https://doi.org/10.18524/1810-4215.2023.36.290222

TEST OPTICAL OBSERVATIONS OF THE COSMOS 1408 FRAGMENTS

O.M.Kozhukhov [1], Y.V.Omelchenko [1], D.M.Kozhukhov [1], O.G.Solomakha [1], M.V.Kulichenko [2], O.V.Shulga [2], Y.S.Kozyrev [2], N.V.Maigurova [2]

[1] National Space Facilities Control and Test Center, State Space Agency of Ukraine, Kyiv, Ukraine, *a.m.kozhukhov@gmail.com*

[2] Research Institute "Mykolaiv Astronomical Observatory", Mykolaiv, Ukraine, *nadya.maigurova@gmail.com*

ABSTRACT. The non-functioning spacecraft COSMOS 1408 (NSSDCA/COSPAR ID: 1982-092A) was destroyed as a result of tests involving Russian anti-satellite weapons on 15 November 2021. This led to the creation of a significant debris cloud that poses a threat to other objects in low Earth orbit (LEO), particularly those in close orbits. More than 1500 of these fragments reached trackable sizes. Such events require rapid and immediate monitoring through all available ground tracking means, including radar and optical observation. The following study presents the results of optical observations of the selected fragments of COSMOS 1408 in Ukraine. These observations were carried out by the telescope OES30 from the National Space Facilities Control and Test Center of the State Space Agency of Ukraine and the Fast Robotic Telescope (FRT) of the Research Institute "Mykolaiv Astronomical Observatory" in February 2022. The observations demonstrated that Ukrainian optical sensors are capable of tracking LEO space debris objects with radar cross-sections (RCS) less than 0.1 square meters when relatively accurate ephemeris data is available. The astrometric reduction has been performed for the acquired frames with fragments of the satellite, which revealed that orbital parameters of a significant part of the targeting objects were close to the orbital parameters of the original satellite before the event. Furthermore, the results of processing the available observations indicated that the range of apogee heights significantly exceeds the range of perigee heights. These findings align with conclusions drawn by previous researchers. In the future, it will be essential to assess the capabilities of sensors for observing the aftermath of object destruction in LEO, especially during the initial hours and days following such events when precise debris orbit data may be lacking.

Keywords: space debris, optical observations.

АНОТАЦІЯ. Недіючий космічний апарат COSMOS 1408 (NSSDCA/COSPAR ID: 1982-092A) був знищений в результаті випробувань російської протисупутникової зброї 15 листопада 2021 року. Це призвело до створення величезної хмари уламків, які становлять загрозу для інших низькоорбітальних об’єктів, що знаходяться на близьких орбітах. Більше 1500 з цих фрагментів мали розміри, які можна відстежувати. Такі події вимагають швидкого та негайного моніторингу за допомогою всіх доступних засобів наземного відстеження, включаючи радіолокаційні та оптичні спостереження. В цьому дослідженні наведено результати оптичних спостережень окремих фрагментів супутника COSMOS 1408, що були отримані в Україні. В спостереженнях приймали участь телескоп OEC30 станції оптико-електронного спостереження Національного центру управління та випробування космічних засобів Державного космічного агентства України та Швидкісний автоматичний комплекс (ШАК) науково-дослідного інституту (НДІ) «Миколаївська астрономічна обсерваторія» у лютому 2022 року. Спостереження показали, що українські оптичні засоби спостереження здатні спостерігати об'єкти космічного сміття на низьких навколоземних орбітах з радіолокаційним перетином менше 0.1 кв. м. при наявності відносно точних ефемеридних даних. Була проведена астрометрична редукція отриманих кадрів з окремими фрагментами супутника, яка показала, що орбітальні параметри значної частини об’єктів, що спостерігалися, були близькими до орбітальних параметрів супутника перед подією. Крім того, результати обробки наявних спостережень вказують на те, що діапазон висот в апогеї значно перевищує діапазон висот в перигеї. Ці висновки узгоджуються з висновками, зробленими іншими дослідниками. У майбутньому буде важливо оцінити можливості спостережень за наслідками руйнування об'єкта на НЗО, особливо в перші години та дні після подібних подій, коли можуть відсутні точні дані про орбіту сміття.

Ключові слова: космічне сміття, оптичні спостереження.

1. Introduction

Spacecraft COSMOS 1408 was destroyed on 15 November 2021 as a result of tests of Russian anti-satellite weapons and the huge cloud of debris that poses a threat to other LEO objects in close orbits was generated. Also known that this event was the reason for the creation of a permanent Internal Task (IT) for the observation of LEO fragmentation events in Working Group 1 of Inter-Agency Space Debris Coordination Committee (IADC WG1).

Table 1: OES30 Specifications (Romanyuk et al, 2021 as OEOS-2)

	OES 30	FRT
Aperture,mm	300	300
Focal length, mm	300	1500
Camera (chip)	QHY-174M GPS (Sony 1/1.2" CMOS IMX174LLJ / IMX174LQJ)	Apogee Alta U9000
Size, pix.	1936x1216	3056 × 3056
Pixel size, µm	5.86	12
Scale without bining ("/pix)	4.01	1.6
FoV (deg^2)	2.89 (130'x80')	1.96 (83'× 83')
Slew rate, deg/s	Up to 10	Up to 20
Tracking	yes	no

In order to monitor the debris cloud special international campaign for observation of fragments of this event was organized in February 2022. The purpose of these observations was to determine whether telescopes with our receivers can observe such debris using standard observation modes and techniques.

2. Equipment and Observation Techniques

Two instruments participated in the observations of COSMOS 1408 debris fragmentations. These were the Type 2 Optoelectronic Observation Station (OEOS-2 or OES30) telescope of the National Space Facilities Control and Test Center of the State Space Agency of Ukraine and the Fast Robotic Telescope (FRT) of the Mykolaiv Astronomical Observatory.

OES30 (or OEOS-2) located near Kyiv. Telescope was installed in 2019 and have modified German with direct drive mount. Standard tracking mode was used for the observations.

Fast Robotic telescope (FRT) was designed and manufactured by NAO in 2004. Maksutov mirror lens and rotating platform with photographic lenses are installed on the parallactic mount telescope. Time delay and integration (TDI) mode with rotation stage are used for the observations.

Some characteristics of the used telescopes are given in the Table 1.

3. Proceeding resuts

3.1 OES30

The observations were made on February 13, 2022. A total of 6 fragments were observed. Observations were carried out with an exposure of 0.3 s with tracking mode. Detailed information about observation frames are given in Table 2, where ID and RCS (S – Small, M – Medium) column given

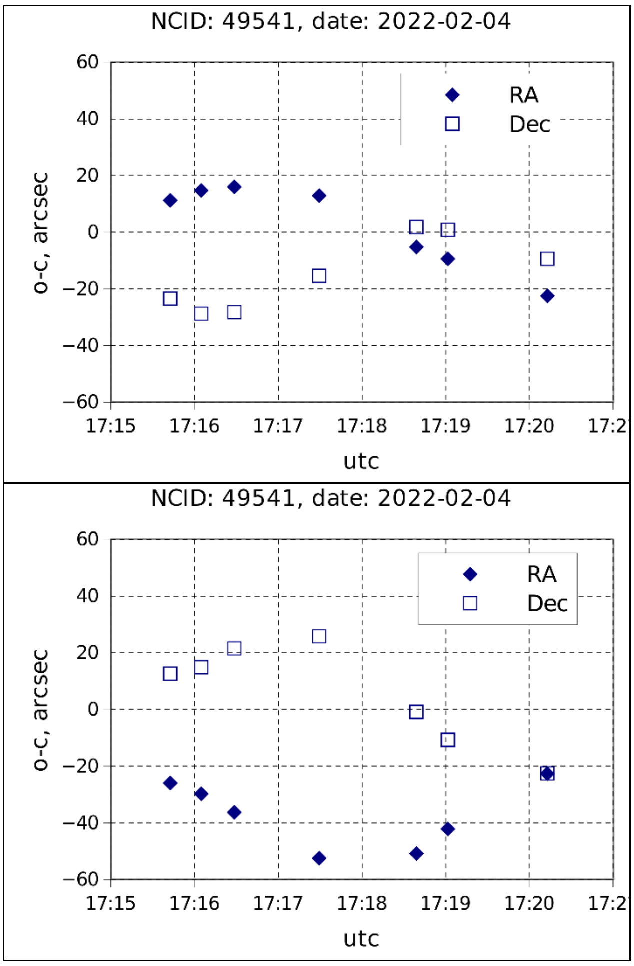

Figure 1: Residual differences (O – C) vs UTC, where O – obtained positions, C – ephemeris data (down – USSPACECOM, up – FindOrb).

according unclassified USSPACECOM (previously NORAD) catalogue (https://www.space-track.org) data. The main orbital parameters close to the observation epoch from USSPACECOM catalogue, are shown in Table 3. As could be shown from tab.3 the objects have similar orbit parameters values.

3.2 FRT

FRT observations were performed on 4 and 11 February 2022. Results of astrometric reductions were shown that positional accuracy of reference stars is about 1 arcsec in both coordinates. The limited magnitude was 13^{mag} with in exposure 1^s. Detailed information about FRT observational data are shown in table 2 and 3.

The Fig. 1 shows the trend of residual differences between the obtained positions (from FRT observations) and the ephemeris data USSPACECOM (https://celestrak.org/NORAD/elements/) and FindOrb software (https://www.projectpluto.com/sat_id2.htm) for the object 49541. It can be noted that the positional differences between the FindOrb ephemeris and obtained observations are smaller

Table 2: Statistics of the observational data

ID	COSPAR ID	N	RCS	Data	Tel
49528	1982-092-R	133	S	Feb.13	OES30
49540	1982-092-AD	88	M	Feb.13	OES30
49582	1982-092-BX	137	S	Feb.13	OES30
49634	1982-092-EB	115	S	Feb.13	OES30
49635	1982-092-EC	120	S	Feb.13	OES30
49662	1982-092-EH	100	M	Feb.13	OES30
49522	1982-092-K	3	M	Feb.04	FRT
49530	1982-092-T	6	M	Feb.04	FRT
49531	1982-092-U	3	M	Feb.04	FRT
49535	1982-092-Y	1	M	Feb.04	FRT
49537	1982-092-AA	1	M	Feb.04	FRT
49538	1982-092-AB	1	M	Feb.04	FRT
49541	1982-092-AE	7	M	Feb.04	FRT
49576	1982-092-BR	1	M	Feb.04	FRT
49590	1982-092-CF	2	M	Feb.04	FRT
49626	1982-092-DT	1	M	Feb.04	FRT
49653	1982-092-EW	1	M	Feb.04	FRT
49694	1982-092-GP	2	M	Feb.04	FRT
49707	1982-092-HC	2	S	Feb.04	FRT
49723	1982-092-HU	2	M	Feb.04	FRT
49784	1982-092-JA	1	S	Feb.04	FRT
49787	1982-092-JD	1	M	Feb.04	FRT
49789	1982-092-JF	1	M	Feb.04	FRT
49822	1982-092-KD	1	M	Feb.04	FRT
50010	1982-092-QW	1	M	Feb.04	FRT
50026	1982-092-RN	1	M	Feb.04	FRT
49530	1982-092-T	1	M	Feb.11	FRT
49694	1982-092-GP	4	M	Feb.11	FRT

than between the ephemeris from USSPACECOM catalogue and observations. However, the small number of points and short arc of observations involved in the initial orbit determination using FindOrb and atmosphere drug influence has not been taken into account.

4. Brief Analysis of Results

The graph (Fig. 2) clearly shows a dense group of objects, whose orbit parameters are close to those of the satellite before fragmentation. Something similar was also observed in the TIRA observations obtained in November 2022. (Cerutti-Maori et al, 2023).

It is also worth noting that the difference in the perigee heights of these objects is much smaller than the difference in the perigee heights (Fig. 3). This is in good agreement with other observations (Fig. 4) (Ramos et al., 2022, Oltrogge D.L. et al. 2022).

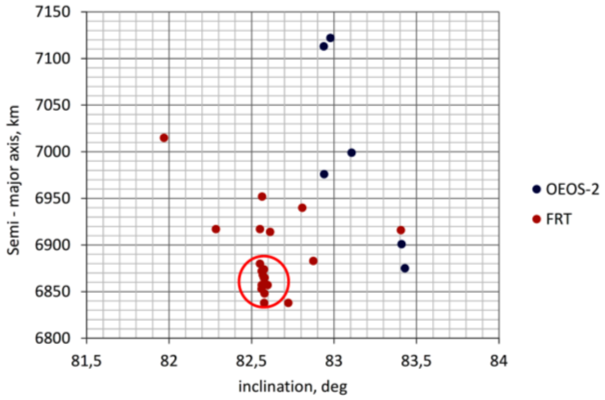

Figure 2: Orbital parameters of the observed fragments: semi-major axis - inclination. The group of objects with orbits close to the COSMOS-1408 orbit before the event is marked with a red circle.

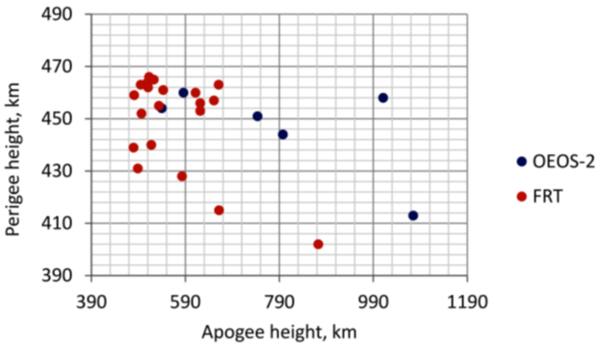

Figure 3: Orbital parameters of the observed fragments: perigee heght – apogee height.

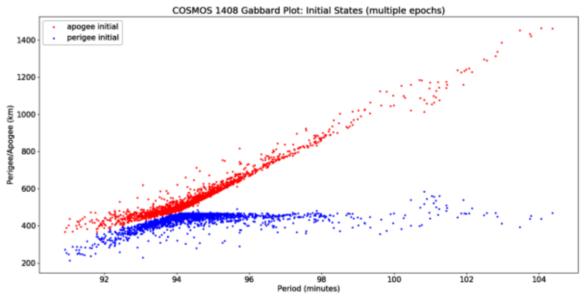

Figure 4: COSMOS 1408 Gabbard Plot-Initial States (Ramos et al, 2022).

5. Conclusion

Ukrainian optical sensors are able to observe LEO space debris objects with RCS less than 0.1 sq. m. in the presence of relatively accurate ephemeris.

The orbital parameters of a significant part of the observed objects were close to the orbital parameters of the original satellite before the event. It can also be observed that the range of apogee heights is much larger than the perigee heights. These facts are also confirmed by reports of observations by other participants that were made earlier.

Table 3: Main orbital parameters of objects for an epoch close to the observation epoch

ID	Epoch (UTC) 2022	Inclination	Semi-major axis, km	Apogee, km	Perigee, km	Tele-scope
49528	02-12 11:34:18	82.978°	7 122	1 075	413	OES30
49540	02-12 17:25:03	83.107°	6 999	798	444	OES30
49582	02-12 11:04:00	82.940°	6 976	744	451	OES30
49634	02-12 17:47:43	83.410°	6 901	586	460	OES30
49635	02-12 10:51:29	82.938°	7113	1011	458	OES30
49662	02-12 17:47:11	83.430°	6875	540	454	OES30
49522	02-03 17:19:52	82.579°	6848	481	459	FRT
49530	02-0312:43:32	83.405°	6 916	622	453	FRT
49531	02-03 17:59:31	82.874°	6 883	583	428	FRT
49535	02-03 12:38:17	82.562°	6 857	495	463	FRT
49537	02-03 18:02:16	82.564°	6952	651	457	FRT
49538	02-03 17:54:24	82.284°	6917	662	415	FRT
49541	02-03 12:16:44	82.808°	6 940	661	463	FRT
49576	02-03 17:26:56	82.598°	6 857	518	440	FRT
49590	02-03 18:27:20	82.551°	6 917	622	456	FRT
49626	02-03 17:57:12	82.561°	6853	497	452	FRT
49653	02-03 19:23:44	82.551°	6880	543	461	FRT
49694	02-03 17:31:11	82.580°	6 865	511	462	FRT
49707	02-03 19:38:58	82.723°	6 838	489	431	FRT
49723	02-03 21:56:30	81.969°	7 015	873	402	FRT
49784	02-03 17:53:08	82.568°	6 868	513	466	FRT
49787	02-03 12:35:04	82.574°	6865	510	464	FRT
49789	02-03 12:54:33	82.613°	6914	612	460	FRT
49822	02-03 12:29:39	82.576°	6874	534	455	FRT
50010	02-03 18:05:18	82.562°	6 872	523	465	FRT
50026	02-03 18:05:21	82.577°	6838	480	439	FRT

In the future, it is necessary to evaluate the capabilities of sensors to observe the consequences of fragmentation of objects on the LEO in the absence of accurate data on the orbits of debris (the first hours and days after the event).

References

Romanyuk Ya.O., Shulga O.V., Shakun L.S. et al.: 2021, *Odessa Astron. Publ.*, **34**, 85.

Cerutti-Maori D., Carloni C., Rosebrock J., Siminski J.: 2023, *Proc. 2nd NEO and Debris Detection Conference, Darmstadt*, Germany, 24-26 January 2023, published by the ESA Space Safety Programme Office, Ed. T.Flohrer, R.Moissl, F.Schmitz, [online] Available at: (https://conference.sdo.esoc.esa.int/proceedings/neosst2/paper/38/NEOSST2-paper38.pdf) [Accessed 7 September 2023].

Ramos C., Hutchinson D., Skrehart B., Gillespie D., McKissock D.: 2022, *Proc. of 23 Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS)*, 283.

Oltrogge D.L., Alfano S., Hall R.: 2022, *Proc. of 23 Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS)*, 1875.