Digital platform as a tool for efficient reservoir management

Alex Katashov[1], Kirill Ovchinnikov[1], Dmitry Tatarinov[1], Evgeny Malyavko[1]* and Valery Ogienko[1] analyse a new digital platform combining the use of actual downhole data, machine learning, and verification of the results obtained with hydrodynamic simulators.

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To date, a unified analytical platform based on machine learning methods enabling highly automated operations with data on production, well interventions, and logging is required to optimize HC exploration and production. The purpose of this paper is to analyse the Geosplit digital platform for interpreting data across the entire field sector to provide and evaluate field development recommendations. The unique feature of the platform combines the use of actual downhole data, machine learning methods and verification of the results obtained from hydrodynamic simulators. The platform modules have a flexible role-based access control model allowing for field data digitalization and data access configuration for all users along with control over the data usage, resulting in improved reservoir management.

Due to the development of machine learning methods and a growing amount of oil and gas field data, the oil industry has become a very attractive area for applying technologies to analyse these data, including predictive analytics. The following are fairly obvious applications of machine learning methods along with mathematical optimization:

- Methods for predicting abnormality in equipment operation (anomaly detection) to optimize the operation of drilling rigs, pumps, and power plants;
- Pattern recognition methods (deep convolutional neural networks) for automating geological modelling processes using data arrays of various sizes;
- Measurements (seismic, logging, core) and minimization of the uncertainty of geological models;
- Methods for information retrieval from documents when creating question answering (QA) systems (digital assistants) for production operators, drillers, and reservoir engineers;
- Methods for simplifying problems of mathematical physics to create systems for fast screening of field development options.

The concept of optimizing HC exploration and production processes has been implemented as a comprehensive analytical platform based on machine learning methods that uses geological and geophysical input data, production data, equipment and technological process telemetry data, as well as hydrodynamic modelling. However, despite the obvious advantages of predictive analytics methods that use field data, these methods cannot be implemented on a large scale due to a number of certain hindering factors. It is clear that the industry faces the challenge of limited data availability. Not all fields have sufficient data collection and storage systems, as indiscriminate sensor installation and IT systems debugging are expensive and time-consuming, and therefore require proven economic viability.

Some time ago, GeoSplit made a breakthrough in horizontal well logging by utilizing innovative technologies to perform long-term production logging without well intervention. Over time, as more and more wells were studied in Russia and abroad, the amount of data for processing and storage, as well as the geological and engineering factors to be taken into account, have increased tenfold. By 2020, there emerged a need for creating a digital platform allowing for highly automated operations with the data on production, well intervention, reservoir energy, well interference, injection to withdrawal ratios, and logging.

The existing GEOSPLIT technology for horizontal well logging is a combination of the following:

- High-molecular chemistry principles applied to manufacture fluid phase-selective production profile indicators;
- Advanced equipment for detecting indicators in reservoir fluid samples;
- Machine learning-based software for calculating production profile indicators in reservoir fluid samples;
- A digital platform for interpreting data across the entire field sector in order to provide and evaluate field development recommendations.

The concept of the digital field involves the use of tools for modelling each of the elements of integrated models in the formation-well-ground infrastructure-processing facilities bundle. While sensors can be installed on the ‘ground infrastructure’ to obtain a multi-parameter real-time data flow, the ‘well-formation’ system is often out of reach. Currently, medium-term forecasting processes mainly utilize simplified reservoir models

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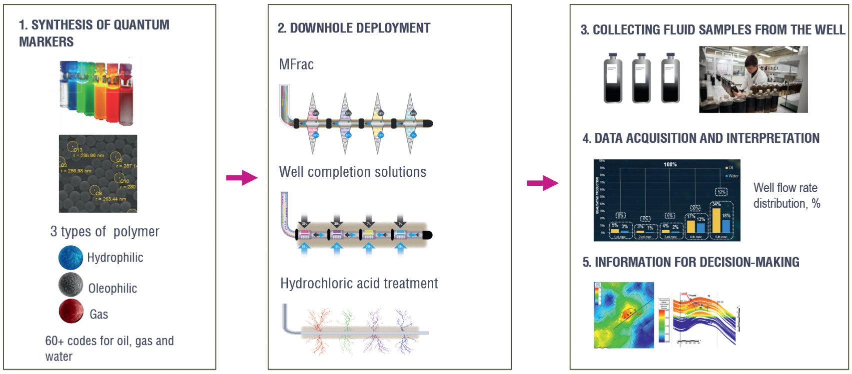

Figure 1 General cycle of the technology.

based on statistical estimates of the production decline rates. If used for short-term (daily) oil production planning, this approach leaves aside well interference and significant changes in the production process, which results in considerably higher calculation and prediction errors. This is especially relevant if the forecast is based on actual performance where current potential development indicators are used as a total potential of all parts of the integrated model with allowance for the difference between the potential and actual indicators. To identify the potential, the maximum permissible scenarios for implementing the well intervention program are modeled, as well as changes in well operation modes, commissioning schedules for new wells, etc. Such a tense state of the system cannot be adequately explained by the current production decline rates, since the system undergoes critical changes. There is no actual data on the system's performance under the new conditions to optimize the production decline rates. Therefore, it became necessary to develop a reservoir model for daily flow rate forecasting for each well that would take into account the features and limitations mentioned earlier. Most of the engineering challenges cannot be solved effectively using machine learning algorithms or physical and mathematical algorithms separately. It would be inefficient to address the tasks using only one approach, since it would require describing all the processes of the system and building a comprehensive physical and mathematical model (which is not always feasible) or may lead to probabilistic solutions and a significant error (if only machine learning methods are applied), unlike in the case of combining a physical and mathematical model with machine learning models for more precise results.

The unique feature of the Geosplit digital platform is a hybrid approach combining the use of the following elements:

- The use of actual downhole data obtained by applying the dynamic horizontal well production profile surveillance methods (marker or tracer-based production logging or fibre optic systems) for immediate verification of emerging hypotheses on how certain factors affect well operation;
- Machine learning methods for choosing the most realistic and rational predictive scenarios and a physical and mathematical model of processes occurring in the reservoir for minimizing calculation errors that occur due to the lack of a sufficiently detailed basic model that would incorporate implicit correlations from the machine learning model to make the main prediction more precise;
- Verification of the results obtained with traditional hydrodynamic simulators well-known among the field development engineers in order to align them with seismic data, build geological models, calculate hydrodynamics and geomechanics simultaneously, and model PVT properties of the gathering lines.

A schematic view of the digital platform is shown in Figure 2.

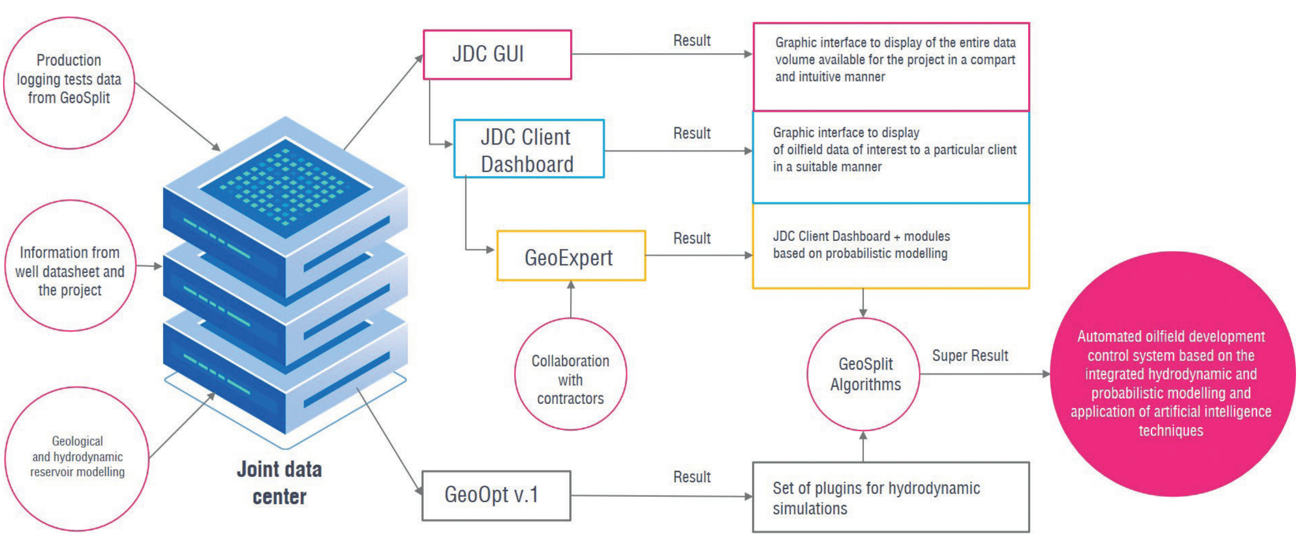

Figure 2 Schematic view of the digital platform.

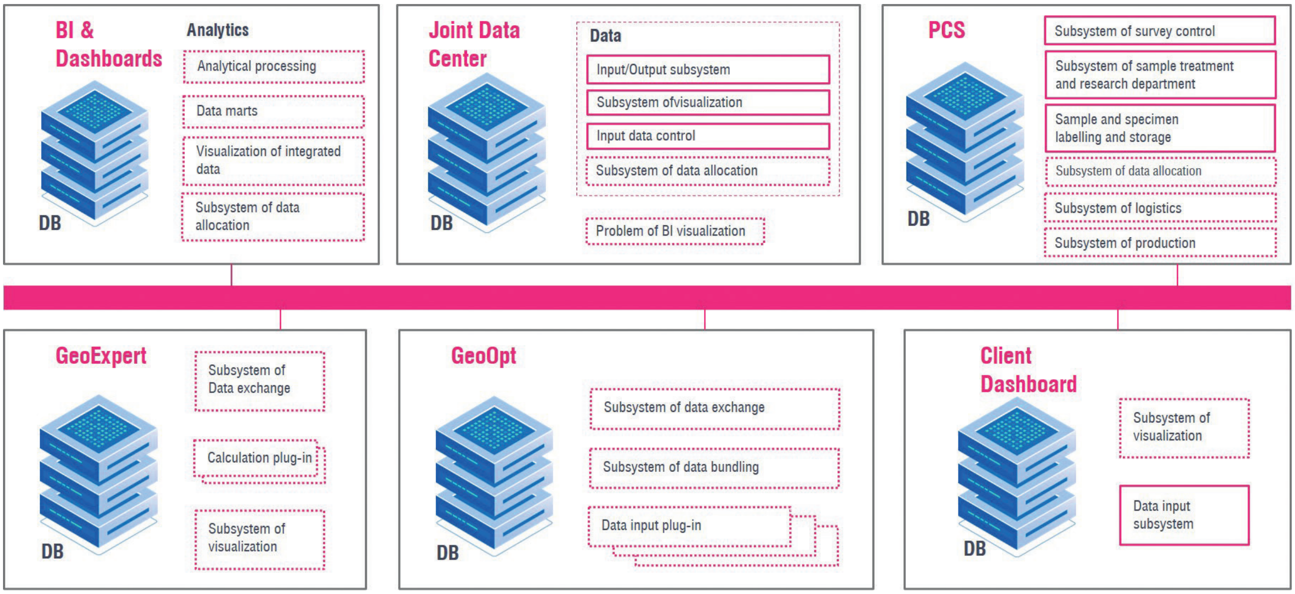

Figure 3 Digital platform architecture.

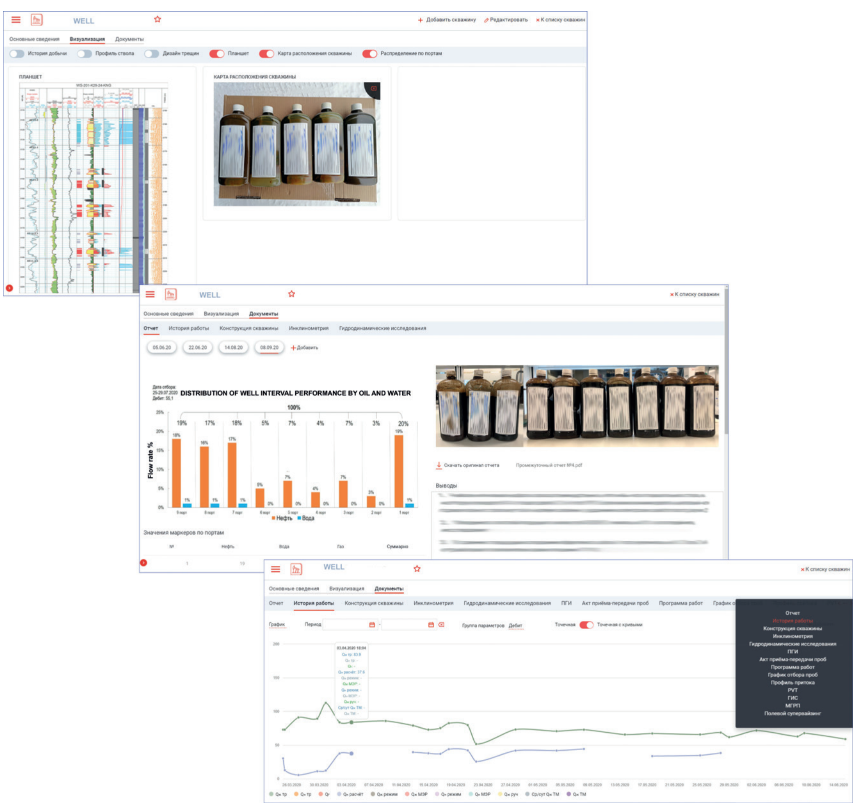

Figure 4 Visualization of the Joint Data Centre module.

The digital platform provides for structured storage of geological and engineering data and allows for the use of dynamic production logging data in stochastic and traditional geological and hydrodynamic modeling. It is worth noting that stochastic CRM models and traditional modelling used in the digital platform can be applied independently or in combination to the same field, offering an entire set of tools to address tasks arising in the process of field development. Figure 3 shows the architecture of the digitalplatform.

To date, all internal modules — BI, JDC, and PMS — have been put into commercial operation. The Client Dashboard, GeoExpert, and GeoOpt modules are being tested.

The Joint Data Centre module is designed for convenient hierarchical storage of the well documentation, the well's technical parameters and characteristics, as well as for input of initial data, their visualization, and preparation of reports. The system provides a platform for further development of the information and analytical reporting complex. In addition to automating input, storage, consistency checking, and field data visualization, it can generate machine-readable data to be further transmitted both to other modules within the digital platform itself, and to other information systems. The JDC helps to manage the data storage lifecycle and reference information, forms documentation hierarchy, and is a source of data for other systems.

The Client Dashboard module is a system that provides external users with data on well logging projects. The module is designed to provide the external user with detailed information in an online mode and properly structure the final data. This module helps users access information about the fields under study, states and statuses, as well as reporting materials and data visualization tools.

The data sources are Project Management Systems (PMS) and the Joint Data Center (JDC). Once data is collected, BI processes and supplements it, and then creates data marts to further transform it and generate 2D and 3D graphs.

The Project Management System module is designed for managing information on well logging projects carried out. This module is used by the company's personnel. The system can be utilized to ensure transparent project execution, in particular, surveying, planning, schedule development, and reporting on field operations, marking, and sampling with subsequent delivery of samples and their laboratory analysis. It also allows splitting the scope of works for managers, supervisors, and the laboratory, simultaneously keeping users updated on the current stages and statuses of all major process operations.

The GeoExpert-GeoOpt bundle is a hybrid model that uses a simplified reservoir physical model and a machine learning algorithm configured to make the results predicted by the physical model more precise. The physical model is the capacity resistance model (CRM or material balance), and the machine learning model is based on the Random Forest and more advanced Long Short-Term Memory (LSTM) algorithms that are tooled for learning from the classification, processing, and forecasting of statistical data on the well-reservoir system parameters collected at different points in time. Machine learning algorithms analyse big data on the development of various fields, reveal hidden correlations between different parameters of the field being developed (for example, mutual effects of well spacing, the current reservoir pressure in a particular well, and the skin factor), and use these correlations to estimate hydraulic conductivity between the injection and production wells. These correlations are to a large extent true also for new fields where development is only about to commence. Below is the high-level description of the software algorithm:

1. Efficient processing and evaluation of large arrays of actual downhole data for dynamic production profiling surveillance (in fact, it is chemical logging with high-frequency surveys).
2. Automated generation of hypotheses for interpreting a particular profile.
3. Hypothesis testing with the use of various modules that apply different 'datasets' containing direct and indirect correlations between factors.
4. Identification of possible measures to enhance reservoir production in the range from 1 to 100 wells and preparation of feasibility studies.

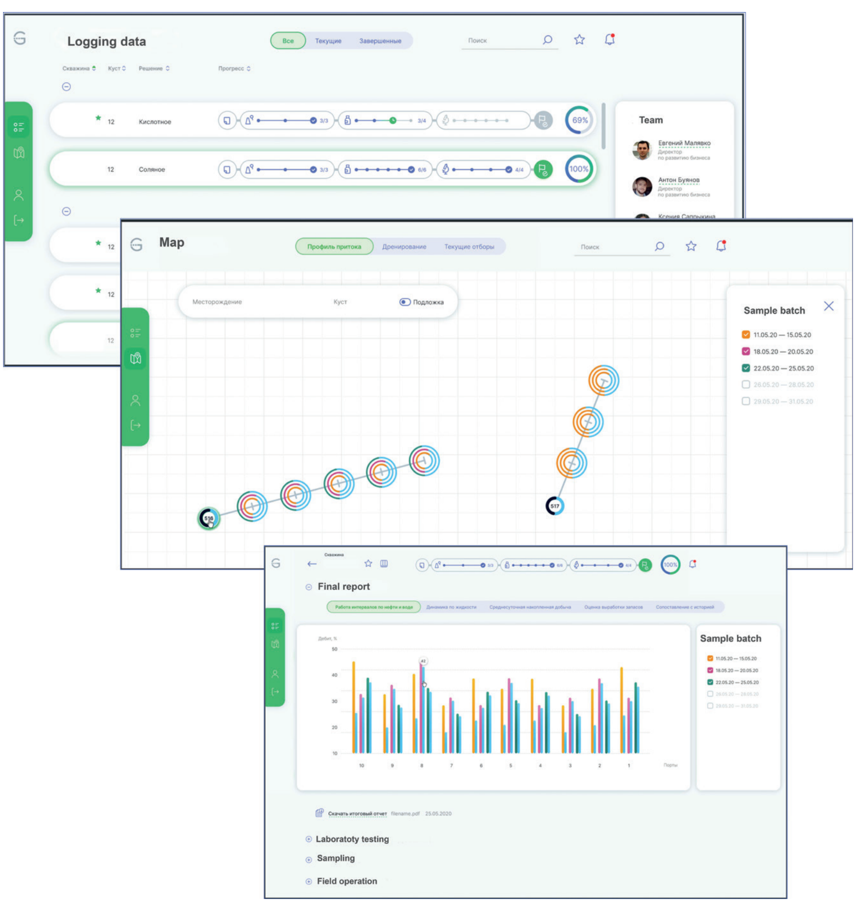

Figure 5 Visualization of the Client Dashboard module.

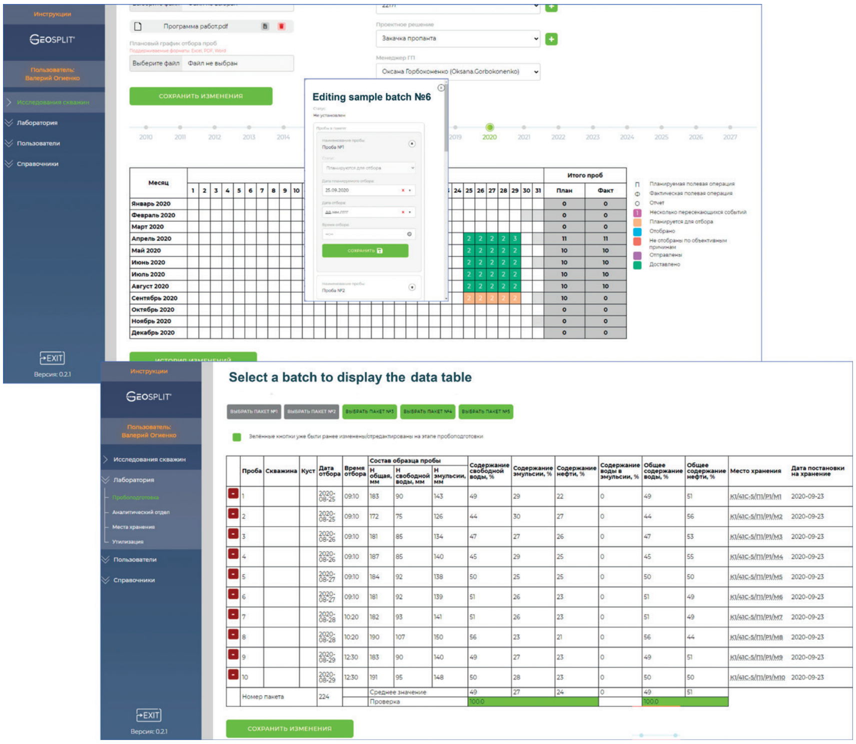

Figure 6 Visualization of the Project Management System module.

5. Prompt verification of proposed solutions in traditional 3D simulators using plug-in kits.
6. Implementation of recommendations and rerun of the cycle in order to maintain the results achieved to secure an efficient reservoir development process.

The digital field concepts are mainly designed to help improve the tools for real-time monitoring of the well stock, which, in turn, would facilitate efforts to provide better solutions to a number of applied tasks in the field development management, from optimizing the reservoir pressure maintenance system to identifying self-induced fractures that often require evaluating the hydrodynamic interconnection between wells. Hydrodynamic simulators used to estimate the necessary parameters are very time- and compute-intensive, unlike semi-analytical models that enable relatively quick calculations.

Due to the relative simplicity of the CRM model, physical and engineering parameters of the reservoir fluids' inflow to wells can be evaluated using a minimum computing capacity and a small amount of initial data (fluid flow rate, bottom-hole pressure, injection well injectivity, well coordinates, and reservoir porosity and permeability). On the other hand, the models have significant limitations in application, making it difficult to use them when dealing with real data, especially without regard to the specifics of field development with horizontal production and injection wells.

This platform provides the licence holder with all the necessary data in a digital format along with a user-friendly interface to work with these data. In addition, apart from significantly reducing time for experts to provide recommendations based on well studies, it can also greatly improve the quality of decisions made, and, consequently, make the production and field development more efficient.

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