# 1. MAIN METHODS AND MEANS FOR OBSERVATION, DETECTION AND IDENTIFICATION OF AEROSPACE OBJECTS AND PHENOMENA

This section of the **Manual** provides a general description and features of the main methods and means of observation, detection and identification of aerospace objects and phenomena.

## 1.1. Methods for observation, detection and identification of aerospace objects and phenomena

**AOP monitoring** consists of the following main stages (Fig. 1.1).

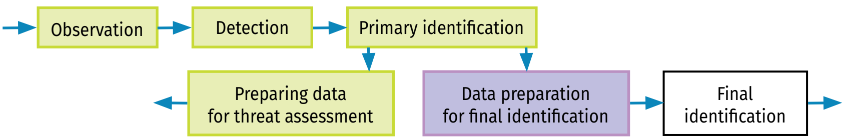


**Figure 1.1** – Main stages of aerospace objects and phenomena monitoring

**The scope of this Manual** is to monitor, detect and initially identify AOPs, as well as to prepare data for assessing threats from them and, if necessary, data for the final identification of unidentified AOPs.

**Observation** of the ASD is carried out visually or with the help of technical means.

**Detection of** AOP in ASD is the process of establishing presence of AOP as a result of observation of ASD using various methods. At the present stage, the following main **methods** are known for **detecting** AOP in ASD:

– visual;
– thermal;
– acoustic;
– radio frequency;
– radar.

**Visual methods for** detecting AOP include both the use of an eye gauge and special technical means that allow detecting the characteristics of AOP for further identification.

The advantages of visual methods of detecting AOP are their availability, high mobility and speed of usage. The disadvantage of visual methods of detecting AOP are the inability to detect AOP in low light conditions (for example, at night) without special equipment, such as night vision devices, thermal imaging cameras, etc. In addition, visual detection is sensitive to the possibility of so called overidentification. Many moving objects, such as birds, insects, balloons, certain types of clouds, satellites, missile launch effects, etc. can be mistakenly identified as unmanned aerial vehicles (UAVs) or missiles, etc. Visual detection methods without the use of special technical means are not very informative in modern conditions. Also, identification of “friend or foe” is complicated because many countries use the same or mostly similar models of aircrafts and UAVs. Visual distinguishing marks on an object are usually difficult to see from a long distance, and other countries may take misleading measures, such as disguising UAVs as birds, using symbols of your country, or protective coloring that distorts the visible outline and/or color of the object.

**Thermal detection methods** detect the heat emitted by engines or other components of AOP. Specialized thermal imaging devices can record the infrared radiation of any object with a temperature and convert it into a visible image. This process is called thermography. It makes possible to detect AOP that are invisible to the naked eye by their thermal signatures.

However, adverse conditions such as fog, smoke or heavy rain can seriously affect the performance of thermal imagers. In addition, modern artificially intelligent aerial vehicles (AV) and UAVs are often made of low-emitting materials, such as insulated, polished or reflective surfaces; thermal signatures can be intentionally distorted by camouflage. In addition, not all AOPs have distinct thermograms.

**Acoustic methods** use special sensors to detect the unique sound signature of objects in the air and locate them. These sensors perform advanced analysis of the sound spectrum of the environment, detecting activity that corresponds to the unique acoustic signatures of different types of objects. When these sensors detect the presence of an object, they automatically extract its sound and compare it to the reference points in an integrated database. When an equivalence is found, the system records the identification information and sends an automatic notification. The main disadvantages of acoustic methods are low accuracy and the inability to detect AOP in an airless (space) environment. In addition, some AOP may be supersonic, silent or low-noise in nature, mixed or jammed with other natural sounds.

Radio frequency methods. The majority of artificial aerospace objects are controlled and/or communicate using radio frequency radiation. Using special receiving equipment for radio frequency spectrum analysis, even weak radio signals can be detected at a considerable distance and potentially detect the presence of artificial objects in the ASD.

The main advantages of the radio frequency methods are the detection range and the ability to identify a specific type of objects in limited visibility, regardless of weather conditions, and the passive operation of the equipment. Radio signals also propagate at the speed of light, which allows detection systems to respond extremely quickly to changes in the radiation of objects.

The disadvantages of radio frequency methods detection of AOP are the need for special equipment, the possibility of signal spoofing or avoiding detection through radio silence, non-standard frequencies, etc. Some autonomous, swarming, or wired-controlled

UAVs cannot be detected by radio frequency methods. Ultimately, radio frequency spectrum analysis can only detect man-made objects in the ASD, being of little use for identifying all other, including natural, AOP.

**Radar methods.** Radar detection is carried out using special radar systems. The transmitter of a radar system emits radar signals that interact with objects as a result of reflection or scattering. These altered waves are then received by the radar receiver, where sophisticated algorithms convert them into a visual format, providing valuable information about the size, structure and composition of the object. Objects located closer or further away from the transmitter create the Doppler effect, i.e. distortion of the radio waves. Pulsed Doppler radar systems used to detect UAVs periodically emit radio waves and measure the returned radar signal to estimate the distance, speed and characteristics of the detected object.

However, UAVs, for example, are mostly made of plastic that is invisible to radar, and only their metal cameras, batteries and engines provide reflectivity for signals. The disadvantage of radar detection methods is the limited radar range: UAVs are smaller than manned aircraft and tend to fly close to the ground surface, making them difficult for most radars to detect [8].

Special coatings and shapes of aircraft, as well as deception measures and the use of dipole and corner reflectors, can distort the reflected radio signal, making it difficult to detect and identify AOP. Certain natural phenomena, such as groups of birds, have a significant **effective scattering area** (a characteristic of a target's reflectivity, determined by the ratio of the power of electromagnetic energy reflected by the target in the direction of the receiver to the surface energy density of a downgoing plane wave), which can lead to misidentification.

These **Manual includes only visual and thermal methods for detecting AOP** in ASD, as they are common and available for use. The most effective method is a combination of different methods for detecting and identifying AOP.

**Initial identification** is carried out directly by the persons involved in monitoring and detection of AOP or automated using specialized technical systems. Initial identification is the basis for assessing threats and making a quick decision on how to neutralize them if detected.

The **data for threat assessment** is **prepared** directly by the persons involved in monitoring and detecting AOP or by other specialists, based on the initial identification, in order to prepare and promptly transmit information to the relevant officials for making decisions on neutralizing possible threats. Data for threat assessment includes the following key AOP parameters: direction of movement, trajectory, speed, general description, etc. It should be sufficient to make a decision on how to neutralize possible threats, which is the absolute governmental priority.

The **data for a final identification** is **prepared** directly by the persons involved in the monitoring and detection of AOPs or by other specialists, based on the initial identification. The final identification is aimed at conducting an analysis, which is carried out if, as a result of the initial analysis, the AOP remained unidentified. The data required for final identification are described below. However, non-identification as a result of the initial identification is not an obstacle to preparing threat assessment data and making a decision on the possible neutralization of the observed AOP.

The limits of applicability of AOP detection methods depend on the features of the technical equipment for monitoring the ASD and the means necessary for its placement [9].

## 1.2. Means and devices for monitoring aerospace objects and phenomena

AOP **monitoring tools and devices** are divided into passive and active. The active ones are characterized by the presence of radiation or other impact in the direction of the monitored object, while the passive ones have no radiation in the direction of the object.

Visual monitoring is carried out with the naked eye or with the help of special optoelectronic means (binoculars, monoculars, telescopes, scopes) and devices (thermal imagers, night vision devices, sighting devices). As a rule, visual monitoring equipment and devices are passive; exceptions are special searchlights, targeting lasers, and infrared illumination of night vision devices. Visual monitoring means and devices for AOP can be either individual or group, worn or integrated into equipment.

**Monitoring equipment and devices** are individual (micro-level), local (meso-level) and global (macro-level) electronic and mechanical systems that measure and record the state of the environment.

Global monitoring systems for ASD in Ukraine include satellites, meteorological stations and radar stations. Local systems currently include departmental and private devices, aircraft, etc. Individual electronic and mechanical systems that are rapidly developing include mobile devices, smartphones, surveillance cameras, mini-radars, portable stations for determining meteorological conditions, environmental parameters, etc. [6, 8].

Different methods of monitoring and detecting ADA determine the use of different technical means and devices for monitoring of AOP:

– cameras, night vision devices, telescopes, binoculars, etc.;
– thermal imagers;
– satellites and spacecraft;
– manned and unmanned aerial vehicles, missiles;
– probes, aerostats, stratospheres;
– special stationary and mobile monitoring systems.

Due to the full-scale aggression of the russian federation, Ukraine currently has tens of thousands of different ASD monitoring devices. As the number of ASD monitoring systems and the level of professionalism of the personnel involved grows, the number and quality of AOP reports increases.

**Identification of AOP** is the process of establishing the identity of the observed parameters and features of AOP to the corresponding parameters and features of known AOP of anthropogenic and natural origin.

**AOP parameters** are data that describe the AOP and can be expressed numerically (e.g., speed, size, brightness, etc.).

**AOP features** are data that qualitatively describe AOP and cannot be expressed numerically (e.g. color, shape, etc.).

The identification of AOP can be carried out **visually, on the basis of prepared hardware data**, **and automated (software)**. The final decision on the results of the AOP identification is made by a designated responsible person.

Cameras, **night vision devices**, **telescopes**, **binoculars**, **etc.** are visual monitoring devices and instruments for ASD (Fig. 1.2). They can be portable, stationary or mounted on moving vehicles and equipment.

Visual identification of AOPs is carried out by their details, outline, behavior, distinctive marks, aeronautical lights or light effects.

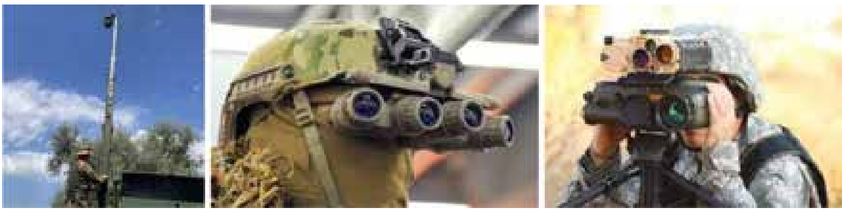

**Figure 1.2** – Examples: A stationary video camera; an individual night vision device; a portable handheld visual reconnaissance system

**Thermal imagers** are specialized devices that detect thermal (infrared) radiation from AOPs and generate images based on temperature differences (thermal signatures). There are portable thermal imagers, stationary thermal imaging systems and those integrated into vehicles, aircraft/ UAVs that allow detecting AOPs even in the dark or in bad weather conditions (Figure 1.3). The thermography of AOPs includes their observability in the infrared spectrum; temperature distribution over the body of the AOP; type and rate of change of the AOP temperature over time, which may indicate certain processes occurring with the AOP. The disadvantages of thermal imagers are a long switch-on time, blurring of objects at high background temperatures, inability to detect AOP at low temperature differences between the background and the object, the need for optical focusing on the object, and some dependence on weather conditions.

**Satellites and spacecraft** monitor AOP from an extremely long distance. Space imagery is capable of providing highly accurate visual detection of AOP, thermography, electronic reconnaissance, etc. Almost all types of equipment for collecting information on AOP can be installed on satellites and spacecraft.

The visibility of near-Earth space makes it possible to carry out global monitoring by space assets over all areas of the Earth's surface, including the AOP, in near-real time.

The disadvantages of satellites and spacecraft as carriers of monitoring tools are their considerable distance from the Earth's surface, which requires the use of powerful optical devices; possible incomplete coverage of the Earth's surface due to the insufficient number and mobility of satellites and spacecraft in orbit; observation is usually focused only on narrow areas. The high cost of satellites and spacecraft and the limited possibilities for their launch and modernization cause inertia in the implementation of the latest methods of the AOP observation from space.

**Manned and unmanned aerial vehicles**, **missiles**, due to their relatively low cost, are the most affordable carriers of monitoring systems in the ASD (Fig. 1.3). The active use of UAVs in the ASD, especially in the area close to the warzone, makes it possible to monitor the AOP in close to real time and to make prompt decisions based on threat analysis.

Manned vehicles can be more informative and facilitate faster decision-making when the crew detects an AOP, but they put the crew at risk.

The low visibility of UAVs, their maneuverability, and the ability of some types to hover for a long period of time over one point on the

Earth's surface allows obtain a significant amount of information about AOP. The high speed of UAVs allows became closer to AOP for better visibility.

**Figure 1.3** – Individual thermal imager; reconnaissance satellite; UAV

Missiles can be quickly deployed for additional monitoring AOP with their prior detection by other means. The disadvantages of using missiles to deploy AOP monitoring systems are their high speed and low maneuverability.

**Observation ballons**, **aerostats**, **stratospheric balloons** are low-mobility means for deploying ASD monitoring systems. Aerostats can be stationary and mobile, with engines or self-flowing in the wind (Fig. 1.4). The advantages of stationary monitoring aerostats are their cost-effective operation at a high altitude and a big area of observation. The general disadvantages of aerostats and balloons are their vulnerability to weather conditions, wind loads, and, for moving types – low speed and limited range. It is difficult to camouflage such equipment on the ground.

**Special stationary and mobile monitoring systems** are among the most promising for monitoring and detecting AOP, as they are relatively inexpensive, allow deployment of a monitoring network, are easy to disguise, and can be quickly upgraded. Stationary systems are placed on the ground, towers and masts, building elements, etc. Mobile monitoring systems are placed on vehicles, equipment, special

**Figure 1.4** – Observation balloon; reconnaissance stratospheric balloon

unmanned mobile platforms, etc. The peculiarity of monitoring systems is multispectral, availability of hardware, data recording and transmission devices.

**Figure 1.5** – Mobile monitoring systems for ASD

The disadvantages of stationary and mobile monitoring systems are the low height from which observations are made and, accordingly, the low visibility range.