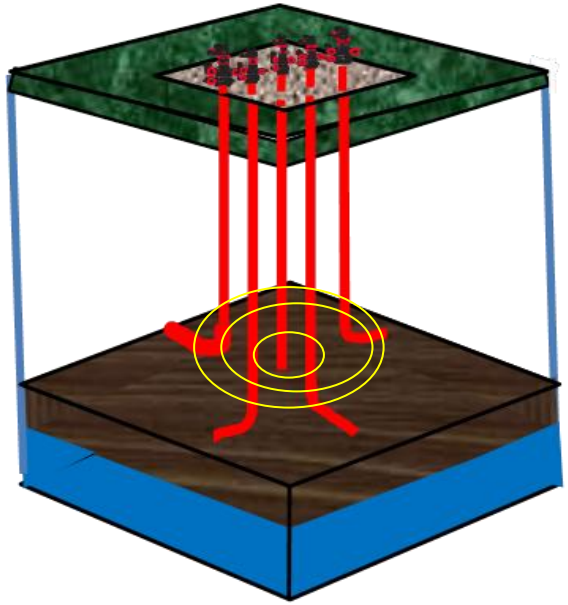
STAR, ¨Synchronized Thermal Additional Recovery¨ **is a technology based on In situ Combustion concepts developed by Pacific Rubiales Energy to increase the recovery factor and creating value in most of the heavy oil crudes reservoirs.**

STAR™ applies artificial Intelligent concepts to generate a Synchronized Model as wells as ¨thinker wells¨ to identify the combustion front position at real time. This knowledge is essential to increase the volumetric sweep efficiency and reserves.

STAR can be applied in most conventional heavy oil reservoirs in North, Central and South America, among others countries.

FUNDAMENTS OF STAR TECHNOLOGY

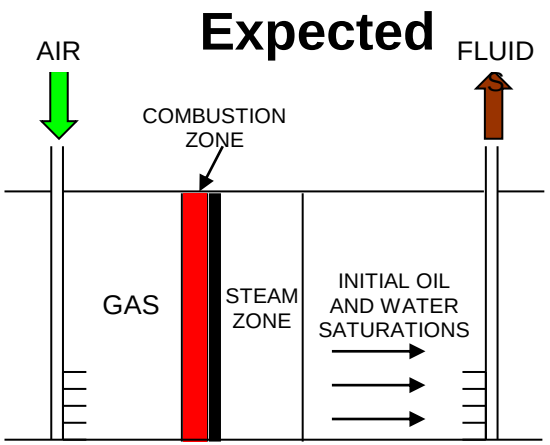
- Outward completion
- Combustion front is fully monitored and controlled at real time.
- Well synchronization at real time
- Higher oil displacement area
- Higher volumetric sweep efficiency and reserves.

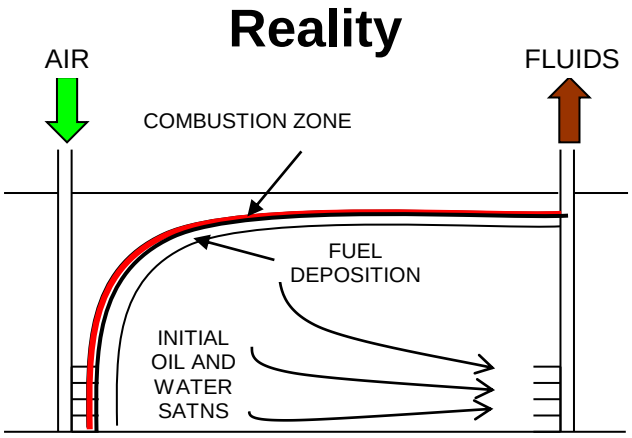


WHY STAR

To minimize the following risks:

- **Lack of knowledge of the combustion process and the reservoir characterization**
- **Unknown of the combustion front behavior.**
- **Channeling or bypassing of air injected. Extinction or cooling of combustion front**
- **Poor crude combustion characteristics and low fuel content**
- **Poor knowledge of the kinetics reactions and air segregation phenomena**
- **Inadequate compression facilities. Well Failures. No conventional Emulsions**





50 % of the combustion projects carried out in US until 1997, failed

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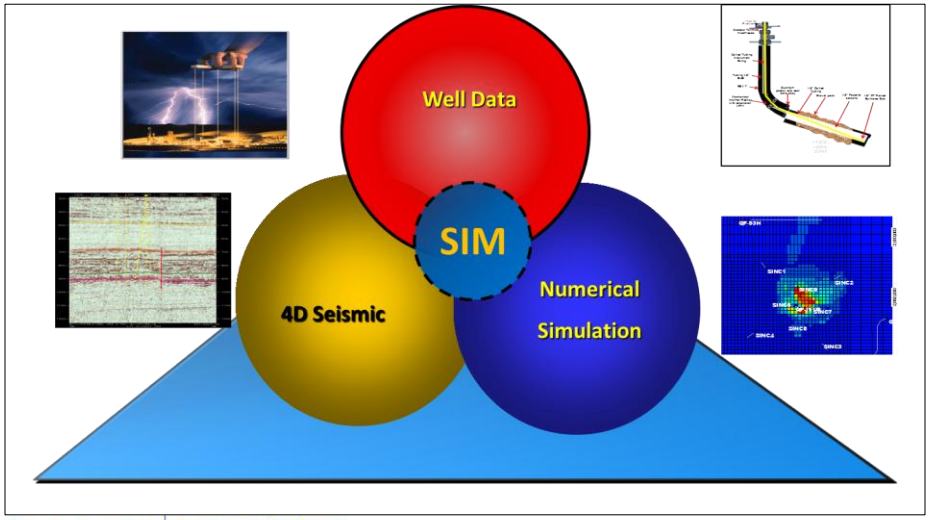
HOW STAR TECHNOLOGY MINIMIZES MOST OF THE TECHNICAL RISKS

Reservoir & Geological Model	To know the reservoir and geological characteristic. Layers continuity and preferred flow units
Specialized Lab tests	To determine the combustion and oxidation reactions and crude behavior during In situ combustion.
Kinetic Model	To identify the kinetic reactions of the crude.
Numerical Model	To know how the reservoir behave under In Situ Combustion for different scenarios
Synchronization Integrated Model	To identify and synchronize the combustion front and fluids at real time and distance
Synchronized Operations Model	To identify the right management decisions to improve the combustion front position, volumetric sweep efficiency and reserves

Unique Models patented by PRE

WHAT IS A SYNCHRONIZATION INTEGRATED MODEL, SIM

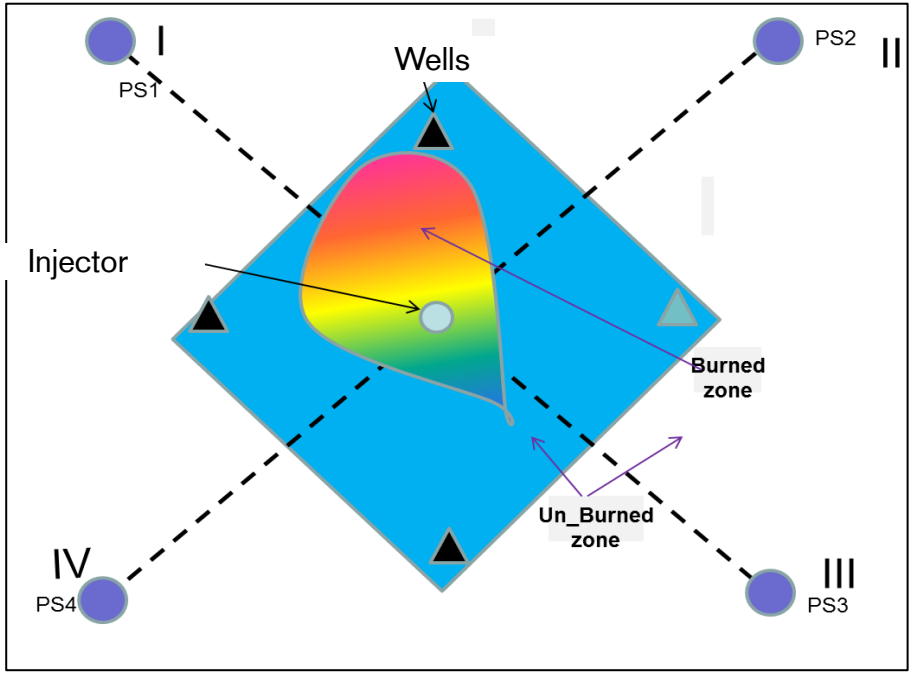
The Synchronization Integrated Model, SIM, is an unique intelligent system compounded by four (4) sub-models and eight (8) Matlab applications developed by PRE to identify and control the position of the combustions front and its fluids, at any time and distance. It is supported for three sources of information such as real time well data, numerical simulation and seismic data which are integrated and updated continuously.



The Artificial intelligent techniques developed by PRE allow us to identify the right decisions to synchronize producer and the injector wells, on time. It's called **"Synchronized Operations Management, SOM"**

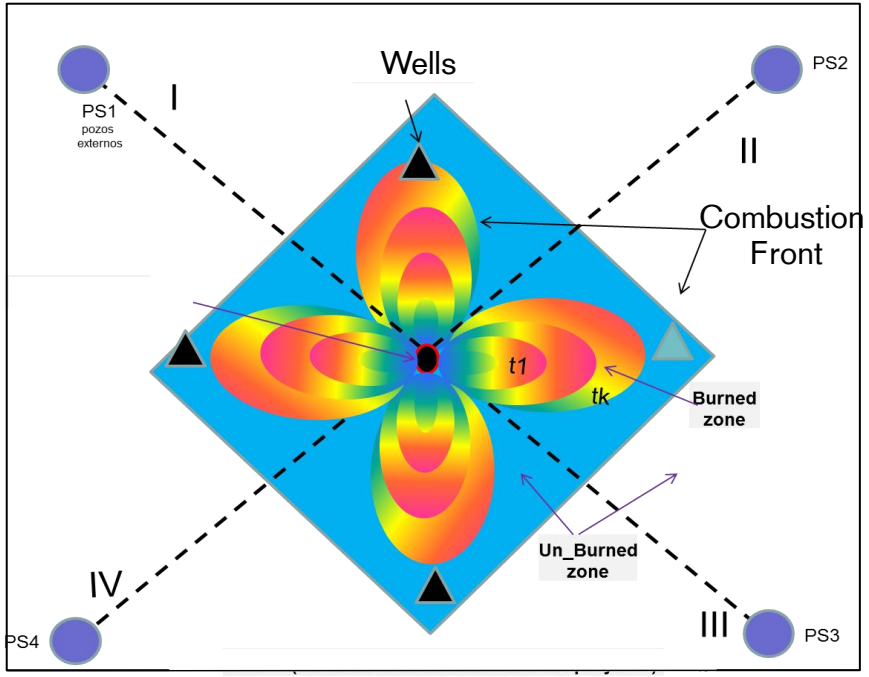
IMPORTANCE OF THE SYNCHRONIZATION

Combustion Displacement without STAR



Gas channelization towards to best quality area. Low volumetric sweep efficiency and reserves

Combustion Displacement with STAR



Better displacement and higher volumetric sweep efficiency and reserves

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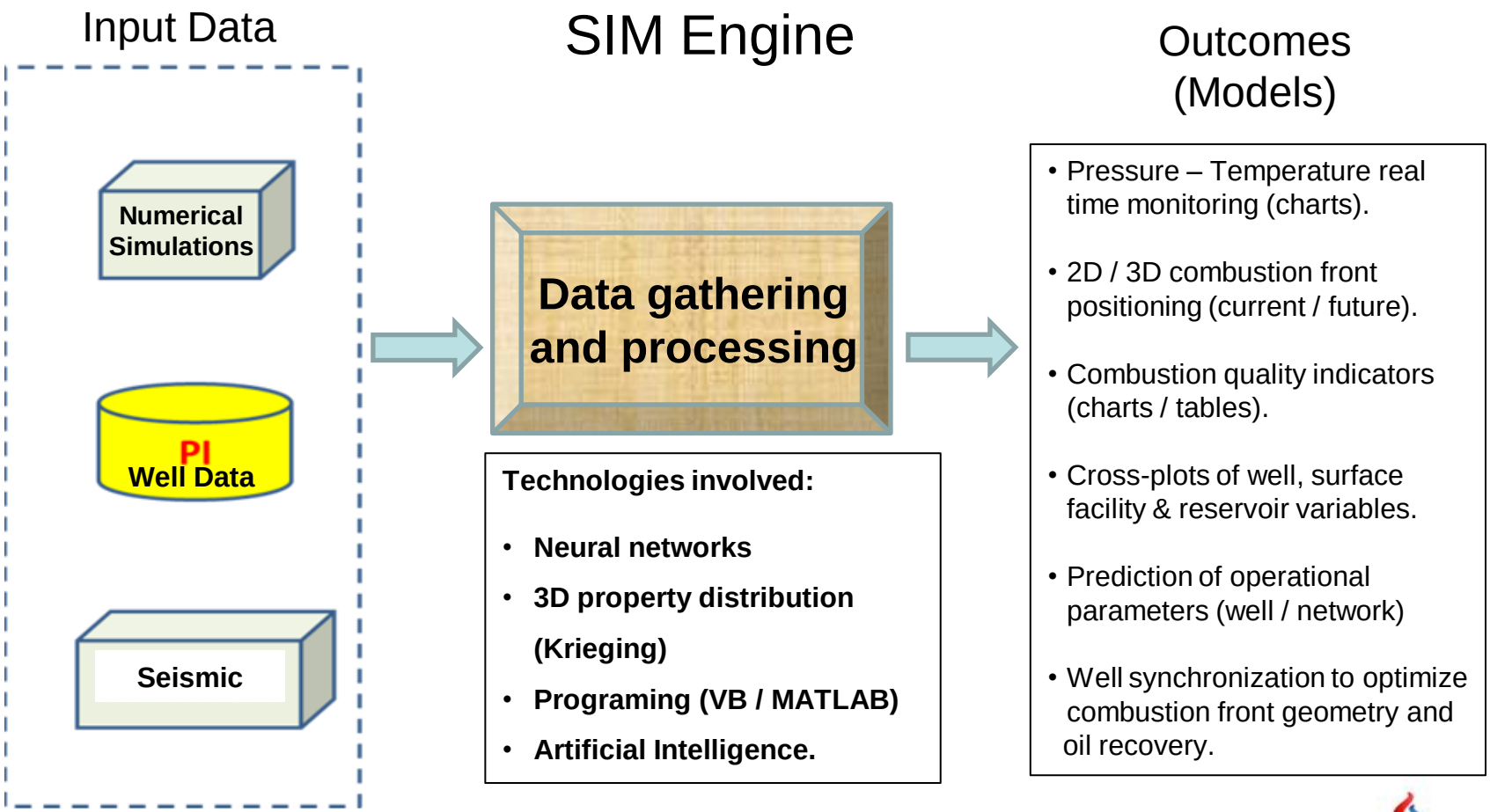
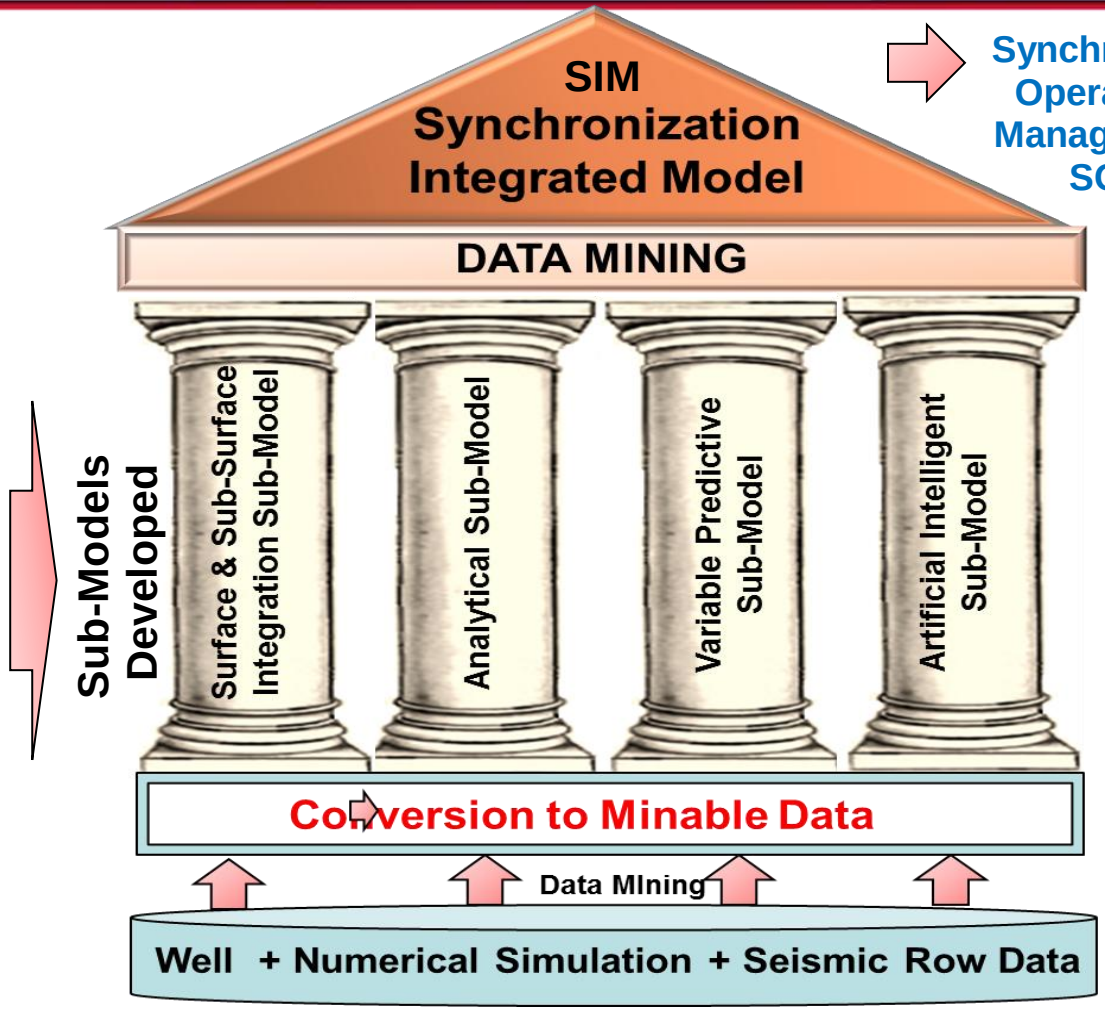
SYNCHRONIZED INTEGRATED MODELING (SIM) WORKFLOW DIAGRAM



SIM STRUCTURE

Applications Developed

- To generate the DM model and determine Productions & knowledge rules
- To convert numerical simulation data to Matlab data
- To convert seismic data to Matlab data
- To normalize all combustion variables
- To convert Fiber Optical Data to Matlab data
- To determine combustion parameters



Synchronized Operations Management, SOM

To identify the right Management Decisions and Strategy

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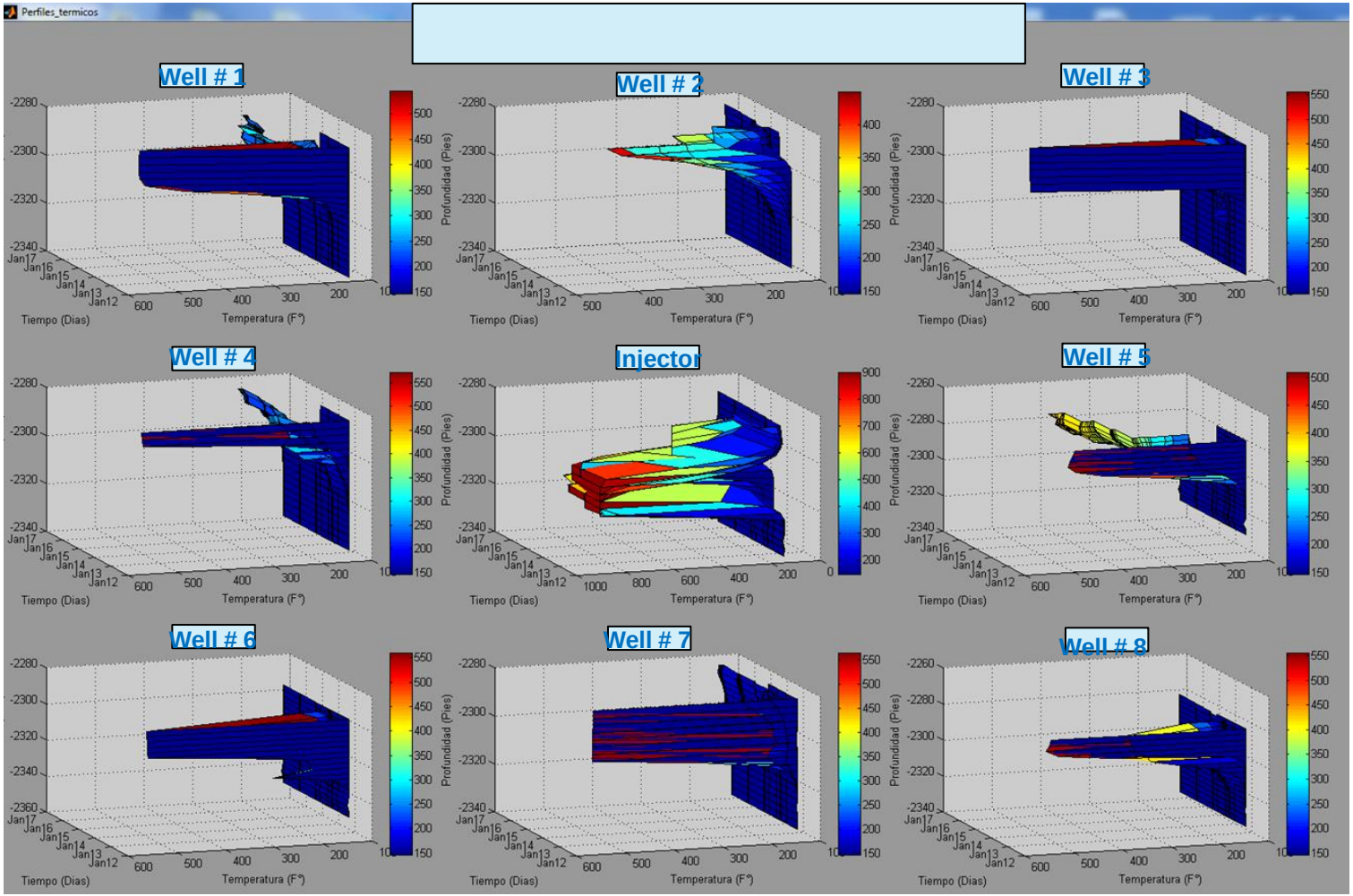
Some Results

3D TEMPERATURE PROFILES OF THE WELLS JULY 2013



Temperature profile for each well of the pattern, as function of time and depth.

Well # 2 has the most influence of the air injector so far

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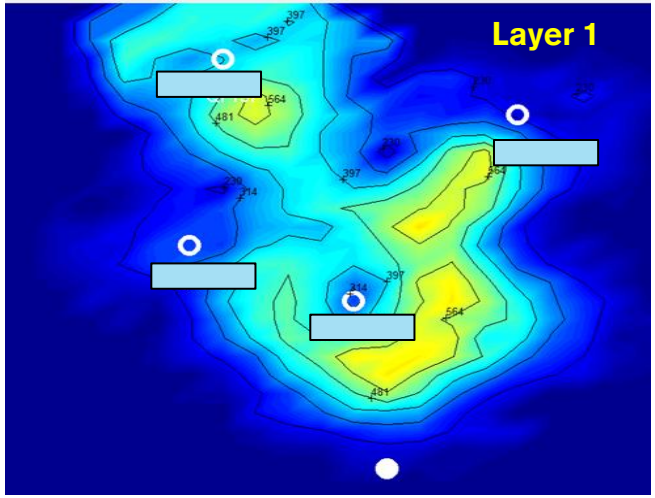
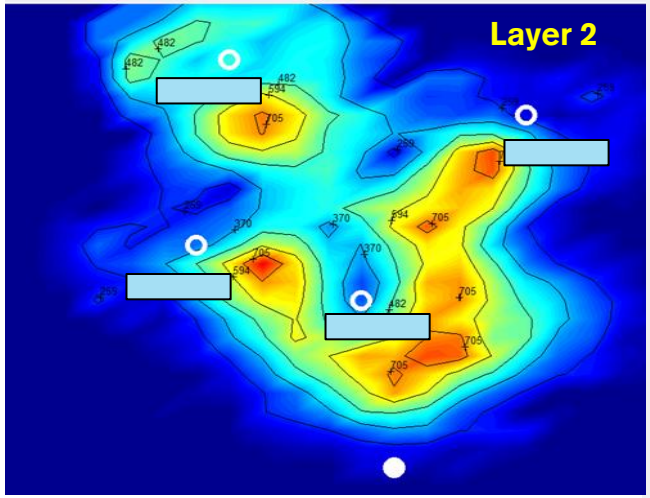
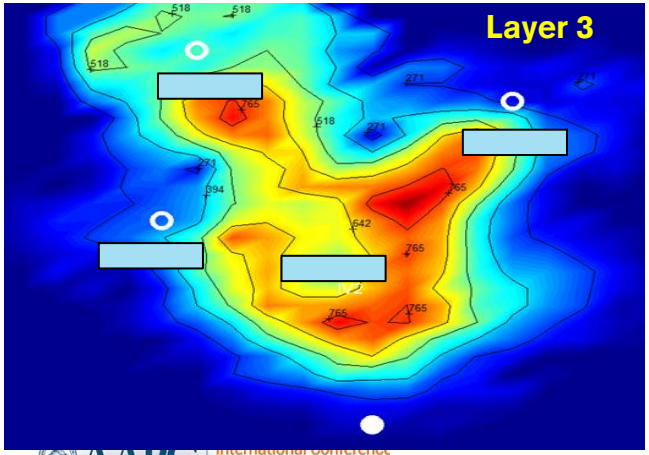
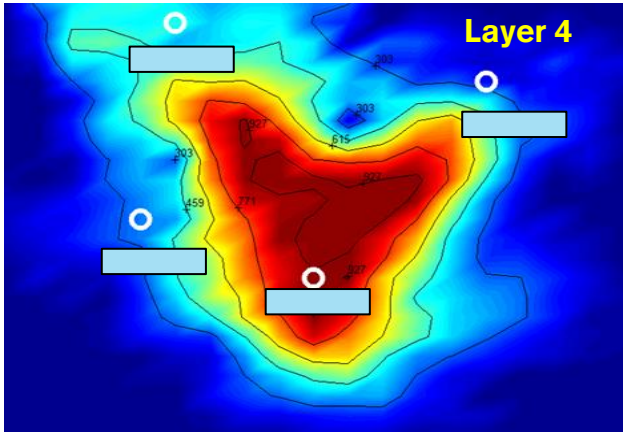
POSITION OF THE COMBUSTION FRONT JULY 2013









To improve the geometry of the combustion front and volumetric sweep efficiency 52 Well Synchronization have been made so far, 75 % of them successfully

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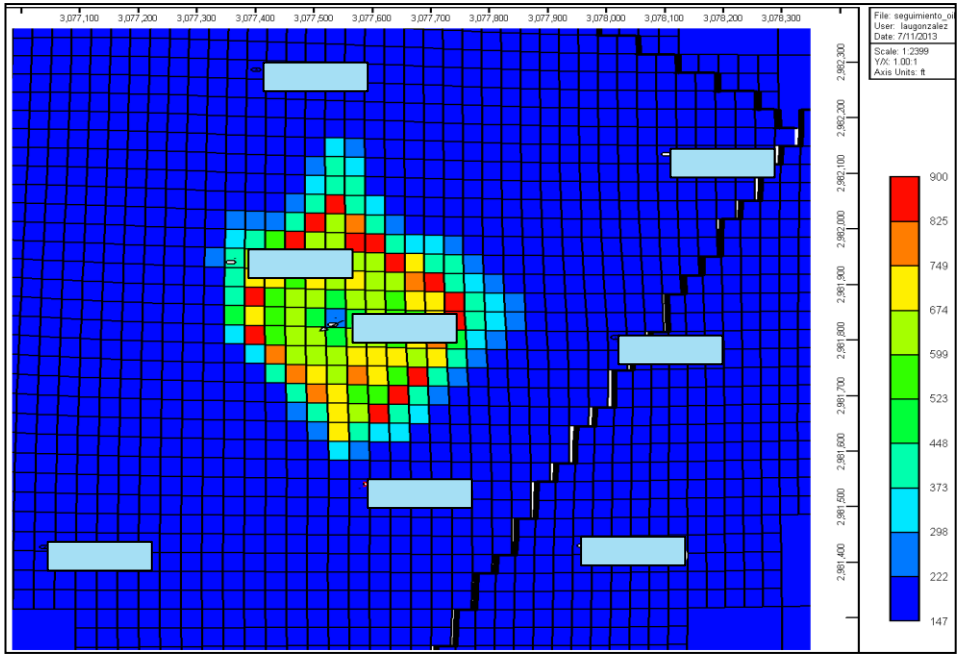
NUMERICAL SIMULATION VS SYNCHRONIZATION INTEGRATED MODELS

TEMPERATURA PROFILE

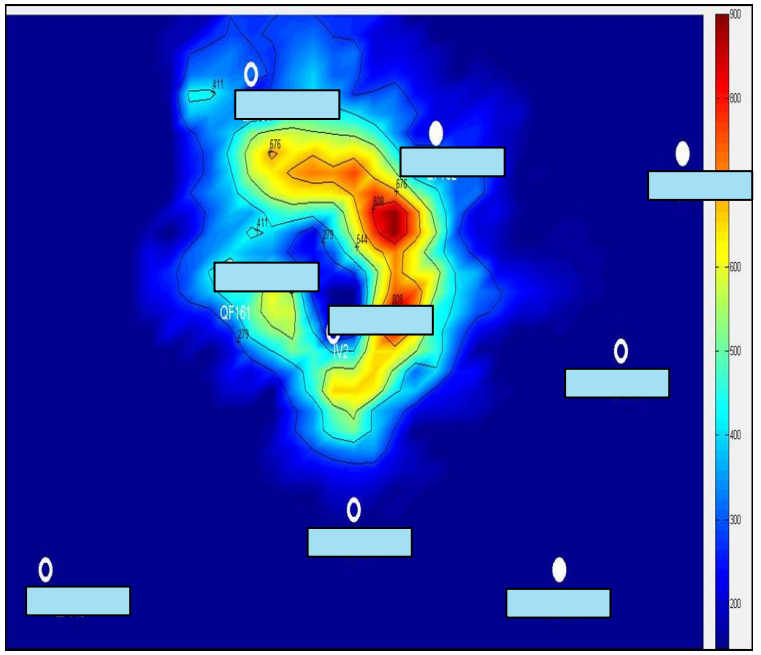
Unreal shape

Numerical Simulation Model



Real shape

PRE Synchronized Integrated Model

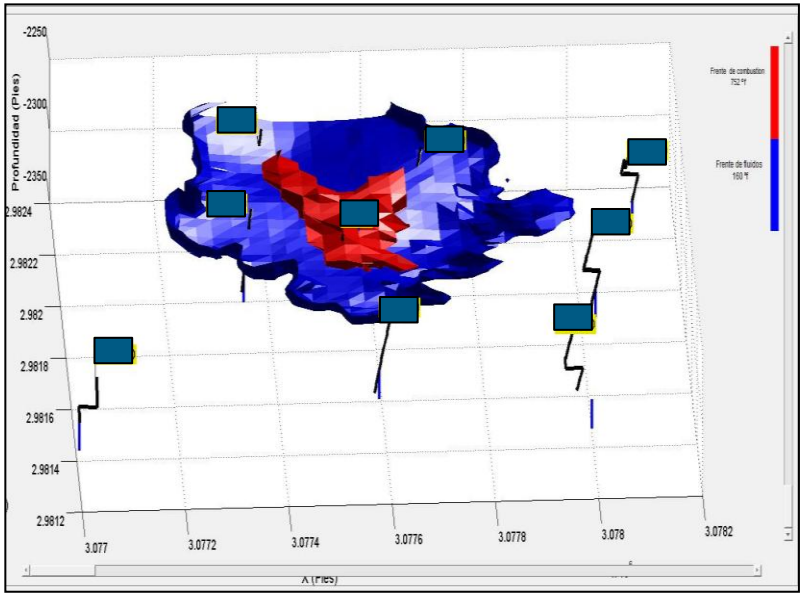


…. Decision taken based on numerical simulations may be wrong

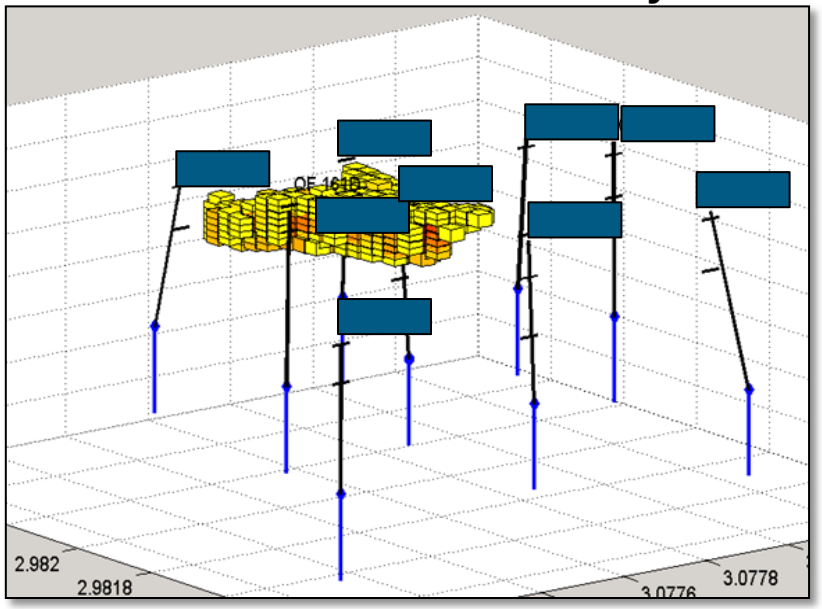
PRE just take it as reference, we apply SIM and SOM Models

STAR TECHNOLOGY RECOVERY FACTOR

Combustion Front & Fluids



Combustion Front Only



- Successful synchronization of producing wells achieved
- Results to date indicate a doubling of the recovery factor in pilot test area
- Certification of STAR pilot project recovery factor in progress
- Examining plans to expand STAR to wider field trials in Quifa SW

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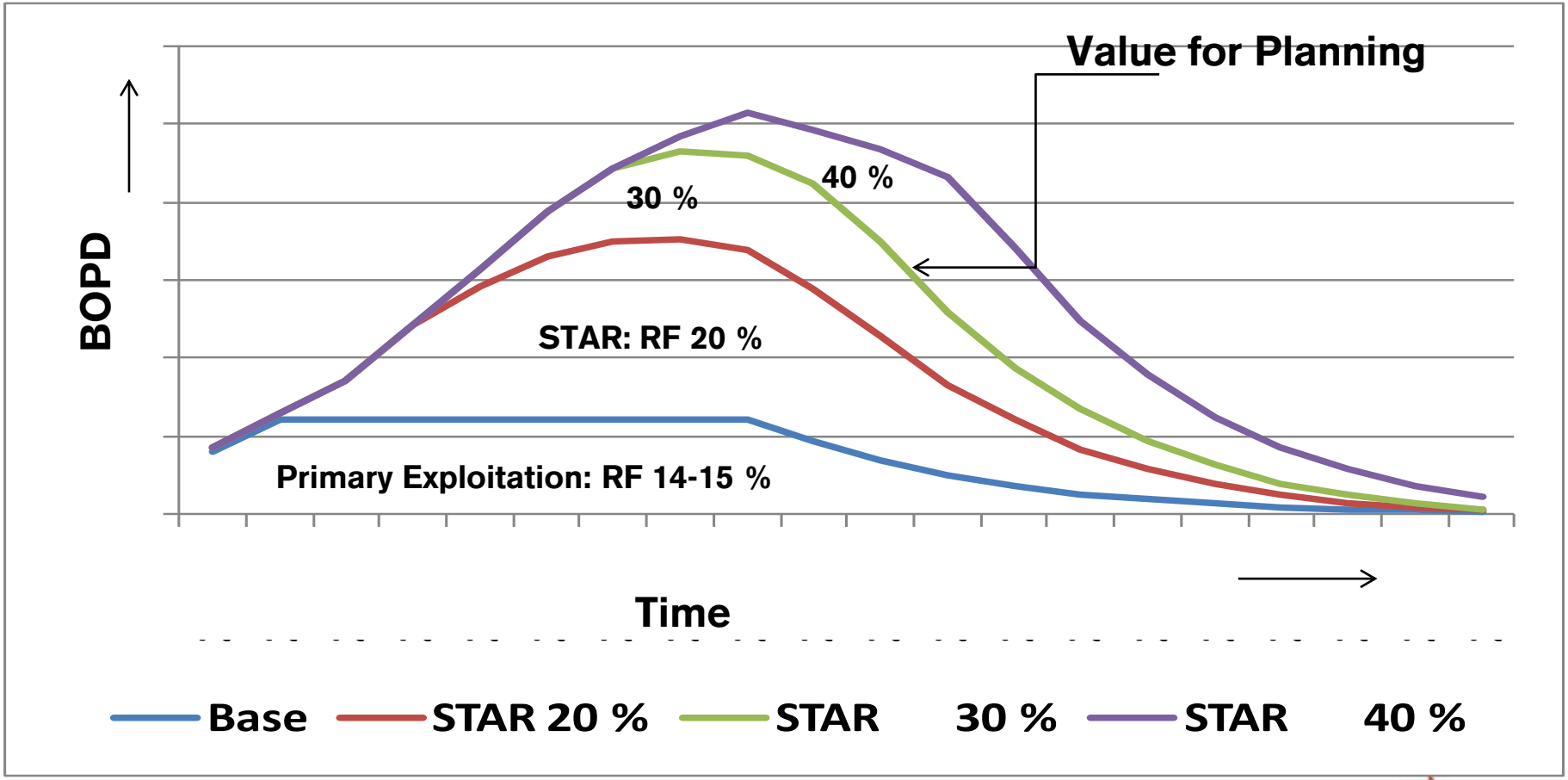
ESTIMATED VALUE CREATION BY STAR



VALUE CREATION BY STAR TECHNOLOGY MASSIVE APPLICATION

Parameter	Field # 1	Field # 2	Total
NPV of the Project, MMUSD	6450	5150	11600
NPV of the Royalty, MMUSD	3200	2200	5400
NPV of the Taxes, MMUSD	4250	400	4650
Estimated Addittional Reserves, MMBls	1230	530	1760
Estimated Recovery Factor, % OOIP	30	30	30

……. 1760 MMBls of additional reserves may be gotten in Colombia by STAR in just two oil fields. This represents 70 % approximately of the proven reserves of the country

Conclusions

Successful synchronization of producing wells have been achieved so far

Results to date indicate a doubling of the recovery factor in pilot test area

Examining plans to expand STAR to wider field trials in Quifa SW