New Two-Tubes Telescope for Observation of Near-Earth Space

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ABSTRACT

At the end of 2021, a new telescope of the State Space Agency of Ukraine was installed in Transcarpathian region to observe near-Earth space objects in the interests of the Ukrainian Space Monitoring and Analysis System.
The telescope consists of two tubes (0.35 m, f/2.0 and 0.25 m, f/12.0), mounted on one equatorial mount with direct drive and equipped with CMOS cameras. The telescope and cameras are controlled by original software.
We will present a description of the design and individual systems of the telescope, as well as the first results of its use to observe near-Earth space objects in different orbits.

1. INTRODUCTION

Optical sensors are important sources of information for the Space Situational Awareness (SSA). They make it possible to obtain highly accurate estimates of the angular coordinates and apparent brightness of near-Earth resident space objects (RSO) in order to refine their orbits and determine their state. They can observe RSO in all possible orbits from LEO to GEO and beyond. Optical observations are especially important for objects in medium (altitude 20,000 km) and high (GEO and above) orbits, where the use of radars is difficult.

With all its benefits, optical sensors also have serious limitations. Most of them work only at night and, unlike radars, they seriously depend on the weather (cloudiness). In addition, most optical sensors have a relatively low throughput when observing LEO objects [1]. Partially fend off the last two limitations can be the creation of new sensors. At the same time, various tasks facing optical sensors often require different tools for the most effective performance. This problem can be solved by combining different types of lenses on the same mount, as was done in the described below. It should also be noted that the installation of two lenses on one mount, both identical and different, has been used for a long time in different countries [2] - [4].

2. TELESCOPE SPECIFICATIONS

The telescope is part of the Optical-Electronic Optoelectronic Observation Station Type 3 (OEOS-3), located in western Ukraine. in the Zakarpatska region (Fig. 1). It is separated from the rest of the country by the Carpathian Mountains, so the climatic conditions here are significantly different from those in the rest of Ukraine. It allows us to assume that the sensors. those in this area may have good observation conditions when it is cloudy in the rest of Ukraine, and vice versa.

The OEOS-3 telescope consists of two lenses mounted on the same equatorial mount (Fig. 2): a wide field of view (WFoV) Hamilton lens and a narrow field of view (NFoV) Maksutov lens. Both lenses are equipped with QHY-174M GPS CMOS cameras (Fig. 3). At a relatively low price, they provide accurate timing of observations. It is especially important for LEO observations.
The mount is equipped with a direct drive. This drive provides a maximum slew rate of 20 degrees/second and tracking of any RSO in near-Earth orbits. The characteristics of the telescope are presented in Table 1.

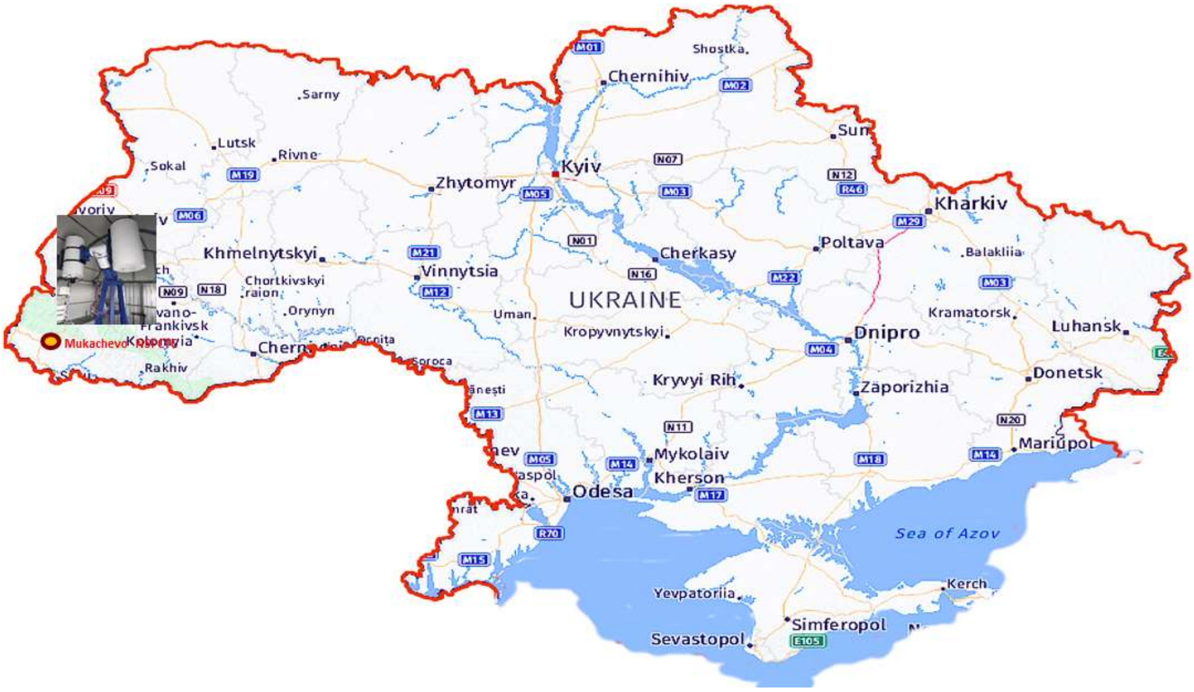


Fig. 1. OEOS-3 location

Fig. 2. OEOS-3 telescope

Fig. 3. CMOS camera QHY-174M GPS

Table 1: The OEOS-3 specifications

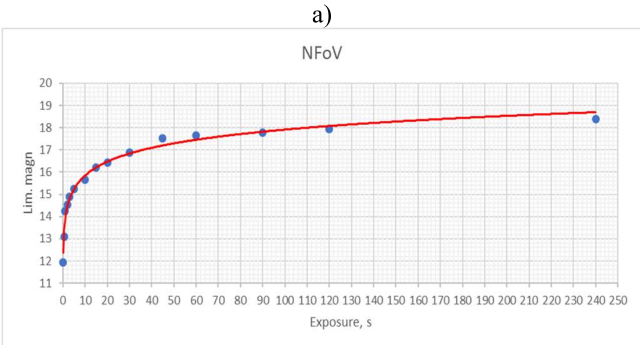
	WFoV lens	NFoV lens
Optical scheme	Hamilton	Maksutov
Aperture, mm	350	250
Focal length, mm	700	3400
Camera	QHY-174M GPS	QHY-174M GPS
Scale without bining	1.7"	0.36"
FoV	55'x35'	12.9'x8.1'
Монтування	Equatorial with direct drive and two lenses	
Max. slew rate	Up to 20 °/s	

Ukrainian software is used to control the telescope and process the received observations. Its earlier modifications were described in more detail in [2].

3. RESULTS AND DISCUSSION

The telescope was mounted in December 2021, however, due to weather conditions and the outbreak of hostilities, the first light was received only at the end of March 2022. Subsequently, estimates of limiting magnitude were obtained for both lenses at a SNR of 3 (Fig.4).

a)

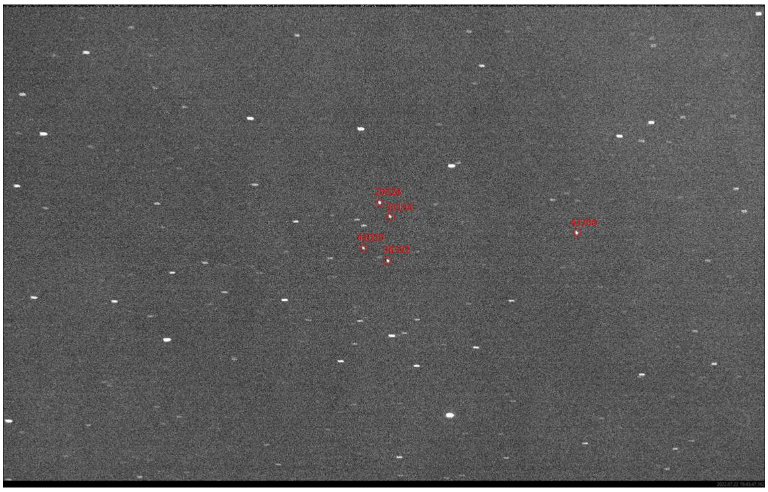


b)

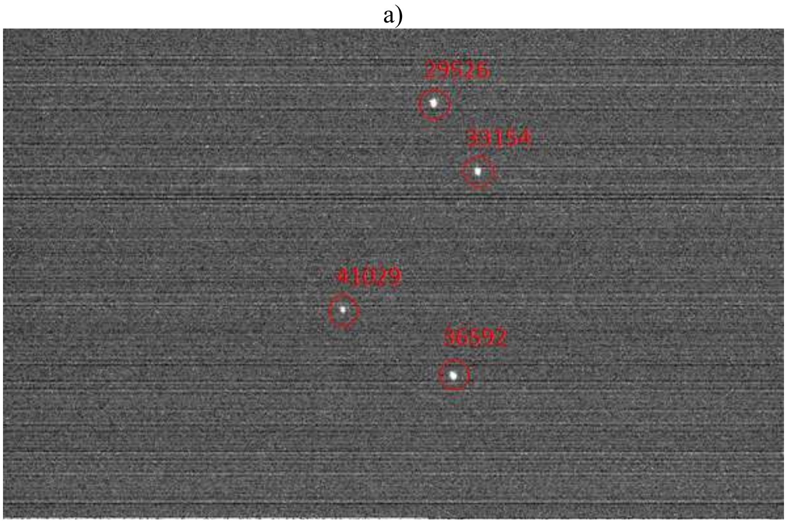
Fig. 4 Limiting magnitude of the OEOS-3 lenses: a) Wide field of view; b) Narrow field of view

As can be seen, the more or less effective exposure time is limited to 120 s. In our opinion, it is more expedient to provide a further increase in limiting magnitude using the stacking technique (“shift-and-stack”).

A visual difference in the resolution of the lenses is given by Fig. 5. It shows images of the same geostationary cluster obtained with WFoV and NFoV lenses. The downside of the high resolution of the NFoV is its small size. It makes it difficult to obtain an astrometric solution due to the lack of the required number of stars. On the other hand, this lens is well suited for photometric observations.



a)



b)

Fig. 5. Image of GEO cluster obtained by OEOS-3: a) Wide field of view; b) Narrow field of view

Test observations of ILRS objects on the LEO were also carried out, because the orbital parameters of this objects are known with high accuracy. The results of these observations showed that the telescope can observe objects on the LEO with a relatively high accuracy (Fig. 6). It is not yet clear, what caused a slight bias of the across-track O-C values, but we think that we will be able to find it with further observations.

Fig. 6. Errors of positional observations of ILRS objects on LEO.

4. CONCLUSIONS

The new telescope allows for positional observations of near-Earth RSOs with limiting magnitudes up to 18^m-19^m.

Various characteristics of lenses allow to choose one of them for observations that best suits the task.

In the future, it is planned to conduct research on photometric systems of lenses, as well as to equip the NFoV lens with a set of color filters. It will expand the capabilities of the telescope for obtaining non-coordinate information.

5. REFERENCES

[1] O. Kozhukhov. Throughput of the Optical Telescope for Observation of LEO Objects, *Space science and technology,* 27, 3, 28—38, 2021 [in Ukrainian]. (https://doi.org/10.15407/knit2021.03.028).
[2] O. Kozhukhov et al. Ukrainian Optical Sensors for Space Surveillance, *AMOS Technical Conference Proceedings*, 2020.
[3] E. Cordelli, P. Schlatter, T. Schildknecht. Simultaneous Multi-filter Photometric Characterization of Space Debris at the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald, *AMOS Technical Conference Proceedings*, 2018.
[4] S. Karpov et al. Mini-Mega-TORTORA Wide-Field Monitoring System with Sub-Second Temporal Resolution: First Year of Operation, *RevMexAA (Serie de Conferencias)*, 48, 91–96, 2016.