INTELLIGENT SOLUTIONS, INC.


# SMART FIELDS

## A NECESSARY PARADIGM SHIFT IN ANALYSIS & MODELING

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Our industry has invested hundreds of millions of dollars in the past decade to build the required infrastructure for the smart fields. The E&P industry has developed instrumentations and hardware that provide access to wellbore and completion in real-time. These tools can minimize cost and shut-in time during intervention and provide means of implementation of detail reservoir management decisions. What our industry still does not have is the means of making effective reservoir management decisions, based on analysis and modeling, at the same time scale where data from the well and the reservoir is being accessed and transmitted to the remote office.

In other word, we have significantly modified and enhanced our access to data, to wellbore and to the reservoir, but we are still using the same old methodologies for analysis and modeling. Analysis and modeling techniques that had been developed when our access to the data, the wellbore and the reservoir were measured in days and months and not in seconds and minutes. In other words, we are trying to control the new situations with old tools, and then we wonder why it so hard to get more out of these new investment. It is time for a change. It is time for a paradigm shift. It is time to revisit how we solve problems.

Intelligent Solutions, Inc. is dedicated to play its role in leading this paradigm shift in our industry. Our significant investment of twenty years of research and development in developing technologies, workflows and products in application of data-intensive modeling and analysis is a testimony to our leadership and dedication. Our contribution includes:

- Providing the technological capabilities to automatically and autonomously handle high frequency data streams received from permanent downhole gauges (data cleansing, data summarization, pattern recognition, adaptive online modeling).

- Providing the modeling framework and workflows that allows running of the existing reservoir simulation models in real-time, thus making Real Time Reservoir Management (RTRM) possible.


**SUMMARY**

Smart completions provide the means for engineers to intervene with details of well's operation from a distant. Smart wells (that include smart completions) transmit high-frequency (real-time) data streams (pressure, rate, etc.) to the remote office providing immediate feedback on the consequences of the decisions made and actions taken. Smart field includes multiple smart wells providing the possibility of managing the entire reservoir remotely and in real-time. Our industry is now on the eve of making Real-Time Reservoir Management (RTRM) a reality. The enabling technology for RTRM is Artificial Intelligence & Data Mining (AI&DM). AI&DM enables us to process, model and utilize the high-frequency data streams, build accurate prototypes of sophisticated reservoir simulation models that can respond to changes in model input in real-time to help us make crucial reservoir

engineering decisions and close the loop on high-frequency feedback to the reservoir model for making Real-Time Reservoir Management a reality.

## DATA-INTENSIVE SCIENCE, THE FOURTH PARADIGM

History of science and technology can be divided into several eras (Hey, 2009). It all started with experimental science at the early age of science. Several hundred years ago the theoretical branch of science emerged and gave rise to theories such as Newton's laws of motion, Kepler's laws of planetary motion and Maxwell's laws of electrodynamics, optics and electric circuits. The last several decades have been the age of computational science where fast computers have provided the means for simulation and modeling in areas such as computational fluid dynamics, meteorological and climatological, aerospace and hydrocarbon reservoir simulations, to name a few. According to Jim Gray[1], the legendary American computer scientist, we have now entered the new age of *escience* or *data-intensive science* where massive amounts of data can be collected from physical phenomena and or simulations and new models can be built based on these data.

Moving from each of the above ages of science to the next required a paradigm shift on how we observe, interact, model and attempt to control the phenomena around us. It is now time for another paradigm shift into the fourth paradigm that is the *data-intensive science*.

## REAL-TIME RESERVOIR MANAGEMENT (RTRM); THE ENABLING TECHNOLOGY FOR SMART FIELDS

Reservoir Management is defined as the practical science of developing a hydrocarbon field in a manner that would maximize ultimate recovery. Real-Time Reservoir Management (RTRM), that presents Intelligent Solutions, Inc.'s implementation of AI&DM as the enabling technology for the emerging smart fields, refers to a closed loop process during which the reservoir model is continuously updated by the information/feedback received from the field (via high frequency data streams). The information/feedback received from the field represent the consequences of the decisions made and implemented based on the reservoir model.

Therefore, the ultimate benefit of the smart field depends on the degree of our success in building and implementing RTRM. In other words, the value of high frequency data streams are realized once we are able to use them in effectively updating the reservoir model and subsequently using the reservoir model to make decisions regarding the field operation.

Therefore, the key to moving toward successful smart filed operations is to be able to perform the following steps:

1. ***Acquire process and analyze high frequency (real-time) data streams from the wells.*** These real-time pressure and rate data provide indications of reservoir reaction to the operational decisions made by engineers using the reservoir model.

[1] Jim Gray: (1944-2007) Legendary American computer scientist received the Turing Award for seminal contributions to computer science.

2. ***Use the real-time data as feedback to the reservoir model and for updating the model.*** By analyzing the high frequency data in the context of the reservoir model engineers can compare the actual reservoir/well response with the predictions made based on the operational decisions from the model.

3. ***Make operational decision for implementation.*** Make new operational decisions (continue operation as is, is also a decision) based on the reservoir model and make predictions on possible response from the reservoir/well.

4. ***Go to Step 1.*** Perform all these analyses while taking into account and quantifying the uncertainties associated with the reservoir model.

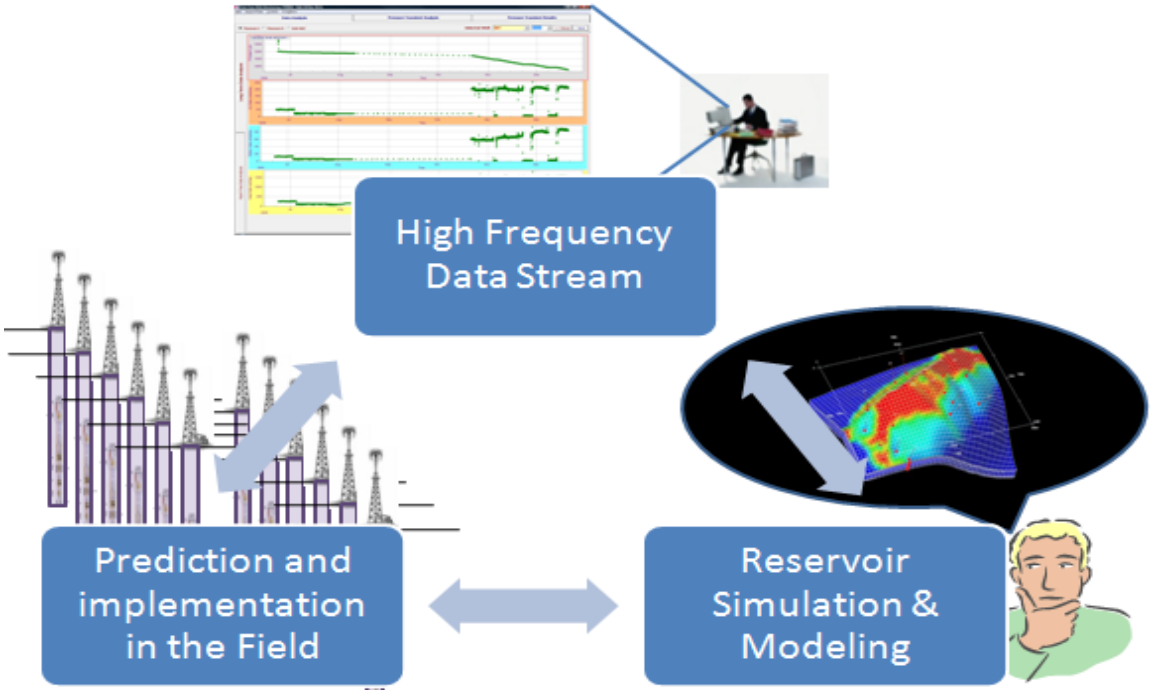


***Figure 1.*** *Schematic diagram of the closed loop Real-Time Reservoir Management (RTRM).*

In order to be able to accomplish steps 2 and 3 in the above process, the reservoir model must have the capability of analyzing multiple scenarios in real-time (or near real-time) and provide real-time responses to changes to the model input or potential modifications that can be made to the well operation. Currently, lack of real-time reservoir modeling and analysis technology (of complex, real fields – not academic toy problems) has forced many operators to settle for crude and limited proxy and analytical models. Limitations of these models are well known and documented and operators are well aware of their serious shortcomings.

It is imperative to be able to analyze and model the complexity and detail heterogeneity of the real reservoirs at a time scale that is relevant to the smart field (seconds and minutes). This seems like a giant and unachievable task since our industry has been struggling with computational efficiency from the dawn of numerical simulation and modeling. We soon learned and using super computers

or computer cluster may ease but not solve our problem. Intelligent Solutions, Inc. proposes a paradigm shift that would make this gigantic task possible. It is called Surrogate Reservoir Modeling[2].

The reservoir/well responses to the modifications are reflected in high frequency (real-time) data streams. Figure 1 is a schematic diagram of the closed loop Real-Time Reservoir Management (RTRM) concept.

## INTELLIGENT REAL-TIME DATA ANALYSIS

The high frequency (real-time) data that is collected from the permanent downhole gauges and transmitted to be stored in data historians is usually unusable in its raw form. Data needs to be curated (cleansed and summarized, prepared and processed) for use in reservoir engineering studies. The high frequency data needs to be de-noised, the outliers must be identified and removed, existing trends and patterns need to be identified and data need to be summarized so that maximum information can be preserved using the least amount of data. Most importantly all these need to be performed reliably, in real-time (at the same time scale – or faster – that data is received) automatically and autonomously without supervision of an engineer.

Furthermore, the intelligent real-time data analyzer needs to have capabilities of taking maximum advantage of the information content of the high frequency data. Intelligent Solutions, Inc. offers a complete set of tools, workflows and products for intelligent data analysis of the high frequency data streams. ISI's services, training and products for the smart fields include high frequency data curation and management and high frequency data analysis. Moreover, high frequency data analysis is divided into well-based analyses and full field reservoir analyses.

### HIGH FREQUENCY DATA CURATION & MANAGEMENT

High frequency data curation and management performs all preparations and preprocessing of the data autonomously and in real time. During this process data is prepared to be used in reservoir engineering analysis. An example of ISI's data curation and management is shown in Figure 2. The process includes:

- Data de-noising
- Outlier removal
- Pattern recognition and summarization
- Data preparation for SRM

[2] Please refer to ISI's white paper on Surrogate Reservoir Modeling (SRM)

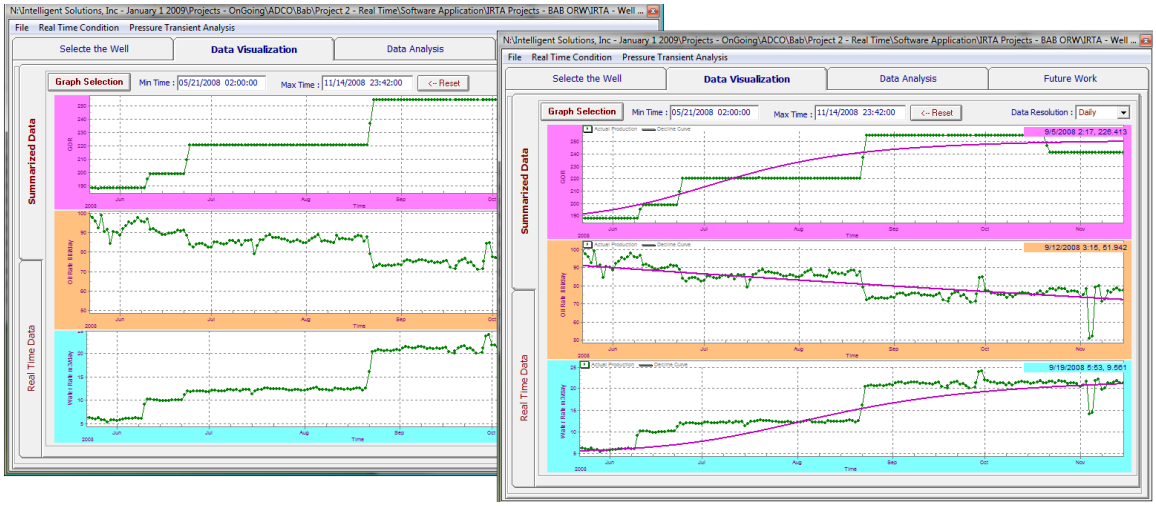


***Figure 2.*** *Autonomous cleansing and summarization of high frequency data and online, adaptive modeling of high frequency data streams.*

## HIGH FREQUENCY DATA ANALYSIS

High frequency data analysis refers to the process through which the high frequency data is turned into information and knowledge that results in effective reservoir management decisions. These data-intensive modeling and analyses workflows integrate the pattern recognition capabilities of Artificial Intelligence & Data Mining (AI&DM) with innovative use of reservoir engineering in order to generate a series of smart workflows for well and reservoir analysis and modeling. These smart workflows for well and reservoir analysis and modeling include real-time monitoring, analysis and modeling of wells and Real-Time Reservoir Management.

### REAL-TIME MONITORING, ANALYSIS & MODELING OF WELLS: WELL-BASED ANALYSIS

Detection, isolation and analysis of pressure transient data used for continuous monitoring of well and reservoir behavior, as well as well behavior modeling using adaptive learning technologies that learns data behavior and continuously modifies itself to match and model the observed data and to predict its behavior are among the real-time well-based technologies that are offered by Intelligent Solutions, Inc.

### REAL-TIME RESERVOIR MANAGEMENT: FULL FIELD ANALYSIS IN REAL-TIME

Detect, model and verify hypotheses about drive mechanisms, continuous modeling and self-modifying and multi-level validating of volumetric estimates that eventually results in detail pressure distribution modeling throughout the reservoir in real-time is one of the key technologies that has been developed and being perfected by Intelligent Solutions, Inc. for the smart fields. Other real-time reservoir analysis workflows that are offered include performing diagnostic analysis in order to detect inter-well connectivity that may or may not exist between multiple wells in a reservoir. Finally, ISI's TDM and SRM technologies provide means for real-time reservoir simulation and modeling with real-time updating of the static model and continuous monitoring and analysis of saturation and pressure distributions in the reservoir as a function of time, production and injection activities.

## REFERENCES


- Tony Hey, et.al. 2009, The Fourth Paradigm; (Data-Intensive Scientific Discover), Microsoft Research.