Design and monitoring of oil and gas industry facilities based on the use of ultra-light aviation and digital technologies

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Abstract. The current stage in the development of the information support of the oil and gas complex is characterized by the transition from corporate information and reference geographic information systems (GIS) to the development and creation of automated information-analytical and information-management systems. Traditional GIS – technologies provide optimal organization and comfortable access to databases of geographically distributed information. The new generation of GIS is designed, in addition to providing information and reference functions, to solve a set of tasks for managing complex multi-level geotechnical systems (GTS) of oil and gas condensate fields for the purpose of rational nature management and sustainable development of natural and man-made GTS.

1. Introduction

The first stage of creating a new generation of GIS was carried out in the course of joint experimental and production work of Okrkomzem (Khanty-Mansi Autonomous Region) and the Department of APS of the Gubkin Russian State University of Oil and Gas at the Petelinsky oil field of Oil and Gas Production Department “Yuganskneftegaz”.

The following basic provisions have been adopted as a conceptual basis for creating information management GIS:

Performance of work on monitoring the field on the basis of fundamentally new technologies providing reliability, detail and relevance of the source information. The implementation of this provision in practice was carried out through the use of the local remote monitoring system “Biosphere TM” located on board the motor-hang glider (figure 1).

The feasibility of using Ultralight monitoring is due to the following.

Ultralight aircraft (UA) can be delivered directly to the object of remote sensing using land transport.

This allows to provide significant savings in flight time spent in the case of the use of high-altitude aircraft on approach to the object of interest. In some cases, when solving environmental monitoring tasks in remote areas of Western Siberia (remote from the locations of civil aviation) these unproductive costs account to 40%.

The ability to take off and land UL on any solid surface (field, meadow, dirt road) allows to select a basing place within the area of interest, and therefore take advantage of the optimal weather conditions at the local shooting-flight operations (SFO) site, which is set even for a minor period of time.
A lower cruising speed (up to 70 km / h) and a wide range of heights (from 100 m. to 3-4 km.) Make it possible to eliminate image blur when performing SFO at extremely low altitudes, which is especially important when collecting remote information for solving problems on the large-scale topographic mapping on a scale of 1: 500 to 1:10 000.

When performing SFO fuel consumption per 100 sq. km. of the shooting area is not more than 30 liters of AI-93 gasoline for an engine of type 2706Р05 (HIRT) and ROTAX 447. Flight operations are carried out by a team of 3 people. The costs of approaching the the area of interest are excluded.

All stated above made it possible to reduce the unit cost of aerial photography materials obtained with the use of UL by 3.5–4 times compared with traditional methods used in aerial photography on the areas up to 100 sq. Km.

Basing of the UA in close proximity to the object of shooting allows to organize synchronous ground surveys and contact measurements. In this case, the selection of reference objects is carried out according to the television broadcast, the operational viewing of which is carried out during field work. With the large-scale thematic mapping (geological, engineering-geological, soil-geobotanical, environmental, etc.), this technique provides an increase in the reliability of the output data and a significant reduction in the cost of performing field work.

Currently, the department of APS of the I.M. Gubkin Russian State University of Oil and Gas, together with organizations of the Russian Academy of Sciences, is working on the issue of deploying compact geophysical monitoring equipment on board of the UA apparatus to perform gravimetric, magnetometric, microwave radiometric, and thermal imaging works in order to ensure additional exploration of hydrocarbon deposits. Such work will be carried out synchronously with the well-established methods of remote sensing. This will allow already at the stage of research to obtain materials suitable for industrial implementation. Currently, at the Department of Automation and Design of Oil and Gas Industry Facilities (ADF) of the Russian State University of Oil and Gas, a basic course of disciplines has been developed and put into practice in the educational process, revealing the methods and technology for designing and monitoring the facilities of the oil and gas industry based on the use of ultralight aviation and GIS technologies.

With its own take-off weight of 120-140 kg., the payload mass is 220-240 kg (in aviation, analogues of the above parameters are unknown). This allows to place onboard the UA apparatus, in addition to the pilot, synchronously operating topographic aerial camera, digital video camera, satellite navigation equipment, a complex of geophysical equipment (thermal imager, microwave radiometer, etc.). Thus, with an unprecedented low cost of operation, it becomes possible to increase the armament of the remote sensing system at the level of airplane laboratories such as TU-134SH, AN-30.
As the conceptual basis for the functioning of the local monitoring system, the first particular-to-general approach to remote sensing practice has been adopted. The essence of the new approach is to compile reliable and extremely accurate information on the geotechnical system of the field as a whole based on summing up data on its fundamentally important fragments obtained at the local level. Ultra-low altitudes (150-300 meters) inaccessible for traditionally used aircrafts and cruising remote sensing speeds (50-60 km/h) made it possible to obtain source information that is extremely informative in terms of spectral, calorimetric and frequency-spatial characteristics at the local level, not only in optical, but also in the near infrared and thermal ranges (figure 2).

The second equally important task is being solved. Fragmented (local) monitoring of the most disturbed elements of the biosphere within the holistic geotechnical systems of an oil field eliminates unproductive expenses for a total "scan" of the entire licensed field in which up to 80% of aerial survey materials are dumped. The most important advantage of using UA in this case is the opportunity for local specialists (customers) to participate in planning flight operations directly at the monitoring object. The operational control of the flight-shooting process, based on the functional tasks of monitoring, the adjustment of the parameters of flight operations depending on changing weather conditions, the dynamics of the spectral and calorimetric characteristics of remote sensing objects, the illumination, and the optical and physical properties of the landscape, increase the effectiveness of the entire monitoring program as a whole.

2. Materials and methods
The technology for creating information-analytical and control GIS developed and implemented by the Department of APS of the Russian State University of Oil and Gas is based on a set of input information that includes the following blocks.

Topographic map with applied information depicting the infrastructure of the field in conventional designations adopted by surveying services of the fields, updated according to the data from remote sensing and ground-based topographic and geodetic works performed using GPS technologies. This data, obtained using the MapInfo software, are essentially the basis for compiling GIS and applying thematic loads of special electronic maps (figure 3).

The landscape base, created according to comprehensive research in accordance with the original methodology developed by the Department of APS of the Russian State University of Oil and Gas on the example of a number of deposits in the middle Ob' region.

Technical parameters of the oil gathering and water pumping network (Parameters of oil pipelines and water pipelines for operating areas: diameter, wall thickness, length, year of commissioning, GOST of the pipe, steel grade of the pipe, type of pipeline insulation, pipeline laying depth (m),

Figure 2. Thermal image of the oil spill.
Pumping parameters (Q liquid. cbm / day; Q oil cbm / day; P (beginning) atm; P (end) atm; % watering.)

![Figure 3. Integrated topographic map.](image)

Information-analytical and control GIS are based on special blocks of input data, which are formed depending on the assigned functional task. For example, when determining the causes and factors of emergencies, the following auxiliary data arrays are formed on the oil gathering network:

- Graphical materials and statistical data confirming the correlation relationships identified during a comprehensive interpretation of geological and structural data and oil spill parameters;
- Data on the dynamics of the largest oil spills, obtained according to the results of vectorization and quantitative assessment of local monitoring materials;
- Data from the field’s operational service on emergency situations during the observation period (date of registration of the accident, place of accident, pipe diameter, oil area, spill volume, estimated cause of the spill, liquidation measure);
- Data on injectivity of water pumping wells (No. of wellhead and well bore, pressure at the exit in atmospheres, injectivity in cubic meters / day) for available test wells.
- Parameters of the oil reservoir (roof topography, productivity, the ratio of water and oil in the pumped liquid, etc.);
- The planned position and characteristics of oil wells (productivity, depth of the ESP descent, % water, N din., Q fluid / Qn.)

The entire thematic database is formed in the MapInfo software in the form of attribute tables and auxiliary cartograms. For individual parameters, in order to facilitate analysis and better visual perception of data, the VoxelAnalyst software product is used, which allows constructing a block diagram of an oil reservoir in a three-dimensional coordinate system with highlighted productivity, obtaining the topography of the formation in isogyps, and performing statistical data processing.

The most important condition for the effective functioning of the information-analytical GIS is the correctly structured hierarchical structure of the queries in the MapInfo software that strictly corresponds to the list of functional tasks and monitoring objects formulated at the initial stage of the study together with the basic services of NGDU and TsDNG. A comprehensive analysis of intermediate cartographic information and the results of processing statistical data ensures the creation of a new generation of GIS at the final stage.

In relation to the considered example, in the process of creating the GIS, a formula was developed for calculating the accident rate of the oil gathering (water pumping) network.

The basic statement that determines the information-analytical and control functions of GIS is a logically based structure of the output data, to which the concept of a new generation of GIS is subordinate. The algorithm for its construction is determined by the following sequence of performing map-making works:
Updating the topographic (landscape) basis; inventory of geotechnical systems and infrastructure facilities of the field; analysis of the dynamics of monitoring objects; forecast of the development of geotechnical systems; development of measures for rational nature management and sustainable development of the territory of oil and gas development.

3. Results
In accordance with the above scheme, the list of electronic maps most fully displaying (but not limiting) the analytical capabilities of a GIS includes the following items:

Electronic maps of the inventory of geotechnical systems on the territory of the Petelinsky oil field on a scale of 1: 25 000 on an orthophoto basis with vector loading and explication.

A set of electronic maps designed to develop scientifically based recommendations for the sustainable development and protection of lands of the natural and anthropogenic complex of the oil field, consisting of:

- a map of the geoeological state of natural and anthropogenic geosystems of the oil field based on landscape and soil data;
- a map of the dynamics of the development of anthropogenic load and the landscape with the allocation of zones of stressful environmental conditions;
- a forecast map for the development of a natural-anthropogenic geosystem of the field;
- a map of environmental management and sustainable development of the field.

Large-scale electronic cartograms (1:2,000 scale) of monitoring objects (cluster sites, oil pump stations, pump stations, communication corridors, as well as oil spills in places of emergency condition of the oil gathering network, sludge pits and cluster sites) obtained in electronic form according to local monitoring and ground surveys for 2006 and 2008 with explications.

The thematic maps mentioned above were obtained in electronic form and were analyzed using the MicroStation and MapInfo software package. In this case, sections of the stress state of pipelines in areas of deformation development were identified, associated with the dynamics of the cryosphere and the influence of neotectonic disjunctive disturbances. Areas of increased danger for laying pipelines, as well as the placement of cluster and drilling sites, have been identified. Areas of development of dangerous exogenous geological processes that are actively developing in the course of increasing anthropogenic loads on the landscape are identified.

Of practical interest are the fundamentally new search criteria for indicating previously unknown sections of oil and gas areas within remote and hard to reach areas of Western Siberia. These criteria are developed on the basis of geological and structural analysis of a complex of information materials obtained at the local level using the monitoring system “Biosphere TM”.

Currently, due to the increase in investment activity of large oil companies, a program has been developed for applying the Biosphere TM local monitoring system to provide an environmental audit and examination of the technical condition of oil and gas facilities, as well as geological and searching works at the Khanty - Mansy and Yamalo-Nenets Autonomous Districts oil and gas condensate fields. The experience gained with minor refinement can be applied in the transition from UA to unmanned aerial vehicles (UAVs) (civil multicopter).

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