

Aerospace Monitoring of Geotechnical Systems to Ensure Environmental Safety of Energy Transportation Through Trunk Pipelines, Based on Gis Technologies .

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ABSTRACT

Improvement of diagnostics systems and application of new information technologies based on high-resolution space imagery decoding play an important role in ensuring safe operation of trunk pipelines for energy transportation. This paper analyses various methods of space imagery to solve the tasks of diagnostics of trunk oil and gas pipelines in order to assess their condition and timely detection of potentially hazardous areas.

Keywords: monitoring, geotechnical, systems, ensure, environmental, safety, energy transportation

INTRODUCTION

Improvement of observation equipment installed on remote sensing satellites, development of digital technologies, emergence of high and ultra-high spatial resolution space images of metre and sub-metre ranges allows solving problems not only for detection and classification of objects, but also for assessment and forecasting of their condition. [1]

Today high spatial resolution space images are available from Ikonos-2 (resolution up to 0.82 m), QuickBird-2 (resolution up to 0.61 m), Worldview satellites with spatial resolution up to 0.47 m, with extended spectral range by adding new spectral channels (423-453nm; 590-640nm; 700-730nm, 900-1500nm).

In diagnostics of objects of geotechnical systems the most promising is the method combining ground-based complex diagnostics with space diagnostics.

METHODOLOGY AND METHODS

According to the spatial resolution OSA and BHRC-60 sensors can be used to solve many problems of geotechnical diagnostics, in particular, to identify such objects as main pipelines (MP), communication routes, natural and anthropogenic disturbances, which are potential sources of MP defects. The disadvantages of these sensors are the narrow spectral range (0.45-0.90 μm .), which makes it difficult to search and identify objects of geotechnical systems, especially if it concerns underground objects. In comparison with them, the ETM + sensor is more efficient in its spectral characteristics, and the presence of red channels, for example, thermal, allows to improve the process of recognising objects in space images. However, due to low spatial resolution, the use of ETM+ sensor is relevant for large-scale projects, for example, in the tasks of assessing the condition of main oil and gas pipelines. [2-3] When conducting aerospace monitoring of natural and engineering objects recognisable within the technical corridor of MT laying, aerial and space imagery materials of mainly visible and infrared ranges are used as initial data. Processing of aerospace data includes the following stages :

-technical processing of imagery materials

- image interpretation;

-analytical processing of interpretation results.

RESULTS AND DISCUSSION

Opportunities of space diagnostics of geotechnical system objects using high and ultra-high spatial resolution sensors include:

Determination of the route for laying the main pipelines.

When solving this problem on the basis of space images received from Ikonos-2 and Quick Bird-2 systems it turned out that the most informative are red channel No.3 and near infrared channel No.4. The use of these spectral channels makes it possible to identify open areas of the MT and clearly detect the route of underground pipelines (Figure.1).



Figure.1 Determination of the trunk pipeline laying route based on sensor data from Ikonos-2 and Quick Bird-2 space systems.

The upper image fragment (Figure.1) shows a trace of the underground section of the MT route in the red channel No.3, while the lower fragments show open sections of the MT in the near infrared channel. [4]

When carrying out diagnostics on high spectral resolution space images of the MT condition, it is necessary to classify not only the object itself, but also the elements of its environment, which allows to give a full assessment of the technological condition of the investigated object.

All objects of the Geotechnical System can be divided into two groups. The first group includes objects of artificial origin: various types of main pipelines, reservoirs of different shapes and purposes, bridges, power lines, infrastructure elements, as well as other industrial objects. The second group includes objects of natural origin located within the technical corridor of the ML laying, first of all, relief, rivers, open ground, vegetation cover.

Interpretation of raw data from OSA and BHRC-60 sensors of Ikonos-2 and Quick Bird-2 space systems has shown that the best results in recognising industrial objects located within the MT laying route can be achieved in the range of 0.6-0.9 μm .

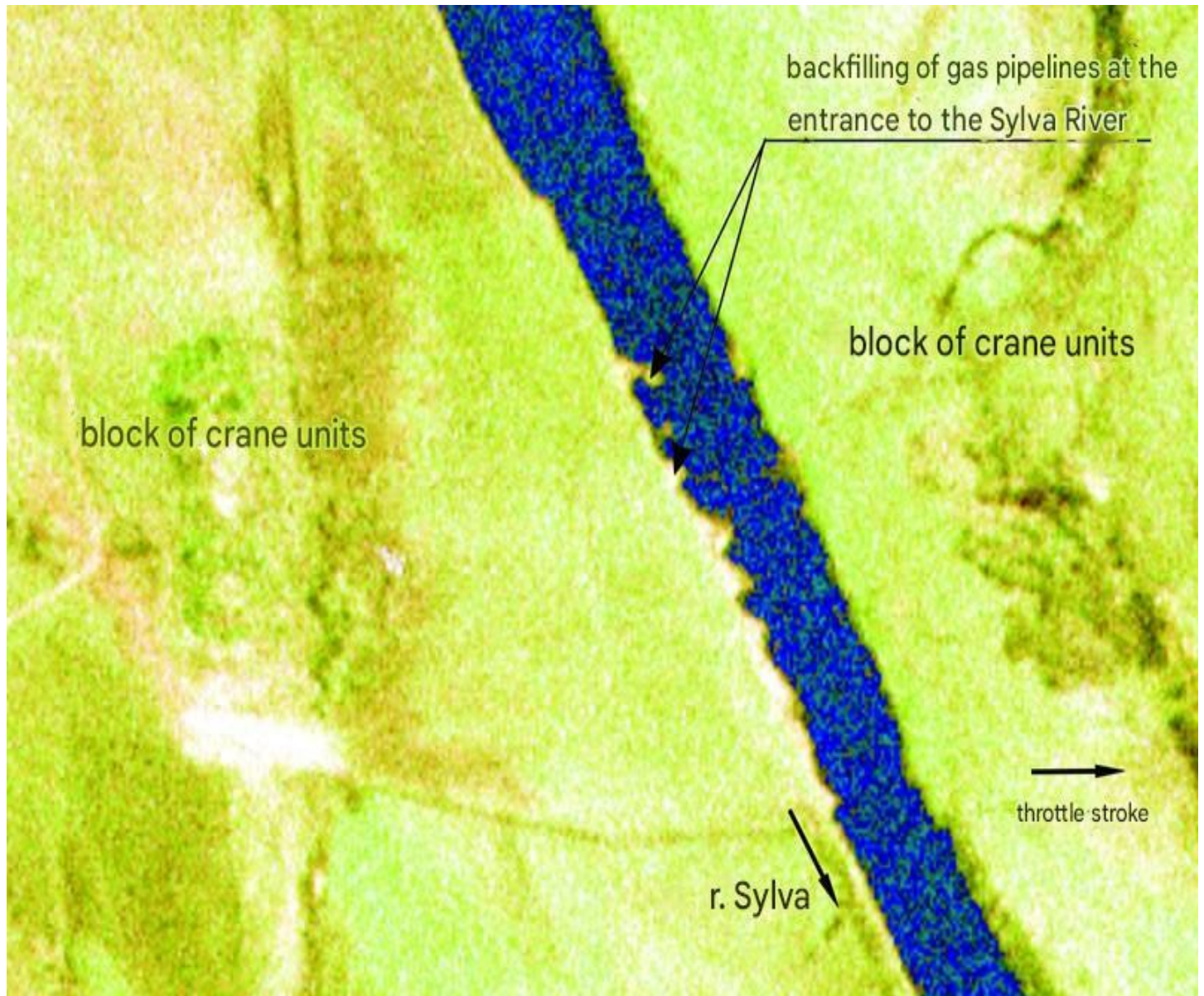


Figure. 2 Industrial elements at the underwater crossing of the gas pipelines across the river

Figure.2 shows the identified industrial elements at the underwater river crossing of the main pipeline. KFA-1000 sensor data obtained from the Resurs F1-M space system was used. Pipeline entry points into the water, blocks of crane units and other objects are easily deciphered.

Modern methods of space diagnostics also make it possible to assess the moisture content of open soils in the area of the MT laying route, evaluate the impact of groundwater, surface water, as well as the displacement of the investigated object caused by gravitational and other forces.

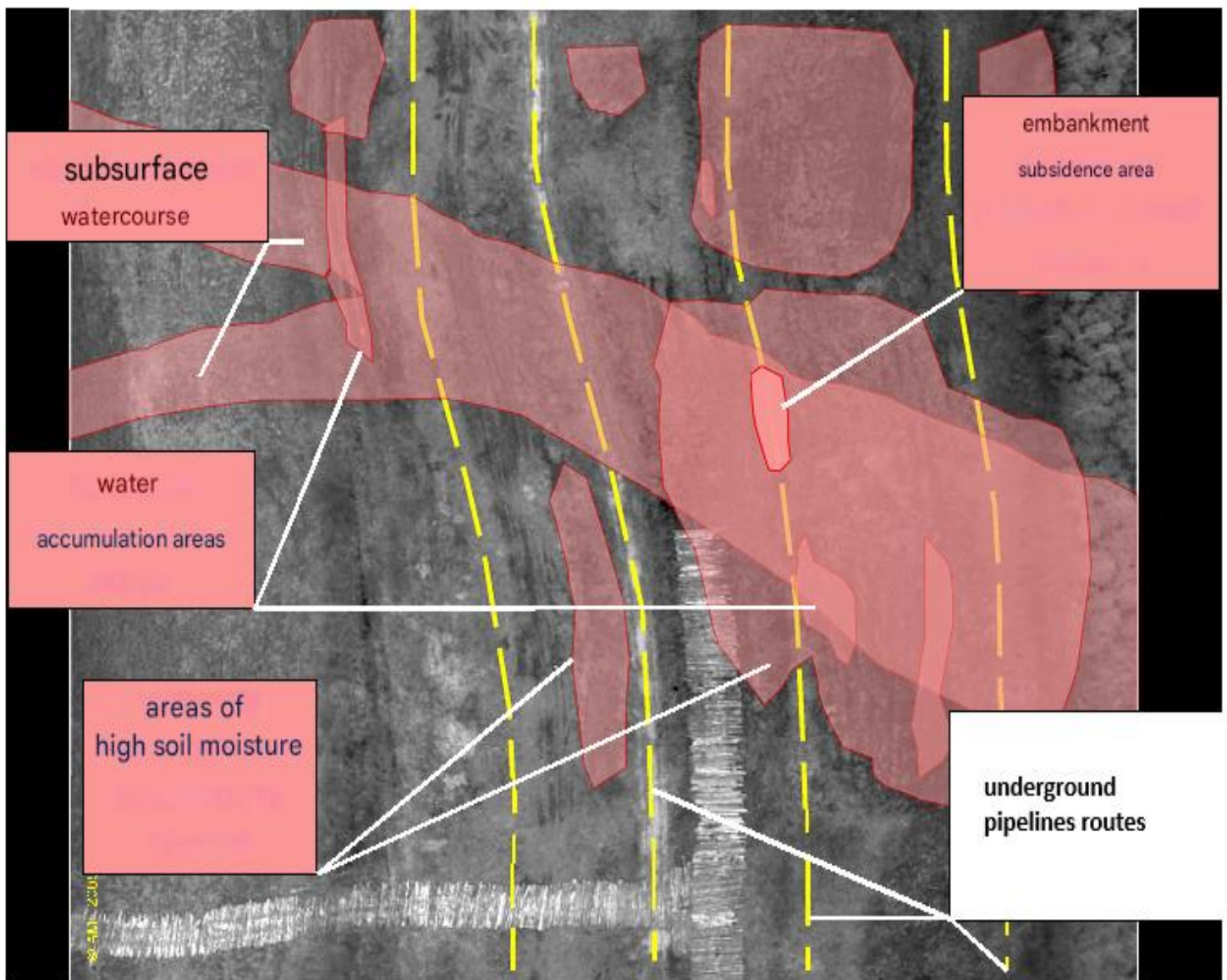


Figure.3 A result of interpretation of the fragment of the image of the main gas pipeline

In Figure.3, as a result of interpretation of the fragment of the image of the main gas pipeline received from the Ikonos-2 satellite, it was possible to identify:

- subsoil flow;
- several areas of water accumulation;
- areas with increased soil moisture, as well as to determine their actual location relative to the routes of the four gas pipeline strings.

As another example, let us consider the results of the work on the assessment of soil moisture around the technical corridor of the main pipeline laying based on the data received from the QuickBird-2 space system. [5-6] The comparative analysis of the informativity of the space image spectral channels showed that the wet soil areas and the boundaries between dry and wet soil are best displayed in the green spectral channel (0.52-0.61 μm). During processing in the ERDASIMAGINE software environment, the original image was classified to identify areas with vegetation cover as well as dry open and wet soil areas without vegetation cover. Eventually, after processing the space image, a thematic map with the following information layers was obtained: open water surface; dense vegetation cover; dry sandy surface; dry soil; wet soil; (Figure.4).



Figure 4. Thematic map of soil moisture assessment around the gas pipeline installation.

As a result, areas of high moisture hazard and areas covered with dense vegetation were identified, which may serve as an indicator of the presence of water. Based on the results of soil moisture assessment in the MT laying corridor, the places where the gas pipeline crosses the areas of high humidity were identified [7]

If space images of the investigated territory are available for different periods of time, it is possible to obtain data on changes in soil humidity, and the results obtained allow assessing the dynamics of waterlogging of the territory and forecasting the trend of further changes in soil humidity.

An important problem is to analyse the relief of the territory of the diagnosed object location. Assessment of the relief of the territory allows to determine the mutual location of objects, to estimate their interrelation and to analyse the influence of the relief height on the object of diagnostics. Modern GIS technologies allow to obtain 3D models with specified accuracy for space diagnostics. When creating a modern 3D model of the investigated object, it is necessary to jointly use technologies of processing of remote sensing data, GIS-technologies, 3D design and visualisation technologies. The information basis for 3D model design is shown in Figure.5 . Here you can clearly see a fragment of DEM of the territory adjacent to the technical corridor of the main pipeline laying with superimposed space image from QuickBird satellite. [8]



Figure.5 The information basis for 3D model design

Spatial resolution of modern ultra-high-resolution sensors allows not only to detect objects of geotechnical system, but also to assess their external condition. By analysing the information of OSA, BHRC-60 and KBP-100 sensors it is possible to detect the violation of the external coating of pipelines, change and violation of the shape or integrity of the surrounding MT walls, change of the geometry and shape of spherical and cylindrical tanks, etc. Earlier we have noted that the main purpose of the method of geotechnical diagnostics of ML using space multispectral images of ultra-high spatial resolution is to identify potentially hazardous areas on the route of its laying. Such potentially hazardous areas may be, for example, areas of the territory subject to water accumulation. In such areas high corrosive activity of soils is possible, which may lead to further development of MT defects. Besides, systematisation and integration of all data obtained during interpretation and analytical processing of space images allows to identify areas of origin of the ML route under roads, under railway tracks, areas of pipeline bends caused by geodynamic processes, etc. Relief analyses are also a source of information on hazardous areas. Figures 6 and 7 show examples of diagnosing potentially hazardous areas requiring continuous aerospace monitoring.



Figure.6 Examples of diagnosing potentially hazardous areas



Figure.7 Examples of diagnosing potentially hazardous areas

Reliability of the results of geotechnical diagnostics of potentially hazardous areas of the technical corridor of the MT installation based on space images of high spatial resolution was checked by comparison with the ground diagnostics data. [9-10] In the selected MT laying area defects were detected in 4 out of 5 sections identified by space diagnostics.

CONCLUSION

The technology of space diagnostics of the state of objects of geotechnical systems allows to significantly improve the characteristics of the complex diagnostics system due to the use of a number of advantages, such as:

- informativeness (due to taking into account the negative impact of natural and man-made factors and prediction of the technical state of objects).
- efficiency (due to the high speed of information processing);
- visibility provided by a large swath of space imagery;
- the ability to provide information in the form of electronic thematic maps with coordinate reference.

However, it should be noted that some problems of aerospace diagnostics of geotechnical objects remain unsolved. First of all, the limited spectral ranges of the applied sensors should be mentioned here, which significantly reduces the possibility of interpretation of objects of geotechnical systems (in particular, underground sections of main oil and gas pipelines).

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