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AEROSPACE SYSTEM FOR MONITORING MAN-MADE AND NATURAL DISASTERS

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Abstract

Monitoring natural and man-made disasters and phenomena is an important element of national security and aims to help address key challenges in detecting and preventing regional crises. This implies the use of a national monitoring system that enables analysis of the stability of the functional structure of natural and man-made systems, and the implementation of short- and long-term ecological forecasts and the operational solution of tasks related to actions during crises and the prevention of their consequences. In this monitoring process, a complex use of information from satellite, aircraft, and ground levels is necessary, which is also the subject of research in this article.

Introduction

Based on the analysis and existing experience, the concept of monitoring is proposed, which consists of a complex use of space-, aviation-, and ground-based methods and means of observation, to be implemented by an aerospace monitoring.

Tasks of system: To define the essence of environmental disasters and critical infrastructures as an object for monitoring and research; Based on the system analysis, to determine the methods, structure and composition of the complex monitoring system; To justify the expediency of using UAVs as an element of the national monitoring system; To determine the type, orbit and duration of the flight over the object of the microsatellites in the monitoring system; To determine the composition and structure of the Center for Receiving Aerospace Information and the possibilities for pre-processing the received information and its thematic suitability.

The main sources of information about the Earth's surface are electromagnetic radiation, reflected solar radiation, intrinsic radiothermal radiation and reflected artificial radiation. The registration of these radiations is carried out by various means. Analysing the characteristics of remote sensing equipment (dimensions, mass and power consumption), conclusions can be drawn about the possibilities for placing on board instruments that are mounted on aeroplanes and artificial Earth satellites (ESAs), possibilities for pre-processing the received information and its thematic suitability. Images and data obtained from satellite and aviation systems are subjected to pre-processing, including analysis and linking to a specific coordinate grid, and then offered to individual users. Linking images to geographic coordinates and developing geographic information systems helps to accumulate a database of data necessary for various industries and application areas.

The database includes the following layers with their respective attributive information: State border, Administrative (district and municipal) borders; River network, Artificial and natural water areas; Road, Railway network; Potentially dangerous objects; Electricity transmission network; Gas transmission network; Settlements; Forests. To solve the tasks of operational monitoring in real or near real time, it is advisable to use the MODIS and VIIRS satellites, since the images received from them have good repeatability of their flight over the same territory. A major drawback in this case is the small spatial resolution. However, this can be overcome if the range up to 250 m is supplemented by the use of a national or regional satellite, providing images with a spatial resolution of 40 to 80 m transmission network; Settlements; Forests. Archival satellite images with medium spatial resolution [1].

Considering the increasing penetration of UAVs, an on-board video system operating in the visible and near-infrared range with a spatial resolution of less than 50 cm can be used.

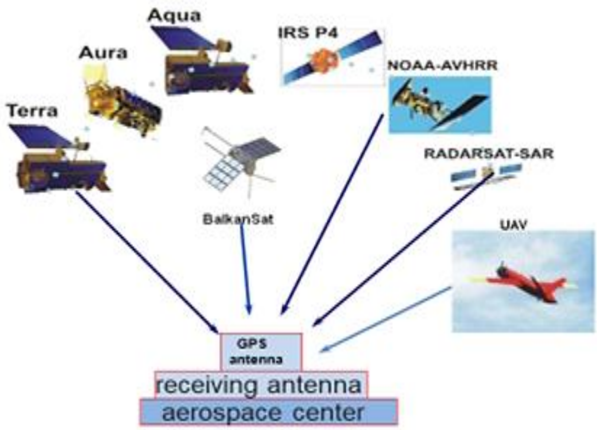

Fig. 1

Based on the analysis and existing experience, a monitoring concept has been proposed, consisting of the complex use of space, aviation and ground-based observation methods, to be implemented by an aerospace monitoring system (Fig. 1) [2, 3].

The proposed concept and centre fully comply with the requirements for monitoring national and regional critical infrastructures set by the European Critical Infrastructure Protection Program [3–6].

To assess the qualities of a UAV in operation, the so-called “formula for its ability to conduct aerial reconnaissance and surveillance” is proposed. It reflects the degree of influence of various factors (mainly the capabilities of the UAV) in forming the tactics of action in the presence of a certain payload.

According to this “formula”, the ability of a UAV to conduct aerial surveillance depends on the following factors: thrust, armament; stability and controllability; payload characteristics/electronics factor; autonomy and multifunctionality; small number of personnel for service; mobile and transportable ground equipment [2].

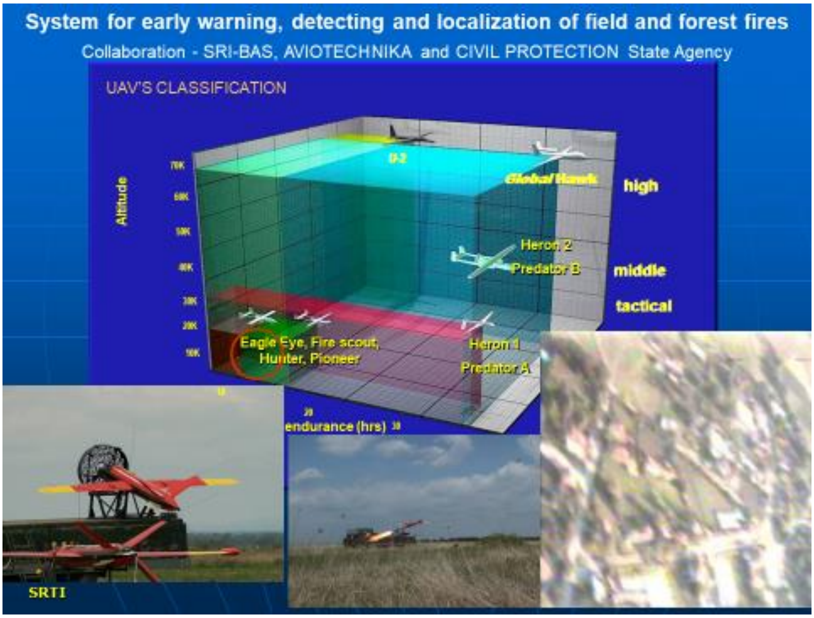

Fig. 2

The design of the UAV should allow for future modernisation to meet additional requirements dictated by the constantly changing environmental and logistical situation. Unmanned aerial systems for reconnaissance, surveillance and control of the earth's surface are currently widespread and are used in a variety of tactical tasks, and UAVs have been analysed, and data for various flight missions have been presented. Key elements of these systems are unmanned aerial vehicles (UAVs) and aerial surveillance systems, including airborne and ground parts. World experience in using UAVs for these purposes shows that they are most suitable where operating conditions are particularly extreme, and there is an unacceptable risk for manned aviation operations. Such is the monitoring of strictly protected sites and areas, as well as areas with large-scale fires and floods. In these conditions, the use of people is associated with a real threat to their lives, and practically, UAVs as a means of collecting and processing information are indispensable. To assess the current state and development trends of UAV types (Fig. 2) [3].

The main criteria by which the analysis was carried out are: the general and aerodynamic scheme of the UAV; weight-mass characteristics; characteristics of the power plant; flight technical characteristics; take-off and landing system; control and navigation systems; and air surveillance systems [2, 6].

When determining the composition of the system for early detection, localisation, and notification of forest and field fires and floods that have occurred on the territory of the Republic of Bulgaria, the results of flight modelling and modern technical achievements, as well as regulatory documents for aviation systems of this class, were taken into account. The exemplary composition of the Unmanned Aviation Complex (UAC) should include: Unmanned aerial vehicle (UAV); Ground control station (GSC); Operational equipment (EO).

The choice to develop a microsatellite as an element of the monitoring system corresponds to the increasingly convincing trend in recent years to move from large and heavy satellites to small high-tech satellites, as well as to economic feasibility based on the tasks assigned to the microsatellite, its orbit should be sun-synchronous, circular with a period of revolution of 92 min and inclination of 97 [3].

From the calculations made, the time for actual use of data from the satellite in orbits between 800 and 900 km is limited to 5.5 years. This figure is justified by the time for the descent of the orbit between 900 and 800 km. Joint lunar and solar disturbances lead to long-term changes in the parameters of the satellite's orbit, with oscillation periods ranging from several months to 84 years. If this disturbing effect is not taken into account within a day, the error in calculating the MS trajectory will be several hundred meters. Therefore, the calculations must account for the first harmonics of the Earth's gravitational field and disturbances from the Moon and the Sun [10].

Currently, the most cost-effective means of launching small spacecraft (MS) into orbit is via conversion rockets, as is the case for launching payloads for space stations into space (Fig. 3).

MS can be financed at the expense of projects under national programs for the development of education and high technologies, as well as with investments from private and state companies. Proposals are also made under the programs of the Government and the EU [3, 6].

As already noted in the concept for complex monitoring for images with spatial resolution in the range of 30 to 50 m, a national or regional satellite can be very successfully used. Based on this, the Institute for Space Research – BAS is working on the topic of “Balkansat” [9, 10].

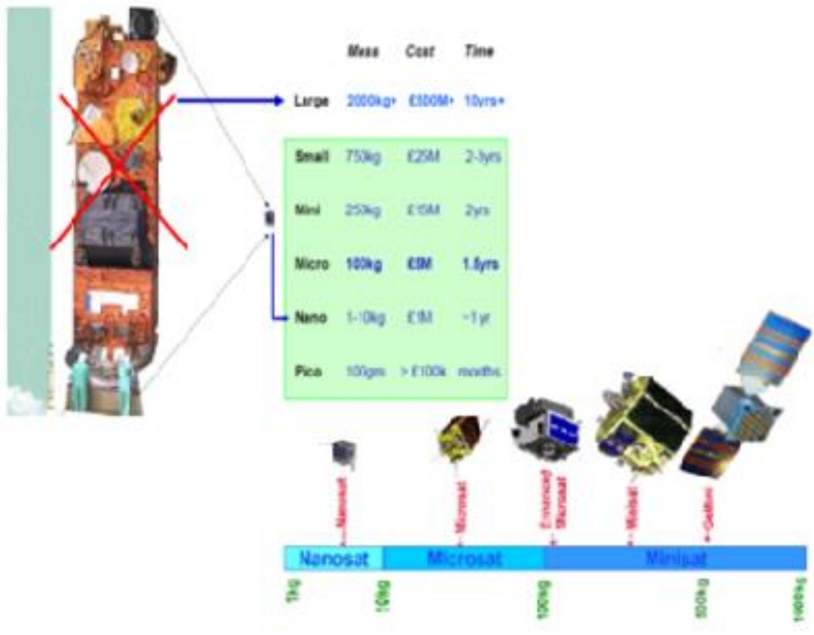

Fig. 3

This satellite should be in the weight range of 10 to 100 kg, i.e. a microsatellite or, as it is commonly called, a “small” satellite [3].

The use of the satellite is mainly aimed at monitoring the Earth's surface, but the possibility of studying the magnetosphere and ionosphere is not excluded.

For the successful solution of tasks related to the prevention of catastrophic phenomena, it is necessary to carry out: Monitoring of fires and other dangerous phenomena and objects on Earth; Monitoring of the atmosphere: control of the distribution and trends of greenhouse gases (CO_2), detection of large releases of hazardous substances into the atmosphere.

Space weather and monitoring of the state of the ionosphere, radiation belts and solar wind.

Based on the tasks listed above, the approximate composition of the specialised equipment of the small satellite “Balkansat” can be determined, including [2, 9]: Photometric equipment complex – KFA; Atmospheric research complex – KAI; Magnetic-wave complex – MVK.

On a circular orbit with an altitude of 800 km, tseq ≈ 3042 days. For a similar orbit of 900 km, tseq ≈ 5085 days.

The base orbit to which a satellite should be launched is selected from the type of circular quasi-geosynchronous orbits [10]. They ensure an approximate passage of the satellite's path on each subsequent day through the path of the previous day.

From the analysis we have made of existing small satellites and taking into account the Balkansat project, we have focused on the possibility of using, as a base platform, the microsatellite "Chibis" (a sketch of its appearance is shown in Fig. 4), which has already flown and is currently being launched into orbit with the cargo ship "Progress", providing the International Space Station (ISS) [7, 9].

Fig. 4

The service systems of the MS in the most general case are the following: Power supply system (PSS); Three-axis orientation and stabilisation system (SOS); Thermoregulation system; Temperature measurement system; Command and telemetry radio lines; Information collection, processing and control system.

The specified inclination of the orbital plane to the plane of the equator indicates the need to create a universal PSS, which must provide the necessary power supply to the MS, constantly changing its orientation with respect to the Sun and must function in a circular orbit with an altitude of 800 km and an inclination of 97^{o}.

To determine the bases for orientation, accurate knowledge of the coordinates of the MS in orbit around the Earth is necessary. The orbit of the MS can be determined on Earth by a number of observations at different points of the orbit. The calculation of the initial conditions for the construction of the MS orbit is published in the space monitoring centres and is specified in the MS control centre based on the data published on the initial conditions, data from radio control and orbits and data from the navigation equipment on board the MS.

Aerospace Information Centre

The creation of the national monitoring system can be carried out based on the implementation of the proposed concept, including the construction of a national aerospace monitoring centre (Fig. 5).

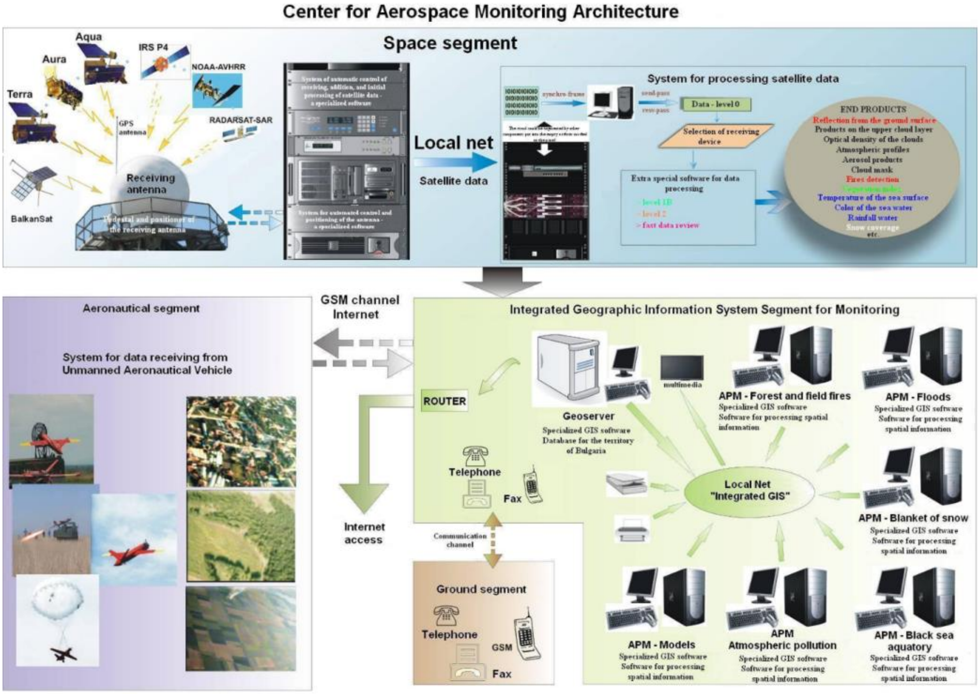

Fig. 5

For the receiving station of the centre, we focused on the Basic configuration of the UniScan™-24 complex, which allows the reception not only of data from the Terra and Aqua satellites, but also of data from other satellites for which, however, additional software and payment of the relevant license are required [3, 5, 11].

The strategy for forecasting and controlling natural and man-made disasters is based on the principle of minimising the time for detection, identification, and recognition of the event, in order to adopt an optimal solution to master and control the situation that has arisen. The implementation of this strategy is based on the use of a multiplicative type of spatial data in different time intervals and their correlation at specifically defined time points. Fig. 6 schematically shows the principle by which the proposed strategy is implemented.

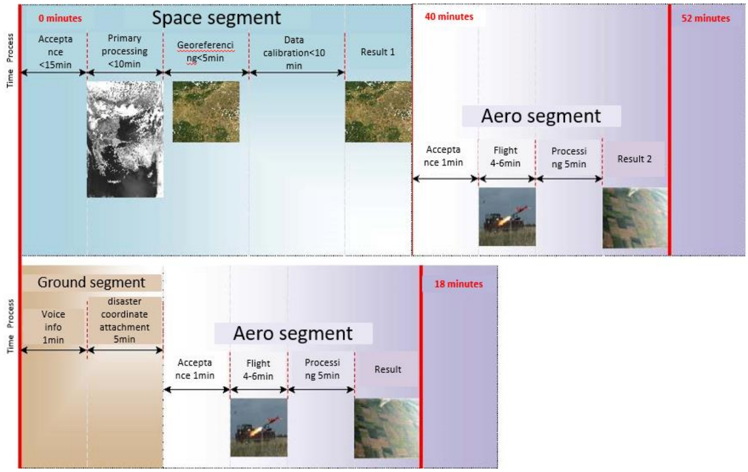

Fig. 6

Implementation of the strategy for using multi-spatial data in different time intervals. The proposed architecture allows for receiving data in real or near real time for the territory of the country and cross-border regions in the event of natural and man-made disasters. Information is received from three independent sources: space, aero and ground segment.

The Aqua and Terra satellites provide 4 images per 24 hours for fire monitoring. MODIS data can be used to monitor stubble burning, vegetation type and condition, smoke aerosols, water vapour, and clouds, providing comprehensive monitoring of the fire development process and its impact on ecosystems, the atmosphere, and climate. This includes the location of the fire, the rate of heat release from the fire, and a rough estimate of the smouldering-to-burning ratio [3].

The 7-2-1 channel combination of the MODIS multi-channel spectroradiometer “colours” objects in tones different from those seen by the human eye. It is suitable for visual identification of water bodies due to the inclusion of channel 7 (2.11–2.16 µm) of the infrared spectral range.

The snow cover product is used to estimate snowmelt during the spring months and thus has applications in water resources management.

Ocean and sea surface color files contain the products of measurements of normalized water surface radiance, aerosol optical density, aerosol epsilon correction, diffusion attenuation; biooptical and optical properties for water including chlorophyll-a, chlorophyll-a + phaeopigment, total pigment and total suspended solids concentration, phytoplankton and total absorption coefficients; pure water epsilon; instantaneous photosynthetic irradiance and phytoplankton absorbed irradiance; chlorophyll fluorescence line height, baseline and efficiency; isolated coccolith concentration, pigment concentration in coccolithophore colors, calcite concentration; phycoerythrin and phycourobilin concentration [12–15].

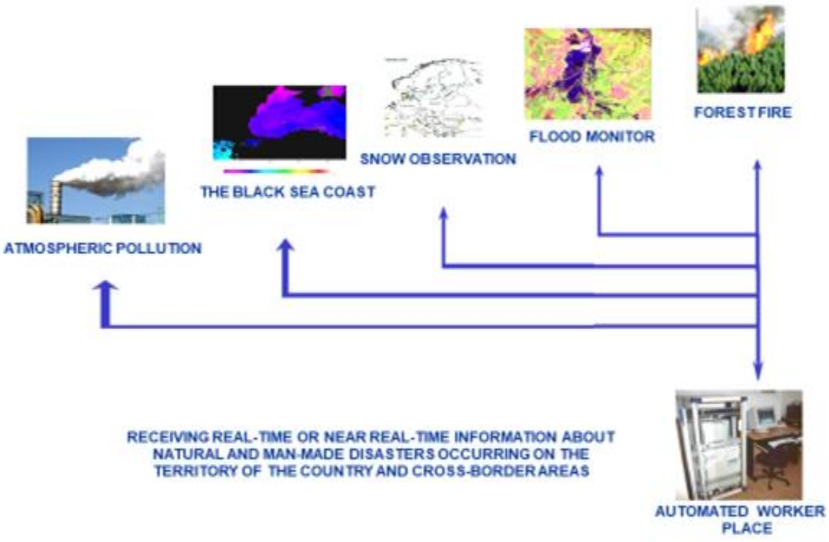

Fig. 7

Most MODIS atmospheric properties products are used to monitor atmospheric pollution.

Using infrared methods, cloud top temperature, height, effective radiance, phase (ice-water, opaque-clear), and cloud fraction are obtained, both during the day and at night. The MODIS cloud properties product includes cirrus reflectance in the visible part of the spectrum at 1 km-pixel resolution, which is necessary to eliminate the scattering effect of cirrus clouds from the land surface reflectance product.

Conclusions

1. Aerospace monitoring has no alternative in objectifying the state of the environment and security.

2. The development of an aerospace monitoring system is part of the general efforts to ensure an effective mechanism for the prevention and averting of crises of various natures. When this is not possible, it can help reduce their consequences and alleviate human suffering.

3. European institutions must provide the necessary prerequisites for the inclusion of the scientific and research community, private business and industry in major European and NATO projects related to global monitoring systems, which, however, should not be at the expense of the development of national and regional activities in this area.

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АЕРОКОСМИЧЕСКА СИСТЕМА ЗА МОНИТОРИНГ И ЗАЩИТА ОТ ТЕХНОГЕННИ И ПРИРОДНИ БЕДСТВИЯ

П. Гецов

Резюме

Мониторингът на природните и техногенните бедствия и явления се явява важен елемент от националната сигурност и има за цел да подпомага решаването на някои основни проблеми, свързани с откриването и предотвратяването на регионалните кризи. Това предполага използване на национална система за мониторинг, позволяваща анализиране на устойчивостта на функционалната структура на природните и техногенни системи и осъществяване на краткосрочни и дългосрочни екологически прогнози и оперативното решаване на задачите свързани с действията по време на кризите и предотвратяване на последствията от тях. В процеса на този мониторинг е необходимо комплексно използване на информация от спътниково, самолетно и наземно ниво, което се явява и предмет на изследване на настоящата статия.