Ukrainian Optical Sensors for Space Surveillance

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ABSTRACT

Optical sensors are a significant part of any SSA System, especially for observation of GEO, MEO and HEO objects.
Ukraine has more than 10 telescopes located throughout the country. They can be used to observe objects in the Earth's outer space in all altitudes ranging from LEO spacecrafts and space debris to NEO. They have apertures from 25 to 80 centimeters, limiting magnitude from 17^m to 20^m acquire both positional and photometric observations. Previously, new instruments were created by upgrading old telescopes, but in recent years, entirely new sensors have emerged.
The majority of observations are processed by the Ukrainian ColiTec software.
The presentation provides a brief description of current Ukrainian optical sensors and examples of their operation. Possible ways of development of optical facilities of Ukraine are discussed.

1. INTRODUCTION

The participation of Ukrainian telescopes in the implementation of space surveillance tasks began in 1957 with observations of the first artificial Earth satellite and since then it has continued almost permanently, despite various economic and political problems. By 2020, about 20 Ukrainian optical facilities, located in nine observatories and observation stations of various subordination, are engaged in or may be engaged in observations of Near-Earth space (Fig. 1). They can carry out both positional and photometric observations of objects of interest in the entire range of heights.

We will provide a brief description of the optical sensors at the disposal of the Ukrainian observatories, as well as the results obtained by them. We do not consider telescopes available on the territory of Ukraine for laser ranging of space objects in this work.

2. OPTICAL SENSORS OF THE STATE SPACE AGENCY OF UKRAINE

Optical facilities of the State Space Agency of Ukraine (SSAU) are part of the National Space Facilities Control and Test Center (NSFCTC) and they are an integral part of the Ukrainian Space Monitoring and Analysis System (SMAS). SMAS is operated by SSAU. Now NSFCTC has three optical sensors (Fig. 2): the ‘Sazhen-S’ Quantum-Optical Station (QOS), the Optical-Electronic Observation Station-1 (OEOS-1) and the Optical-Electronic Observation Station-2 (OEOS -2). Their main characteristics are presented in tables 1 - 3.

QOS was built by the Leningrad Optical and Mechanical Association (LOMO) during the Soviet era. It consists of two main Cassegrain lenses with an aperture of 0.5 m and a focal length of 8 m, mounted in parallel on the same equatorial mount: one is for positional observations; the second is for laser ranging. In addition to the main lenses, there were several additional smaller lenses. In 2016, the Wide Field of View (WFoV) telescope of positional observation channel was replaced with a new high-aperture lens with an aperture of 0.3 m and a focal length of 0.3 m, equipped with a CMOS camera with high frame rate and quantum efficiency. At the same time, the Narrow Field of View (NFoV) lens of the same channel received a new FLI ML16070 Interline CCD camera and a set of colour filters. Last year, a new control system developed by Ukrainian specialists was installed at the QOS (Fig. 3). In the future, it is planned to develop a control system for several telescopes.

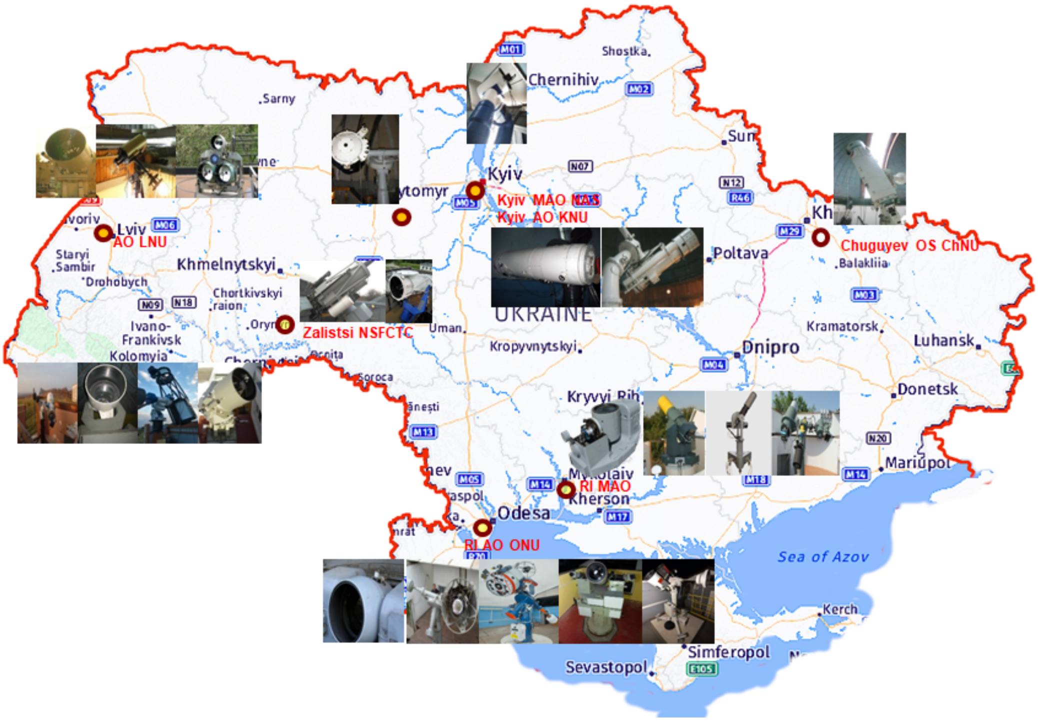


Fig. 1. Ukrainian optical sensors for observation Near-Earth space


a) b) c)

Fig. 2. Optical means of SSAU: a) QOS "Sazhen-S"; b) OEOS -1; c) OEOS -2.

OEOS-1 and **OEOS-2** are new telescopes created in 2018-2019 by Ukrainian specialists. OEOS-1 is a 0.5 m Newtonian telescope with a field corrector. The telescope is equipped with two cameras: NFoV and WFoV (Table 2), that are switched remotely. OEOS-2 is a high-aperture lens (similar to the new WFoV telescope of QOS) mounted on a modified German direct drive mount. The OEOS-2 contains two cameras (Table 2), that can be installed on the lens in turn. Now the OEOS-2 is equipped with FLI ML16070 camera, which gives a much larger field of view. The mounts of all optical equipment of the SSAU make it possible to conduct observations in the mode of mechanical tracking of any Near-Earth objects, including LEO.

Table 1 - Main characteristics of QOS.

	WFoV telescope	NFoV telescope
Aperture, cm	30	50
Focal length, m	0.3	8.0
Camera (chip)	ZWO ASI-174Mono Cool (Sony 1/1.2" CMOS IMX174LLJ / IMX174LQJ)	FLI ML 16070 (Interline ON Semi KAI-16070) + UBVRI filters
Size, pix.	1936 x 1216	4864 x 3232
Pixel size, µm	5.86	7.4
Scale without bining ("/pix)	4.01	0.28
FoV (deg^2)	2.89 (130'x80')	0.039 (14.5'x9.5')
Mount	Equatorial with two parallel lenses	
Slew rate, deg/s	2.5	
Tracking	yes	

Table 2: Main characteristics of OEOS -1 and OEOS -2

	OEOS-1	OEOS -2
Aperture, cm	50	30
Focal length, m	1.9	0.3
Camera (chip)	WFoV camera: FLI ML 16070 (Interline CCD ON Semi KAI-16070) NFoV camera: QHY-174M GPS (Sony 1/1.2" CMOS IMX174LLJ / IMX174LQJ)	1 camera: QHY-174M GPS (Sony 1/1.2" CMOS IMX174LLJ / IMX174LQJ) 2 camera: FLI ML 16070 (Interline ON Semi KAI-16070)
Size, pix.	WFoV camera:4864 x 3232 NFoV camera: 1936x1216	1 camera: 1936x1216 2 camera: 4864 x 3232
Pixel size, µm	WFoV camera: 7.4 NFoV camera: 5.86	1 camera: 5.86 2 camera: 7.4
Scale without bining ("/pix)	WFoV camera: 0.80 NFoV camera: 0.64	1 camera: 4.01 2 camera: 5.1
FoV (deg^2)	WFoV camera: 0.774 (64.8'x43') NFoV camera: 0.075 (20.7'x13')	1 camera: 2.89 (130'x80') 2 camera: ~31.74 (6.9°x4.6°)
Mount	Equatorial fork	Modified German with Direct Drive
Slew rate, deg/s	Up to 5.0	Up to 10
Tracking	yes	yes

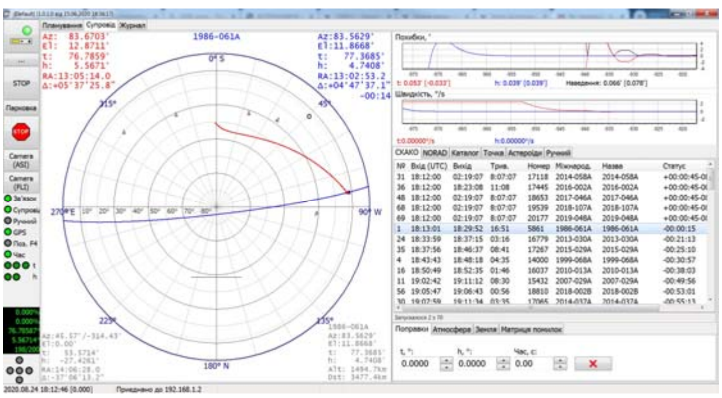


Fig. 3. GUI of the QOS control system.

3. OPTICAL SENSORS OF THE UKRAINIAN NETWORK OF OPTICAL STATIONS

The Ukrainian network of optical stations - UNOS (Fig. 4) can organize space debris observations from the side of the National Academy of Sciences of Ukraine. It includes practically all Ukrainian observatories, which carry out observations of artificial space objects in Near-Earth space. Among them are the Astronomical Observatory of the Odessa National University (AO ONU), the Space Research Laboratory of the Uzhgorod National University (SRL UNU), the Research Institute "Nikolaev Astronomical Observatory" (RI NAO), the Astronomical Observatory of the Lviv National University (AO LNU) and the Main Astronomical Observatory of the National Academy of Sciences Ukraine (MAO NASU).

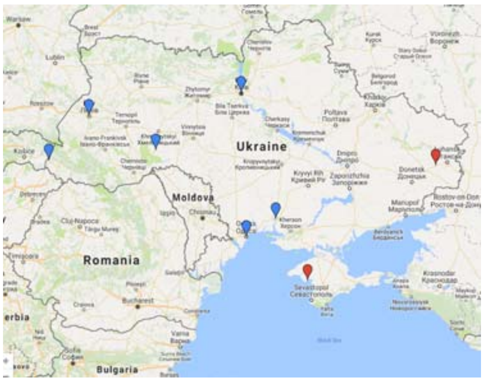


Fig. 4. Observatories that are part of the UNOS.

3.1 Sensors of the Astronomical Observatory of Odessa National University

AO ONU is one of the largest in Ukraine in terms of the number of available observational facilities. In AO ONU they are engaged in both positional and photometric observations of Near-Earth space objects, and the observing facilities themselves are located at three observation points.

3.1.1 Sensors of AO ONU located in Odessa and Kryzhanivka

In Odessa, on the urban territory of AO ONU, there is a high-speed telescope **KT-50** (longitude 30.7557, latitude 46.4778, height 56 m). This is a Soviet Maksutov telescope with an aperture of 0.5 m, equipped with a TV CCD camera (Fig. 5a), Table 3). It is used for positional and photometric observations of LEO objects, down to extremely low target heights. At the suburban observational astronomical station Kryzhanivka, there is a recently created lens of the **Schmidt** system, also equipped with a TV CCD camera (Fig. 5b), Table 3). It can be intended primarily for positional observations of Near-Earth space objects.

a) b)

Fig. 5. Sensors of AO ONU: a) telescope KT-50; b) Scmidt telescope in Kryzhanivka.

Table 3: The main characteristics of the optical sensors of AO ONU in Odessa and Kryzhanivka

	KT-50 (Odessa)	Schmidt (Kryzhanivka)
Aperture, cm	50	21.92/27.125
Focal length, m	2.0	0.44
Camera (chip)	TV-CCD Watec-902H2	TV-CCD Watec-902H2
Size, pix.	752×582	752×582
Pixel size, μm	8.6×8.3	8.6×8.3
Scale without bining ("/pix)	0.85	3.87
FoV (deg^2)	0.0252 (10.8' × 8.4')	0.52 (49.6' x 37.4')
Mount	Alt-azimuth	Equatorial
Slew rate, deg/s	4.0	1.0
Tracking	Semiautomatic	No

3.1.2 Optical sensors of AO ONU located at Mayaki station

Most of the telescopes are installed at the observation station of the ONU “Mayaki”, which is located south-west of Odessa, on the bank of the Dniester estuary (longitude 30.2713, latitude 46.3970, height 18.9 m). Currently, four instruments are used to observe Near-Earth objects and space debris (Fig. 6, Table 4): OMT-800, 20 ”Cassegrain, KTS and TAL-250K.


a)


b)


c)

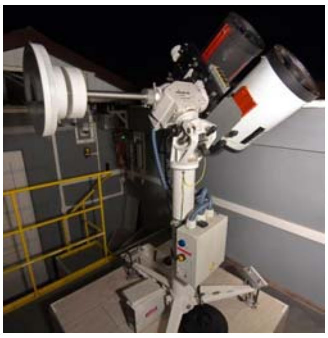

d)

Fig. 6. Optical sensors of AO ONU at the Mayaki station: a) OMT-800; b) 20" Cassegrain; c) KTS; d) TAL-250K.

OMT-800 is a 0.8 m aperture catadioptric anastigmatic telescope, commissioned in 2013 [1]. OMT-800 is intended for positional and photometric observations of spacecraft and space debris in GEO and HEO. Its capabilities allow observing even relatively small fragments, with a magnitude up to 19^m. The **20" Cassegrain** is a classic Soviet-era Cassegrain telescope that is now used for multi-color photometry of objects on GEO. **KTS** is a specialized satellite cine theodolite with a 23 cm 4-lens lens, equipped with a modern CCD camera, designed for observing space objects in different orbits, including tracking objects on LEO, as well as quick surveys of the geostationary area. **TAL-250K** is a small modern telescope of the Klevtsov system on a classic equatorial mount, designed for surveys of the GEO area.

Table 4: The main characteristics of the optical means of AO ONU at the station Mayaki

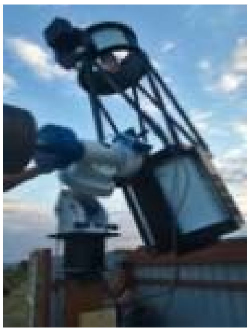
	OMT-800	20" Cassegrain	KTS	TAL-250K
Aperture, cm	80	48	23	25
Focal length, m	2.14	11.05	1.52	2.13
Camera (chip)	FLI ML09000 (Full frame ON Semi KAF-9000)	Single channel photometer (BVR)	Apogee Alta U9000 (Kodak KAF-09000).	FLI ML09000
Size, pix.	3056 x 3056	-	3056 x 3056	3056 x 3056
Pixel size, µm	12	-	12	12
Scale without bining ("/pix)	1.16	-	1.62	1.16
FoV (deg^2)	0.97 (59'x59')	-	1.89 (82.5' x 82.5')	0.3 (33'x 33')
Mount	Equatorial	Equatorial	Alt-azimuth	Equatorial
Slew rate, deg/s	0.75		2.0	2.0
Tracking	Yes (MEO, HEO, GEO)	No	Yes (LEO, MEO, GEO)	Yes (MEO, HEO, GEO)

3.2 Sensors of the Space Research Laboratory of Uzhgorod National University

The Space Research Laboratory of Uzhgorod National University (SRL UzhNU) is engaged in positional and photometric observations of objects on LEO and GEO. It has at its disposal 4 telescopes (Fig. 7), but now it uses mainly two instruments located at the observation station in the village. Derenivka: ChV-400 and Takahashi BRC-250M, it’s characteristics are given in Table 5. **ChV-400** is a Newtonian system telescope with an aperture of 0.4 m. It is intended primarily for positional and photometric observations of NEO and objects on GEO. The **Takahashi BRC-250M** is a Baker-Ritchie-Chretien mirror lens with an aperture of 0.25 m. It is used for positional observation of objects on GEO and MEO, as well as for photometry of LEO objects.

a)

b)



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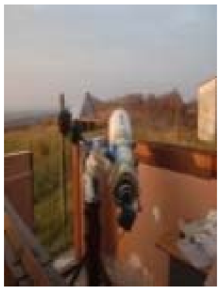

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Fig. 7. Telescopes SRL UNU: a) TPL-1M; b) SBG; c) ChV-400; d) Takahashi BRC-250M.

Table 5: Characteristics of SRL UNU sensors

	ChV-400	Takahashi BRC-250M
Aperture, cm	40	25
Focal length, m	1.75	1.268
Camera (chip)	FLI PL09000 (ON Semi KAF-09000) + BVR filters	Apogee Alta F16M(ON Semi KAF-16803)
Size, pix.	3056 x 3056	4096 x 4096
Pixel size, μm	12	9
Scale without bining ("/pix)	1.43	1.46
FoV (deg^2)	1.44 (1.2° x 1.2°)	≈2.76 (1.66° x 1.66°)
Mount	Equatorial	Equatorial
Slew rate, deg/s	2	2
Tracking	Yes	Yes

3.3 Observational facilities of the Nikolaev Astronomical Observatory

Observations of near-Earth space objects at the Research Institute of NAO [2] are carried out with 4 telescopes (Fig. 8, Table 6). The **KT-50 NAO** telescope is a Maksutov system lens, similar to the AO ONU lens, but equipped with a full-frame CCD camera. The telescope of the Maksutov system with an aperture of 0.3 m is the main objective of the Fast Robotic Telescope (**FRT**). **MEZON** and **AFU-75** are lens objectives with apertures of 0.23 and 0.28 m.

RI NAO's telescopes are used for positional observations of near-Earth objects from LEO to NEO. To increase the permeability of instruments in the absence of mechanical tracking, the methods of "electronic" (using a turntable and CCD in the TDI mode, Fig. 9a) and "digital" (stacking frames with a shift along the trajectory of the object, Fig. 9b)) tracking are used.

a)

b)

c)

d)

Fig. 8. Telescopes of RI NAO: a) KT-50 NAO; b) SAK; c) MEZONE; d) AFU-75

Table 6: Characteristics of RI NAO sensors

	KT-50 NAO	FRT	MEZON	AFU-75
Aperture, cm	50	30	23	28
Focal length, m	3.0	1.5	0.8	0.75
Camera (chip)	Apogee Alta U9 (ON Semi KAF-09000)	Apogee Alta U9 (ON Semi KAF-09000)	Apogee Alta U9 (ON Semi KAF-09000)	Apogee Alta U9 (ON Semi KAF-09000)
Size, pix.	3056×3056	3056×3056	3056×3056	3056×3056
Pixel size, µm	12	12	12	12
Scale without bining ("/pix)	0.8	1.6	3.0	3.3
FoV (deg^2)	0.49 (0.7°×0.7°)	1.96 (1.4°×1.4°)	6.76 (2.6°×2.6°)	7.84 (2.8°×2.8°)
Mount	Alt-azimuth	Alt-azimuth	Alt-azimuth	Alt-azimuth
Slew rate, deg/s	2	20	2	2
Tracking	No	No.	No.	No

a) b)

Fig. 9. Observational techniques, used in the RI NAO: a) "electronic" tracking; b) "digital" tracking.

3.4 Sensors of the Astronomical Observatory of the Lviv National University

The instruments of AO LNU are located at the suburban observation station near the village Bryukhovichi. For positional observations of objects at LEO, old Soviet lens objectives are used: 56-mm **Jupiter-9** on the Meade DS2130 equatorial mount and two 100-mm **Uran-9** mounted on the mount of **TPL-1M** (alt-azimuth mount) and **LD -2** laser rangefinder (four-axis mount) (Fig. 10a, b, Table 7). Observations are carried out using the techniques developed at the RI NAO (see above).

For photometry of LEO objects, a special photometer based on a photomultiplier tube can be used also. It consists of two Cassegrain objectives with an aperture of 0.35 m. It is also mounted on the laser rangefinder LD-2 mount.

Observations of objects on GEO can be carried out with telescopes **AZT-14** (Table 7) and **GLD-250** (Fig. 10c, Table 7). AZT-14 is a LOMO Cassegrain telescope with an aperture of 0.48 m, mounted on an equatorial mount.

a) b) c)

Fig. 10. Telescopes of AO LNU: a) TPL-1M with the lens "Uran-9"; b) A two-channel photometer and a Uran-9 objective on an LD-2 mount; c) GLD-250

Table 7: Characteristics of sensors of AO LNU

	Jupiter-9	Uran-9	Double telescope	AZT-14	GLD-250
Aperture, cm	5.6	10	35	48	25
Focal length, m	0.085	0.25	3.38	7.715	1.250
Camera (chip)	TV CCD WAT-902H2	TV CCD LCL 902K	Photometr with photomultiplier	Trius SX-35 (On-Semi KAI-11002)	SXV-M9 (Sony ICX423AL)
Size, pix.	752 X 582	756 X 592 s		4008 X 2672	752 X 582
Pixel size, µm	8.6 X 8.3	6.69 X 6.69		9 X 9	11.6 X 11.2
Scale without bining ("/pix)	20.1	6.7		0.23	1.8
FoV (deg^2)	13.76 (3.2º X 4.3º)	1.54 (1.1º X 1.4º)		≈0.045 (15.5' X 10.4')	0.12 (24' X 18')
Mount	Equatorial	Alt-azimuth/ 4-axis	4-axis	Equatorial	Equatorial
Slew rate, deg/s	2	2	2	-	-
Tracking	No	Yes	Yes	Noi	No

3.5 Sensors of the Main Astronomical Observatory of the National Academy of Sciences of Ukraine

Instruments for observing near-earth objects of the Main Astronomical Observatory of NASU (MAO NASU) are located on the territory of the Kiev comet station (Lesniki village, IAU MPC code 585). The **Schmidt-Cassegrain telescope** with an aperture of 14 inches is designed to observe the NEA and GEO areas. It is equipped with two cameras at once (Table 8): CMOS and CCD and it is installed on the Ukrainian equatorial mount WS-240. To observe LEO objects, the **CST** (Celestron Satellite Telescope) is used - a wide-field lens mounted on a CGE Celestron mount, modified to an alt-azimuth.

In addition, telescopes of the private Andrushivka observatory [3] and the observatory of Kharkiv National University can be used for surveys of the GEO region.

Table 8: Characteristics of MAO NASU sensors

	14-inch Telescope	CST
Aperture, cm	35.6 (14 inch)	5.6
Focal length, m	3.190	0.085
Camera (chip)	1 camera: QHY-174M GPS (Sony 1/1.2" CMOS IMX174LLJ / IMX174LQJ); 2 camera: SBIG ST-8XME (ON Semi KAF-1603ME)	TV CCD WAT-902H2
Size, pix.	1 camera: 1920 x 1200 2 camera: 1530x1020	752 x 582 pixels
Pixel size, µm	1 camera: 5.86 2 camera: 9	8.6×8.3

Scale without bining ("/pix)	1 camera: 0.94, bin 3 2 camera: 1.44, bin 3	20
FoV (deg^2)	1 camera: ≈0.017 (10′×6.25′) 2 camera: ≈0.028 (12.3′×8.2′)	≈13.46 (4.25° x 3.17°)
Mount	Equatorial	Alt-Azimuth
Slew rate, deg/s	2	2
Tracking	Yes.	No.

4. SOFTWARE FOR PROCESSING OBSERVATIONS OF THE NEAR-EARTH SPACE

Most of the Ukrainian observatories use proprietary software for processing observations. There are also Ukrainian software products designed to process observations from any instrument. The most sophisticated of them is the CoLiTecSAT software - a cross-platform software package for automatic astrometric and photometric processing of frames and automated search for near-Earth spacecraft on them. It is separate version of the software for detection of the Solar System’s small bodies [4].

The software allows you to process frames received both in the tracking mode of the spacecraft and in the hourly tracking mode. After processing, the measurements of the detected objects can be presented in various formats (MPC, MEA, TELEGRAM; TDM is planned to be added in the near future).

The Control Center allows you to manage the process of processing frames. This includes changing settings and configuration frames, launching different types of processing by connecting the appropriate modules.

The interface of the main window of the Control Center includes the following elements (Fig. 11):

1 - Control buttons;
2 - Processing modes;
3 - Program settings;
4 - Messages during processing;
5 - Working area.

Main functions of the Control Center

Intraframe processing:

Luminance alignment of frames of any size (median filter and Fourier analysis);
Autocalibration and automatic removal of "broken" and "hot" pixels;
Adaptive formation of detection thresholds on frames;
Estimation of coordinates for celestial objects.

Fig. 11. Main window of the CoLiTecSAT Control Center

Astrometric and photometric frame reduction:

Fully automatic mode of identification and reduction;
Work with very wide fields of view (up to 10 degrees);
Using the most complete and accurate reference catalogues: USNO B1.0, UCAC5, XPM, Tycho-2, GAIA-DR2;

Automatic rejection of measurements with abnormal errors.

The processing pipeline of the software complex operates according to the following scheme (Fig. 12):
1. Choosing a new series;
2. Selection of the type of processing;
3. Selecting a list of processing modules for the selected mode;
4. Preparation of input data;
5. Control of input data;
6. Start of execution of the sequence of processing modules according to the selected list;
7. Control of modules operation;
8. Output control;
9. Preparation of the imprint;
10. Complete log file and information for the user.

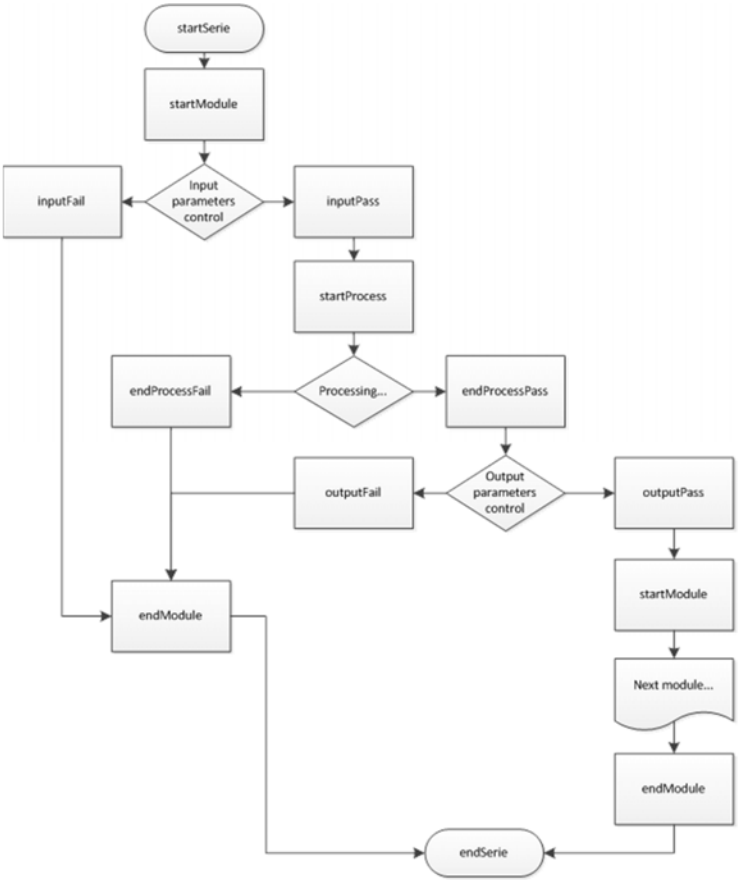


Fig. 12. Diagram of the CoLiTecSAT data processing pipeline

Input information for the Control Center is FITS files of any bit size (*.fit, *.FIT, *.fits, *.FITS, *.fts, *.FTS). The content of files, their structure and headers should be completed in accordance with international standards, using generally accepted identifiers.

Checking the correctness of object detection, manual object detection and generation of measurement files are performed in the **LookSky** program (Fig. 13).

LookSky supports the generation of observation reports in the following formats:
Telegram and Mea - measurements of positions and brightness of artificial earth satellites;
MPCReport - observations in the Minor Planet Center (MPC) format.

In the near future, it is planned to add TDM (Tracking Data Messages) format to the list.

In the latest versions of CoLiTecSAT, there has been a transition to a client-server architecture. Now the processing of frames of any stations is carried out on one server, and the corresponding users only exercise control over the processing and generation of output reports [5].

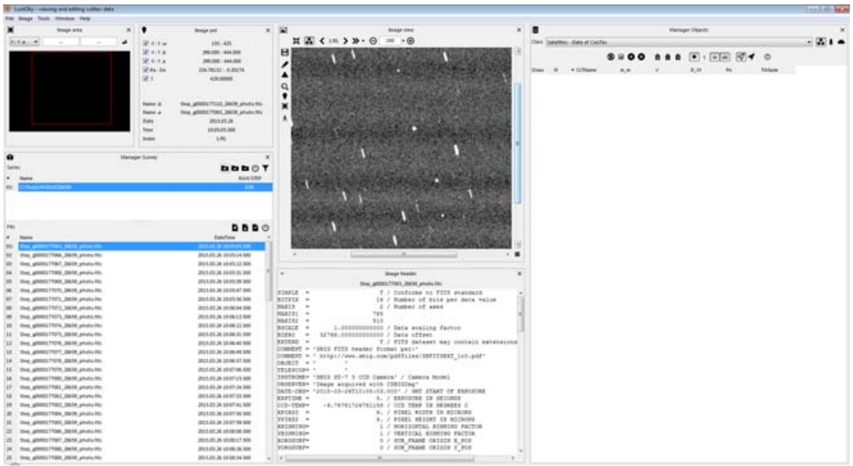


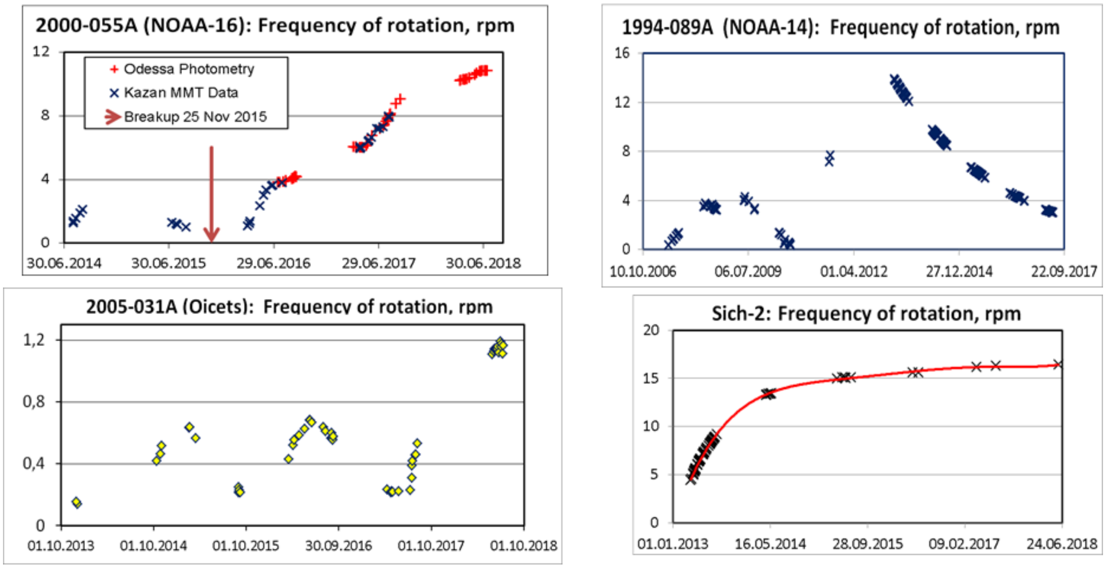
Fig. 13. LookSky's GUI.

5. SOME RESULTS OF THE OPERATION OF UKRAINIAN OPTICAL SENSORS

Of course, it is simply impossible to reflect all the results in such brief report. We have selected only a few of them. In addition to traditional measurements of the positions of the spacecraft and the forecast of orbital motion [6 - 9], non-coordinate observations and, first of all, photometry of spacecraft and space debris have been carried out in Ukraine for many years [10, 11]. For example, in AO ONU using the KT-50 telescope, a database was obtained for photometric observations of LEO objects at large time intervals. Observations using this program were included in the Ukrainian Atlas of Light Curves, created in 2017 by AO ONU together with NSFCTC [12]. Work is underway to analyze the rotation of the spacecraft around the center of mass. Some of the results of this work were presented in [13]. Monitoring the rotation of large objects of space debris shows the complex nature of the change in velocity over an interval of several years (Fig. 14) [14 - 17].

In May 2018, a small observation campaign was carried out to determine the behavior of CubeSat ARKYD 6A (USSPACECOM ID 43130, COSPAR ID 2018-004V). The observations were carried out using the QOS WFoV telescope. Despite the relatively low brightness of the object and poor weather conditions, we managed to obtain several "good" light curves, the analysis of which by specialists of SRL UNU showed that the spacecraft has lost its 3-axis orientation and rotates with a period of about 145 seconds (Fig. 15) [18].

In the summer of 2019, at the request of ISRO, Ukrainian sensors carried out observations of the launch objects of the Indian lunar station Chandrayan-2. As a result, not only qualitative positional observations of the lunar station and the cryogenic stage were obtained (Fig. 16), but also photometric observations of the cryogenic stage, which made it possible to evaluate the features of its behavior in orbit (Fig. 17). QOS WFoV telescope (photometric and positional observations), OMT-800 (positional observations) and ChV-400 (photometric observations) participated in the observations.



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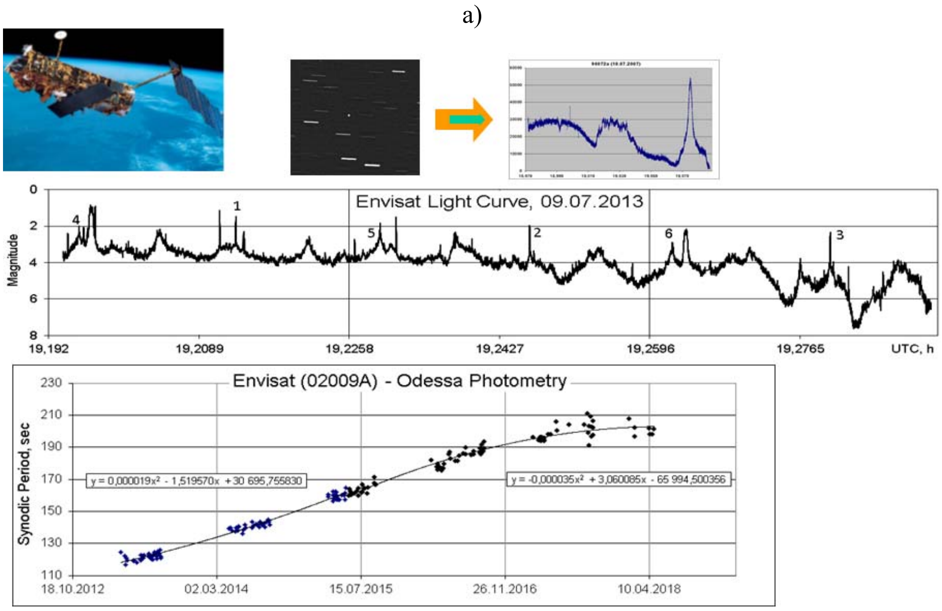
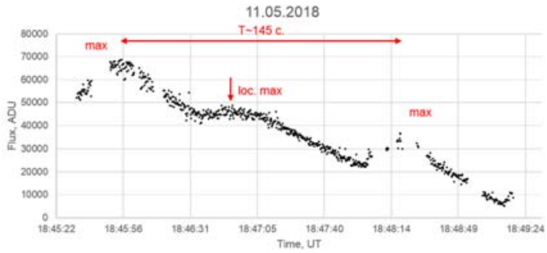
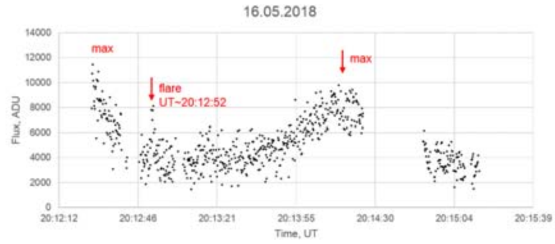


b)

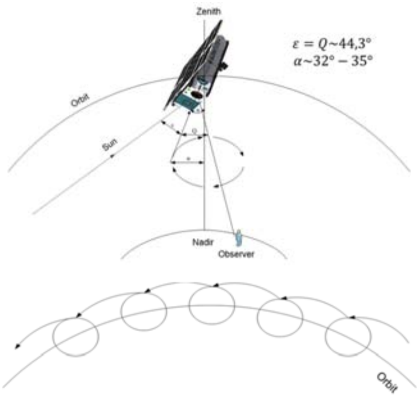
Fig. 14. Change of the synodic period (frequency) of rotation of some low-orbit space objects, obtained as a result of long-term photometric monitoring in the AO ONU: a) NOAA-14, NOAA-16, Sich-2 and Oicets; b) Envisat.



a)

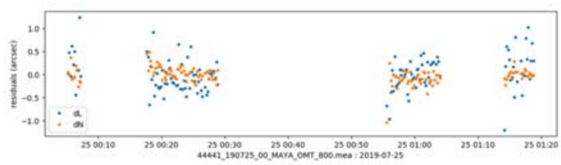


b)

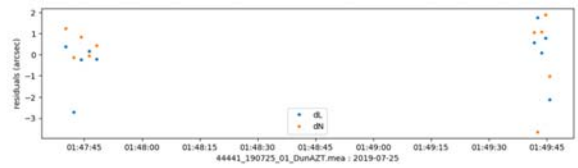


c)

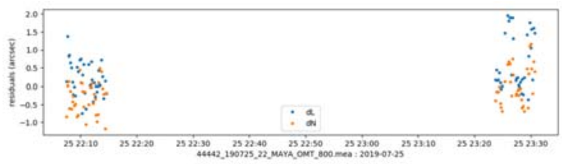
Fig. 15. Analysis of the rotation of the ARKYD 6A spacecraft: a) analysis of the light curve for 11.05.2018; b) analysis of the light curve for 16.05.2018; c) parameters of spacecraft rotation according to the results of observations [18].



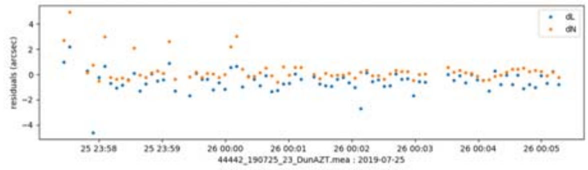
a)



b)

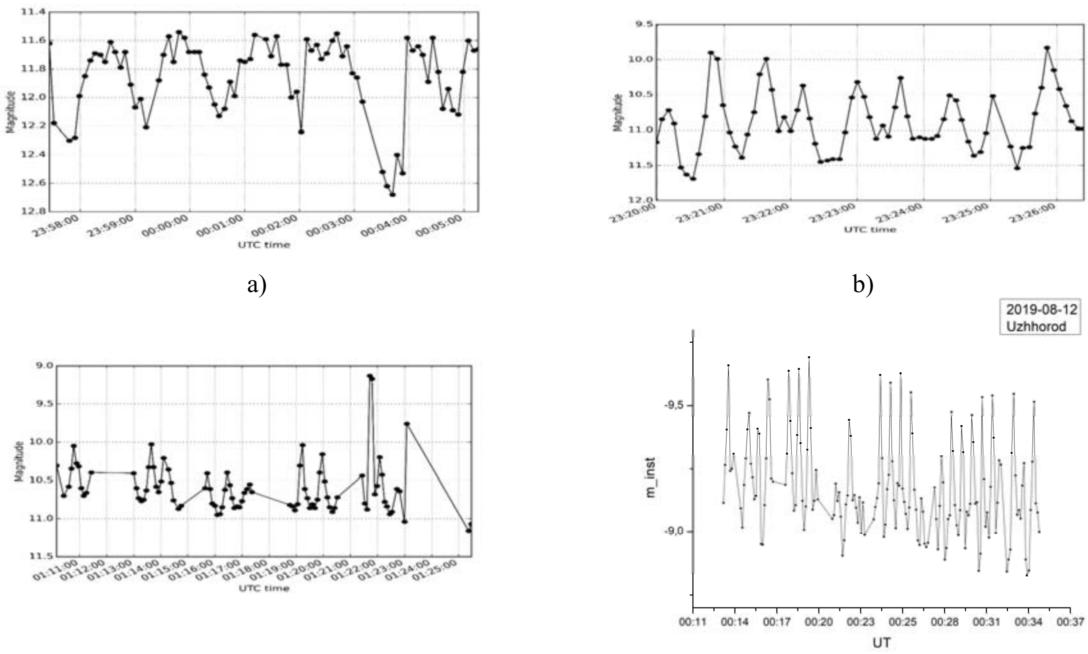


c)



d)

Fig. 16. Positional observations of Chandrayan-2 launch objects: a) 44441, OMT-800 - night from 24.07 to 25.07 2019; b) 44441, QOS WFoV - night from 24.07 to 25.07. 2019; c) 44442, OMT-800 - night from 25.07 to 26.07.2019; d) 44442, QOS WFoV - night from 25.07 to 26.07.2019.



a) b) c) d)

Figure: 17. Light curves of 44442 with rejected anomalous observations: a) QOS WFoV - night from 25.07 to 26.07.2019; b) QOS WFoV - night from 29.07 to 30.07.2019; c) QOS WFoV - night from 30.07 to 31.07.2019; d) ChV-400 - night from August 11 to August 12, 2019 (instrumental light curve).

6. CONCLUSIONS

In spite of the existing financial problems, the replenishment of the Ukrainian sensors is gradually proceeding as due to the modernization of existing instruments, so also by creating completely new ones. The country has created original effective means of conducting and processing observations of Near-Earth space objects.
Problems to be solved in the near future:

cooperation of all Ukrainian instruments into a single network;
increasing the level of automation of sensors;
more active participation in international programs for the observation of Near-Earth objects.

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