Observation and photographing of the Earth's surface during the flight of the Voskhod three-seater manned spacecraft on October 12–13, 1964

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Abstract. Today, orbital-based optical means of observing the Earth's surface is an important element of space technical devices. They went through almost 60-years-long history of development. The history of remote sensing is inextricably linked with the evolution of onboard photographic equipment of manned spacecraft. Observation and photographing of the Earth's surface were part of the flight program of the first Soviet spacecraft of the Vostok series. These studies were continued during the flight of the Voskhod-1 manned spacecraft (October 12–13, 1964). The 24-hours flight of a three-seater spacecraft was an important stage for the formation of approaches to the research program onboard manned spacecraft. The task of this scientific and historical research was to determine the mission contribution to the development of methods and means of remote sensing of the Earth's surface. The article describes the main technical means for fulfilling the tasks of surveying and photographing the Earth's surface during the flight of the Voskhod spacecraft, the methods of their use in flight; an assessment of the achievement of the objectives of the flight program; the main results and conclusions based on the analysis of space photographs are presented. On the basis of historical material, a conclusion was drawn on the novelty of the information obtained in the conditions of the formation of Soviet cosmonautics and on the significance of the flight results of the Voskhod spacecraft in the development of onboard facility and methods for remote sensing of the Earth from space.

1. Introduction

The history of the use of photographic equipment of manned spacecraft for observation and photographing of the Earth's surface is linked with the history of the optical remote sensing development and stages of space technology evolution. A number of authors devoted their works to the study of formation and development of the space-based remote sensing systems [1–3].

On October 12, 1964 a three-seater manned spacecraft Voskhod-1 was launched into the orbit around the Earth by a three-stage rocket 11A57 (based on R-7A). The crew of three people was on board the spacecraft for the first time in the human history. It consisted of a Command Pilot Vladimir Komarov, and two crewmembers, an Engineer Konstantin Feoktistov and a Medical Doctor Boris Yegorov [4].

Voskhod-1 was launched to the orbit close to the calculated one with a period of revolution of 90,1 minutes around the Earth [4]. The mission program was formed taking into account the existing
theoretical concepts and the results of photographic studies during previous flights of the Vostok-5 and Vostok-6 spaceships [5].

During the flight, the crew performed a significant amount of scientific experiments, observations of the Earth's surface, its atmosphere and near-Earth outer space. An increase in the crew of the spacecraft up to three people allowed significantly expanding the program of observations of the atmosphere and surface of the Earth. At the same time, the engineers had to reconsider the composition of the airborne equipment due to an increase in the number of the crew members and minor changes in volume of the capsule. Distinctive feature of the flight was fundamentally a new approach to the composition of the registration equipment.

2. Materials and methods
The research contains materials from the archives of the Gagarin Cosmonaut Training Center, as well as publications and results of previous studies conducted on this topic [3, 6]. The basis of the research is the historic method, which discribes a phenomenon (process) in its development: nucleation, formation and extinction. Historicism as a research tool for understanding the past, present and future involves searching for a root causes of all current phenomena in the past and predicting a future phenomena based on what is happening. In this way, continuity is established between eras, each of which must be evaluated in terms of its historical features and capabilities.

3. Results and Discussion
Among the tasks of a three-seater spacecraft flight was observing and photographing the surface of the Earth. The tasks of the flight determined the basic requirements for the equipment for research, including: high angular resolution; the ability to shoot in various directions; shooting speed; sufficient angular dimensions of the field of view; precise fixation of the moment and direction of shooting; recording auxiliary situation data. During flights of the Vostok series space ships, the KSR-1 movie camera was the main equipment for recording visual information [6]. However, the dimensions of the KSR-1 camera were unacceptably large to work with it in the capsule of the spacecraft, where it was planned to accommodate three crewmembers. In addition, KSR-1 could not obtain images of the Earth's surface with the necessary optical resolution for image analysis.

On the spacecraft Voskhod-1, the shooting was made with a still camera and a movie camera (Figure 1). The use of a camera ensured recording of the exposure time, which is important for the photometric analysis of the results. The movie camera was intended for scientific and chronicle surveys inside the spacecraft and through the porthole. They fully met the requirements for Voskhod-1 on-board equipment.

![Figure 1. Voskhod-1 spacecraft onboard equipment for shooting: a – the Leningrad still camera, the high-aperture Jupiter-6 lens; b – the 16-mm camera Kiev 16S-2.](image)

The Leningrad still camera was the main on-board tool for shooting during space flight (Figure 1, a). The camera was developed in 1953 at the State Optical and Mechanical Plant, the Leningrad city. It was mass-produced in 1956–1966. The camera had no analogues in the world by its design features. It was one of the few completely original developments of Soviet instrumentation. The main feature of...
the camera was the presence of a winding spring mechanism, which allowed automatic shooting of up to 15 frames. It had a manual focusing and a convenient direct optical viewfinder combined with a rangefinder in one field [6].

The camera had a replaceable high-aperture lens Jupiter-6 (Figure 1, a). The lens had been produced by the Mechanical Plant in the Krasnogorsk city since 1958. The lens had: focal length (F) – 180 mm; the limits of the aperture scale are f/2.8–f/22; field of view angle – 14 °; short focus limit – 2 m; weight – 1500 g [7,8].

The 16-mm format movie camera Kiev 16S-2 was also a part of the onboard equipment for recording fast phenomena (Figure 1, b). The camera was mass-produced by the G. Petrovsky Plant for Automation in the Kiev city from 1957 to 1966.

The camera was the first USSR model of narrow-film cinema devices designed for shooting documentary, scientific and expeditionary films. It used 16-mm film with two-sided perforation. The camera had two different lenses, 12.5-mm focal length lens and 50-mm focal length lens Industar-50 are located on a rotary turret, where two objective lenses are also mounted. The camera was equipped with a spring drive, the full spring mechanism of which provides a broach of 3.5–4.4 m of film. To shoot one cartridge, it was required to cock the drive spring 3 to 5 times. The shooting was carried out with a frequency of 16, 24, 32, 48 and 64 fps, as well as in the single-frame shooting mode. Exposure parameters were setting manually by a cosmonaut. Charging cassettes had a capacity of up to 15 m of film. The dimensions of the movie camera are 215 × 130 × 65 mm, weight – 1700 g [9].

Cosmonauts V. Komarov, K. Feoktistov, B. Egorov were trained for the flight at the Cosmonaut Training Center. All crew members had a good theoretical knowledge of cinema, photo equipment and stable cameraman skills (Figure 2).

![Figure 2](image)

Figure 2. Voskhod-1 crew training (1964): a – cosmonauts V. Komarov, K. Feoktistov in the classroom for photo training; b – crew in the Voskhod spaceship simulator; c – cosmonaut K. Feoktistov is working with a 16-mm movie camera Kiev 16S-2 in open area

Photography during the Voskhod-1 flight was made from an orbit 330–342 km high. The orientation of the optical axis of the camera in space at the time of shooting was not recorded. Photographing was carried out on a marked black-and-white film without a light filter at f/22 aperture and 1/500 shutter speed. The astronauts used a special shooting mode: a series of 4–5 frames at intervals of 10–30 s between successive images. The moment of photographing the last image in the series was recorded to the minute [10].

The crew made observations of the terminator and visually made sure of the monotonicity of changes in the brightness of the Earth’s surface from the Sun illuminated to the night side. This was confirmed by photos taken during the flight. To obtain data on the spatial structure of clouds over various types of underlying surface, the Earth’s cloud cover was photographed. These data was necessary for optimizing the parameters of television systems of meteorological satellites, developing methods for automatic recognition of clouds from television images to study the physics and morphology of clouds.
Cloud cover photo shooting was made in areas where was no network of ground-based meteorological stations (the Atlantic Ocean west of southern Africa and the Pacific Ocean west of South America). This circumstance did not allow performing a detailed synoptic analysis of cloud maps constructed from photographs. The lack of accurate data about the time of photographing and the orientation of the optical axis of the camera at the time of shooting did not allow determining the geographical coordinates with an accuracy better than ± 1000 km. It made it impossible to calculate with sufficient accuracy the height of the sun in the survey areas and the illumination of photographed clouds. Some of the images were taken at large angles to the local vertical, which significantly complicated their analysis [10]. The possibility and promising nature of such observations for the study of cloud cover were established after analyzing space photographs (Figure 3, a).

The tasks assigned to the crew of the Voskhod-1 spacecraft included photographing various parts of the earth's surface containing plains, mountains, rivers, and some geological formations (Figure 3, b). The obtained images of the Earth's surface were supposed to be used to identify the possibility of their geographical and geological recognition (Figure 3, c).

The main goal of stereo photography was to obtain spatial data from the Earth's surface, and it was carried out aboard the Voskhod-1 spacecraft for the first time. Stereo pairs were made from the images, which depicted a cloud cover and a mountainous region. It was taken into account that the snapshots were taken by a non-photogrammetric device and experienced an enlargement after printing on paper. The images also had a large overlap (about 90 %) [10]. This reduced the accuracy of the results significantly. For these reasons, the measurement decryption work performed was evaluated as methodological, showing the possibility of stereoscopic measurements of images from outer space.

The orbital flight of the first in the history of astronautics a multi-seater spaceship lasted 24 hours 17 minutes and ended at 7:47 on October 13, 1964.

![Figure 3](image)

**Figure 3.** Examples of snapshots of the Earth’s surface and results of photo decryption: a – result of recognition of cloud cover picture; b – perspective shot of a mountain area, c – result of geological decryption of mountain area picture

The use of a new composition of the equipment made it possible to develop and implement an extensive program of in-depth studies based on cinema and photo equipment during the flight of the Voskhod-1 spacecraft. The use of camera and new methods for space shooting had become a promising step in the development of research on the Earth's surface from space. The results of the research carried out during the flight had a great scientific interest and made it possible to draw several new conclusions.
Geological decryption of images obtained from the board of the Voskhod spacecraft showed the possibility of using space photographs to study the geological structures of the Earth, which cannot be determined by aerial photography. Assessment of the possibility of space photographs recognition confirmed the assumption that they can be used to study various hard-to-reach areas of the Earth's surface.

4. Conclusion
The results of the program for executing the observation and photographing the Earth’s surface onboard the Voskhod-1 spacecraft were obtained by two ways: observation by cosmonauts with subsequent description; photographing and subsequent decoding of photographs. The main tool for photographing was the Leningrad still camera. Photographing on black-and-white film were used (without and with light filters). Color film was used as an additional research tool.

The analysis of the possibilities of geographic and geological interpretation of the Earth’s surface images obtained from Voskhod-1, as well as their stereophotogrammetric processing, made it possible to draw the following conclusions:

1. Outer space photographs cover a 50-100 times larger area than aerial photographs.
2. Space images of the Earth's surface made it possible to identify various geological structures that were unnoticed when conventional aerial photographs were used.
3. The use of ultra-small-scale images (of the order of 1:7000000–1:1000000) is of great importance for the compilation of geographical and geological maps.
4. A crucial advantage of space photographs is the ability to preliminarily observe various hard-to-reach areas.
5. The performed geological and geographical interpretation indicates that such images can be used to draw up preliminary schematic, geological and other maps, as well as for planning work, the contents of which will be specified on the terrain.
6. The stereophotographic measurements showed that it is possible to determine the relative sizes of individual objects on the Earth's surface with various types of recognition and a sufficient number of images.

The Voskhod-1 flight results and conclusions based on them became a platform for further scientific research programs aboard subsequent Soviet spacecraft and orbital stations.

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