SATELLITE SYSTEMS FOR SPACE RECONNAISSANCE

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All space states develop and refine satellite reconnaissance systems because of their significant priority over other methods of reconnaissance. In the paper are described the main priorities of the satellite systems for space reconnaissance. Definitions of some main terms are given such as: trace of field, field of view, military space systems and so on. Put forward is a classification of the space reconnaissance in dependence of observed objects and the characteristics of the obtained information. Discussed in details are the methods of obtaining information and the characteristics of the satellite systems for photoreconnaissance. The main characteristics of the photo systems in USA, Russia, and China are described.

Keywords: space, satellite systems, photoreconnaissance

1. MAIN DEFINITIONS AND CLASSIFICATIONS

The interest of mankind towards space dates back to the ancient times. The development of the astronautics as a leading field in the technical progress has began with the launch of the first artificial satellite in 1957. Politicians and military specialists have realized that the country which first succeeds to control the space will have strategic advantage over its potential opponents. Nowadays it is not possible to achieve informational superiority without space systems.

The space spreads outside the borders of the Earth atmosphere. For the military the space that is closely surrounding the Earth is of great importance. The space, according to its physical conditions is split into ground space (75-150 km), low space (150-2000 km), middle space (2000-50 000 km) and far space (50 000-930 000 km).

The artificial satellites of the Earth are space apparatuses that perform free flight on geocentric orbits. They are launched into space by rockets on given altitude, speed and direction. The active sector of motion varies from a couple of hundreds to two–three thousand kilometers. The speed of the aircraft at the moment of dispatch is equal to the first space speed (around 7.9 km/s) or exceeds that speed with no more than 1.4 times.

The curve formed from the under-the-satellite points of intersection with the earth is known as trace of flight of the satellite. The form of the trace of the orbital flight is measured by the incline of the orbit towards the equator (i), by its eccentricity (e) and by the period of orbiting of the satellite (T). The higher the incline and the height of the orbit, the wider is the observed ground territory.

When measured by satellites or other visual devices, the field of view on the ground is dependent on the height of the flight (see Figure 1).

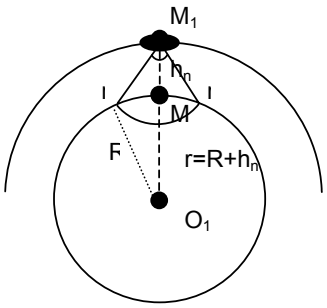

Fig. 1. Field of view on the surface of the Earth observed with Satellites.

Let us assume that in particular moment the satellite passes vertically over the observer who stays at point M and the height of the flight is h_n. It is possible to observe a field on the ground from the satellite limited by GG on the visible horizon. The angle of view γ on the surface could be calculated by solving the rectangular triangle M'GO_1. If we know both the radius of the Earth - R and the radius-vector of the satellite the angle of view of the Earth is measured by the formula:

$$\gamma = 2\arcsin\frac{R}{R+h_n} \qquad (1.1)$$

The field of view center is point M and its radius is the catenary $Z_0(grad) = \cup\Gamma M$, which measures the angle from the center of the Earth – point O_1.

Noting that:

$$Z_0(grad) + \frac{\gamma}{2} + 90^0 = 180^0 \quad \text{that leads us to } Z_0(grad) = 90^0 - \frac{\gamma}{2} \qquad (1.2)$$

The radius of the field of view in kilometers is defined by the following formula:

$$Z_0(km) = Z_0(grad).111{,}2 \qquad (1.3)$$

All space states develop and refine satellite reconnaissance systems because of their significant priority over other methods for reconnaissance. Only these systems can provide such a wide range of observed territory (aquatory) and extensive volume of information for any part of the Earth, regardless the weather conditions throughout day or night.

The information obtained by the satellite reconnaissance systems provides possibilities to solve a number of problems. Some of the global ones include: collecting strategic reconnaissance information regarding regions and countries, control of events of disarmament; monitoring the progress of crisis situations in different regions in the world and assessment of the consequences of military interventions.

According to the types of the observed objects and the character of obtained information the space reconnaissance could be classified as follows (see Fig.2):

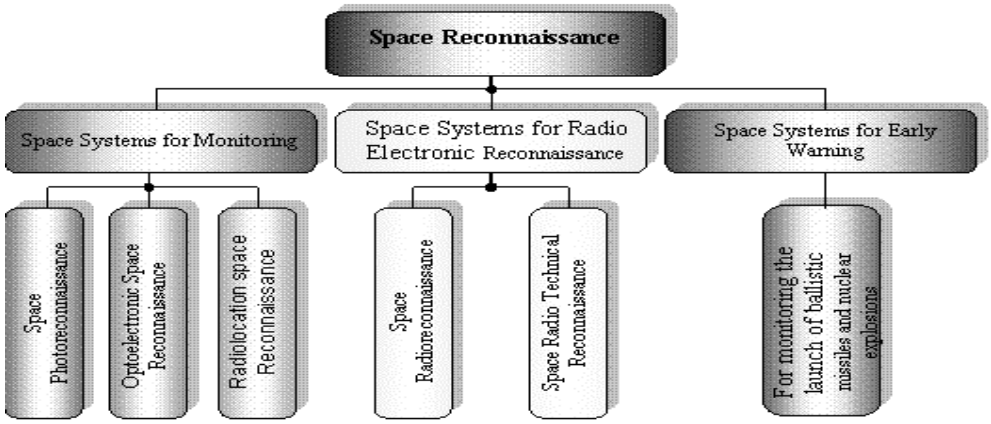

Fig.2. Classification of the space reconnaissance

The great importance of the satellite systems for reconnaissance and the wide usage of the satellite images are explained by the following circumstances:

- Global spatial coverage of the monitored territory (aquatory);
- Possibilities for monitoring given regions on a regular basis in different ranges of the spectrum;
- Possibilities for obtaining informative images with high resolution;
- Possibilities for obtaining information about broadcasting radio and radiolocation means;
- Possibilities for obtaining information regarding the launch of ballistic missiles and nuclear explosions;
- Very well developed global market for satellite video and still images that emerged after they were made free for the public. These are images of good quality with high resolution of up to one meter.

2. CHARACTERISTICS OF THE SATELLITE SYSTEMS FOR PHOTORECONNAISSANCE

The satellite systems for photoreconnaissance are usually used to take photo images of wide territories from every region of the Earth. Moreover they could locate and identify strategic military or industrial bases and military production complexes.

Space photoreconnaissance dates back to the 60s of the 20th century. Project for photographs taken from space have started a decade earlier. At the beginning of the practical flights in space the main difficulty has been the transfer of the obtained information to the ground. At the opening stage the apparatuses did not allow montage of film camera on the satellites and transfer of images through radio

channel. Thus, the first satellite reconnaissance systems provided information of a land area with a size of couple of hundred kilometres; the data on the photo film was processed on board and sent to Earth in capsules /canister/.

The reconnaissance equipment usually contains panoramic scanning camera and a system for compensating the movement of the image. The processed photo film is rolled back into the capsule. After finalizing the photo shoots the capsule is fired from the satellite. At first it is stabilized and then with the use of its own rocket engine it is taken outside of the satellite's orbit. Its special cover protects it from overheating while penetrating the atmosphere. Sometimes observers from the Earth have seen its glowing trace.

At a height of about 15 km a parachute is released that pulls out the photo film from the heatproof skin. Metal stripes, radio location and lighthouses are used to trace the capsule during its landing. Sometimes the capsule is caught during landing by passing airplanes with a special hook. If the air capture fails then helicopters and ships track the capsule's location.

Naturally, at the beginning the reliability of the photoreconnaissance systems and the resolution of the images had been unsatisfactory. Sometimes the capsules landed far away from the locations that had been planed and thus remained unused.

During the development process the optical systems of the satellites have been improved and perfected. From practical point of view one of the biggest achievements in the development process took place in 1962. At that point the single camera on board of the satellites was changed to systems of two cameras. One of the cameras takes photographs at an angle of 15 degrees ahead of the trace of flight while the other one takes images at the same angle from the opposite direction. Thus, by combining the pictures a stereoscopic image of the territory is obtained.

The beginning of the operational systems for space reconnaissance was in 1963. They are based on the artificial satellites of the Earth that allow transmission of the obtained information through radio channels. The experience from the first systems leads to the necessity to separate the detailed and field of view photoreconnaissance. The field of view systems with wide coverage (100 – 400 km) are used to monitor wide parts of the territory that eventually are taken to detailed examination. Detailed pictures do not have wide coverage of the surface but do have very good resolution of up to 0.2 m. This is achieved through using wide focal optical systems and lowering the height of the perigee of the satellite's orbit to 120 km.

The fourth generation photoreconnaissance satellites are created to help solving the tasks of the detailed and field of view photoreconnaissance. In order to support this, additional two types of optical systems have been installed: wide focal lenses camera for detailed photoreconnaissance and camera for field of view reconnaissance. Usually, around 4 – 6 capsules are used to send the photo film on the ground, while the information from the field of view reconnaissance information is transferred through radio channel. Later, on board of the satellites a wide range cartographic camera has been installed helping to locate the coordinates of the ground

objects. These images were also used to programme the route of the cruise missiles (see Fig. 3).

Fig.3. Image of S. Hussein's palace in Baghdad.

Space photo systems were only developed in USA, Russia and China.

Development of satellite systems for photoreconnaissance in USA have begun at the late 50s with the key role of the air force and CIA in two interrelated project – "Corona" and "Centry". The optical systems developed for these projects are called KH (Key Hole). Overall, under the "Corona" project some 141 satellites were launched - 103 of them successfully, 162 capsules returned to the Earth. The collection includes 643 321 meters of film.

Development of satellite systems for photoreconnaissance has also began in Russia in the late 50s. The first projects were "Kometa" and "Resurs - F". For the short period of flight of the "Resurs" satellites the equipment allows to photograph 20 – 24 million square kilometers of the ground regardless were on the surface of the Earth with good resolution of the images of less than 1 meter. Even nowadays, when Russia possesses modern optical electronic devices the satellites from "Kometa" and "Resurs-F" series are still launched. The images are used in cartographic industry, agriculture, natural resources fields, etc.

The Chinese reentry satellites are called FSW. The official name of these satellites is JB (Jian Bing) meaning "pathfinder". Nine of the satellites launched in the period of 1975 – 1987 were called JB-1 and FSW-1, the five launched in the period of 1987-1993 – JB-1A and FSW-1A, and the three satellites launched in the period of 1992–1996 – JB-1B and FSW-1B. On 3rd November 2003 was launched another Chinese satellite for filed of view photoreconnaissance named FSW-18. According to the experts in the filed some of the possible objects for photographing are the US military bases in South Korea, Japan and Okinawa islands, as well as military bases in Taiwan, Afghanistan and Iraq.

The satellite systems for photoreconnaissance have the following advantages:

- Wide range of photographed territory;
- High resolution pictures in the range of 1 meter or less;

- High productivity;
- Well developed technology for decoding the filmed objects;
- Possibilities to store the images for a long time;
- Relatively low cost for the satellites and the obtained images.

Some of the main disadvantages of the satellite systems for photoreconnaissance that lead to limitation of their usage include:

- No capabilities to work for a long period of time in orbit (15-60 days), because of the insufficient amount of film on board;
- Low efficiency of the information received by capsules – 15 – 30 days;
- There is a need to use more precise electro mechanical systems on board of the satellites in order to compensate the effect of the movement of the image in the focal plane.

That is the reason why the images, obtained through satellite systems for photoreconnaissance, are usually taken by users that need photographs of vast territories, instead of efficiently receiving the data.

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