Inter-Agency Space Debris Coordination Committee

IT 34.1

Feasible options to study Molniya population of space debris

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

IT 34.1

Description

The internal task aims to promote a coordinated precursor observing campaign:

- Joint observation of calibration target, in order to improve observation strategies, analysis methods and results refinement and to foster findings exchange among participants.
- Statistical search for uncatalogued Molniya objects.
- Accurate orbital determination of some Molniya-like target objects to investigate long term orbital evolution.
- Statistical survey for some target Molniya-like objects aiming to investigate coupling between attitude dynamics and orbit evolution.
- Support forensics of events in Molniya.

Inter-Agency Space Debris Coordination Committee

IT 34.1

Statistical survey

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

Statistical survey

Planning

To perform **orbit determination** on these 10 targets, it is necessary to acquire **measurements both when they are at apogee and at perigee**. To observe as **many objects as possible** during a single night, instead of continuously observing the object for an extended period while it is at apogee, it is preferable to **observe it twice during the same pass**, leaving a temporal interval between observations. This also **extend the observed arc of the orbit**.

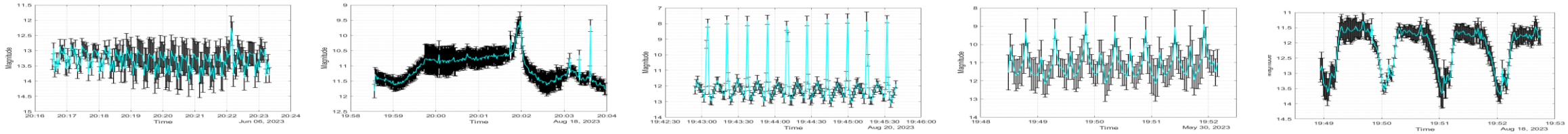
The details for this campaign were:

- **Targets**: 10 objects in TLE tracking
- **Observation period**: Jul. 2023 – Apr. 2024
- **Analysis**: astrometric and photometric
- **Apogee observation**: one series with minimum 200 frame or two series with minimum 100 frame each one
- **Perigee observation**: one series with as high number of frames as possible
- **Output for each observation**: the observatory coordinates and one TDM with topocentric RA, Dec and one TDM with observed luminous flux

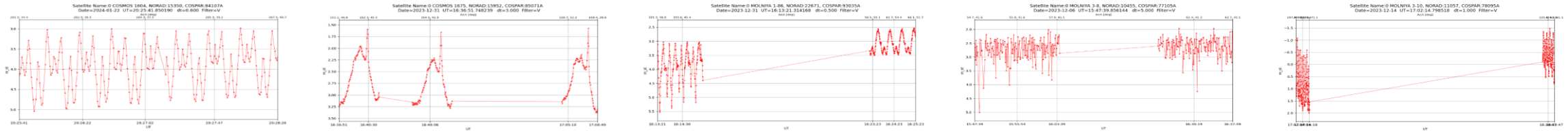
Statistical survey

Participation

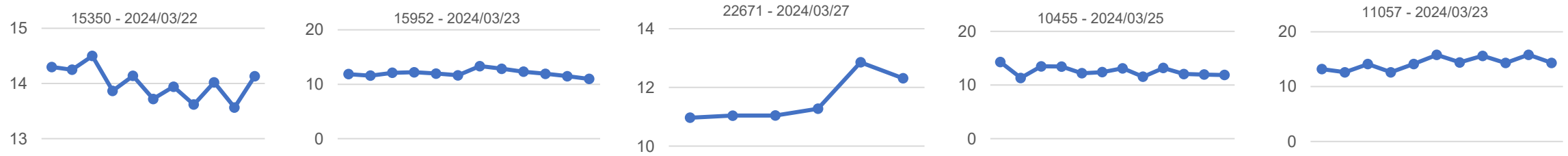
ASI: **92 Molniya** satellites belonging to recent or past constellations were selected by ASI. **About 50% of these objects were observed** and **10 objects** with interesting light curves **were selected** among them.



SSAU: Up to April 2024, measurements have been obtained from **6 telescopes over 73 nights**, with some nights **involving observations from multiple telescopes**.



CSA: In March 2024, **space-based measurements** were obtained from **NEOSSat**. The CSA successfully collected measurements over the course of **six consecutive days**, covering **9 of the 10 designated targets**.

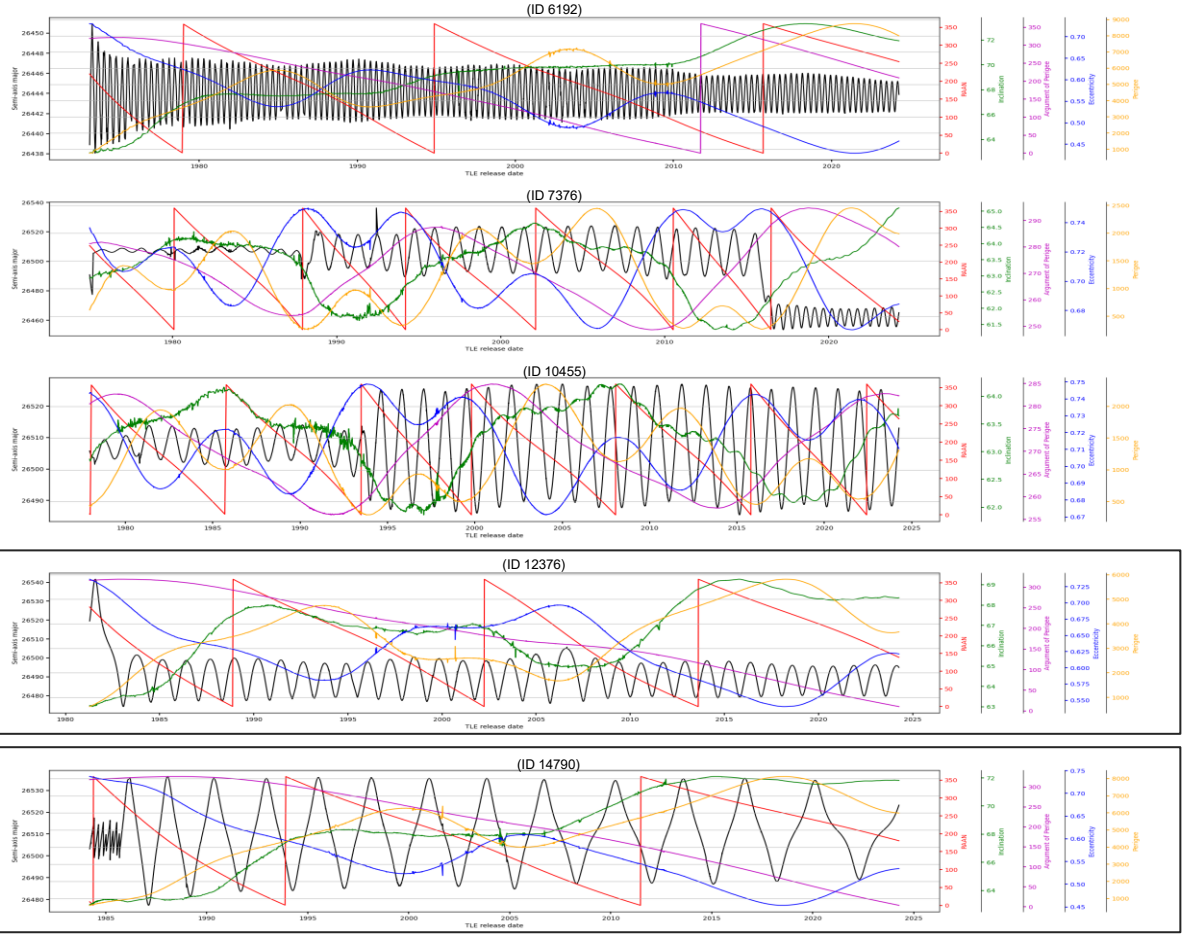


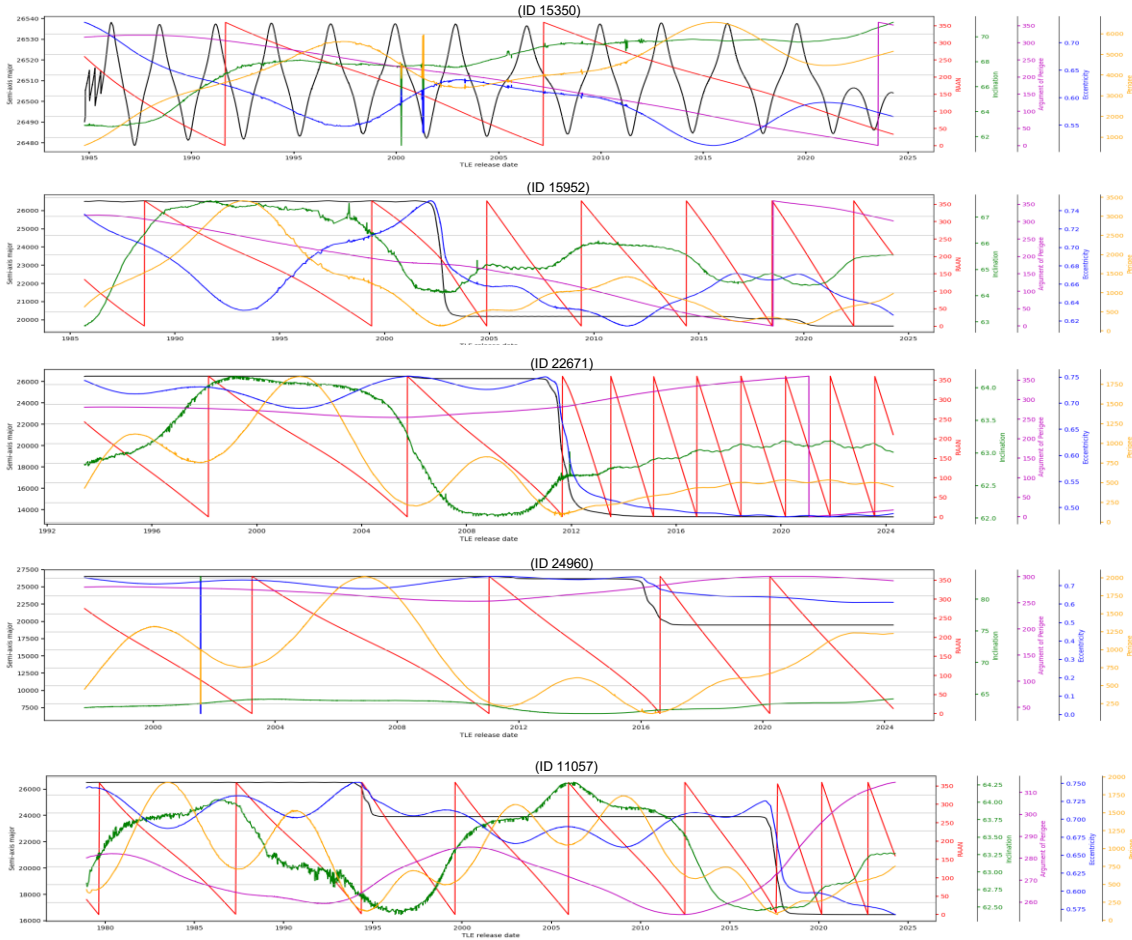
Inter-Agency Space Debris Coordination Committee

Statistical survey

COEs trends

Of these 10 targets **12376 and 14790 have the perigee in the north hemisphere**. It can be interesting to understand **if and how the attitude motion has affected this change**.





Inter-Agency Space Debris Coordination Committee

IT 34.1

Statistical search

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

Statistical search

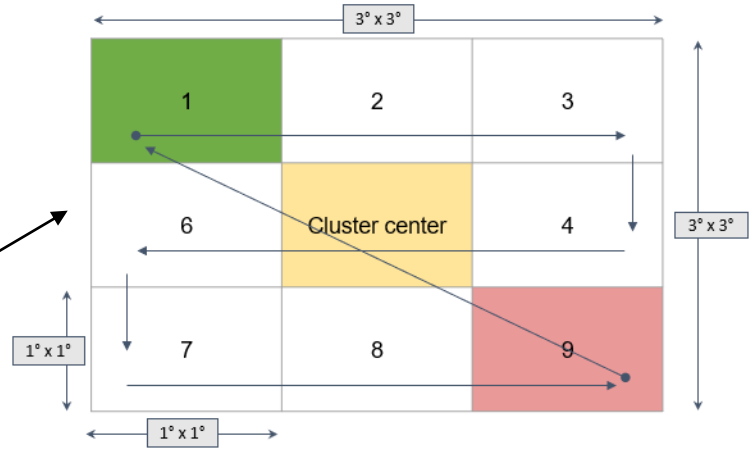
Planning

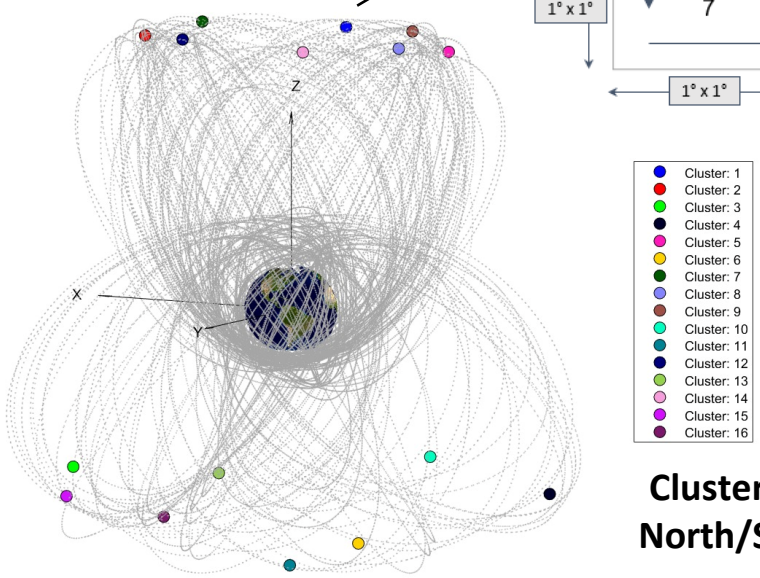
The method presented to identify new objects is based on observe regions in which the current catalogued Molniya apogee density is maximum. The strategy tries to guarantees the acquisition of **more than one frame for the observation of an object**.

The details for this campaign were:

- **Observation mode:** sidereal tracking
- **Observation period:** from March 18th, 2024, to March 24th, 2024
- **Observation duration:** 7 days
- **Suggested consecutive nights:** 3 nights (minimum 2 nights)
- **Suggested observation duration:** 6 hours/night (minimum 4 hours/night)
- **Analysis:** astrometric
- **ROI acquisition strategy:** scanning at least two time the chosen cluster
- **Cluster acquisition strategy:** at least two consecutive frames for each sub region inside the chosen cluster

Cluster observation strategy





Clusters centroids in the North/South Hemisphere

Inter-Agency Space Debris Coordination Committee

Statistical search

Participation

- **ASI**

Three nights of observation were conducted to verify the strategy, focusing on one cluster. Then, **six more nights** of observation were conducted, but with both cameras of the SCUDO observatory, and different clusters was observed. ASI was only able to observe **for two consecutive days**, **March 19th and 20th**, during the planned week due to unfavourable weather conditions.

- **SSAU**

During the survey phase, SSAU conducted observations over **three consecutive nights using a single telescope**. Each night, a varying number of fields of view were captured, with **five frames for each field**. On **March 18th, cluster 3** was targeted with **225 fields** acquired, followed by **227 fields** acquired for **cluster 5 on March 19th**. On **March 20th**, another observation of **cluster 3** was conducted, capturing **251 fields**, **totalling 3515 images**. During this period, **a total of 12 objects were detected, including 2 UTCs, 1 in LEO, and 3 in MEO**.

- **DLR**

DLR conducted observations **from Chile** over the course of **three nights**, specifically **on March 19th, 21st, and 24th**, during which they acquired over **2000 images in total**. The analysis of these images is currently underway, and as such, the exact number of tracklets and objects acquired is not yet known.

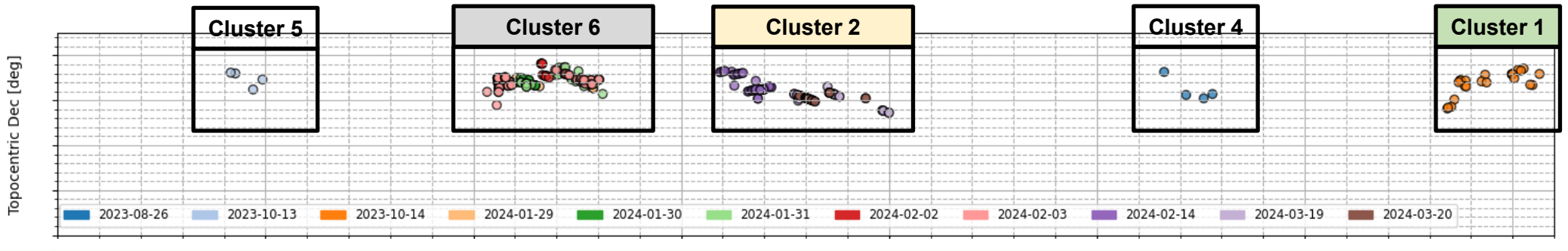
- **CNSA**

5 night of observation was carried out by CNSA from March 18th to March 24th and the data reduction is in progress.

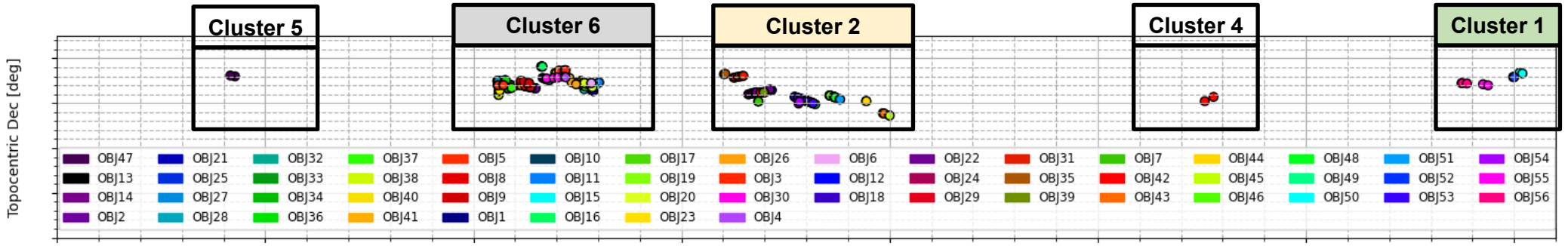
Statistical search

UTCs from ASI

UTCs
Nº tracklets = 260



Associations
Nº objects = 56

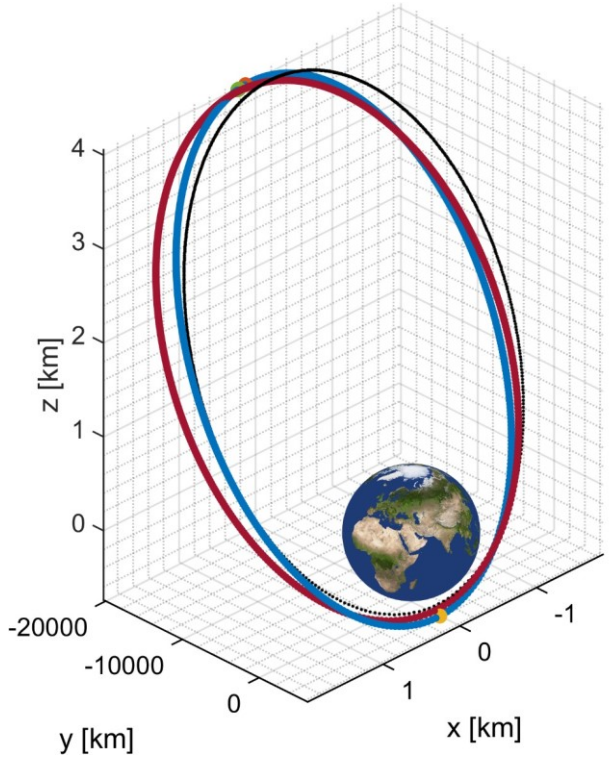


Statistical survey

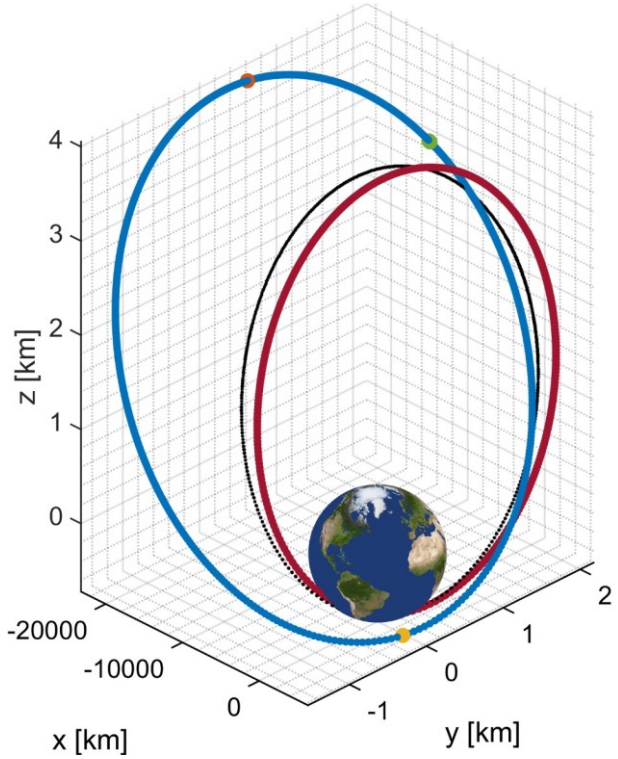
IOD / OD for catalogued

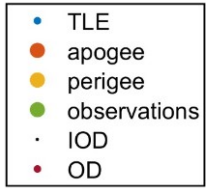
To test the IOD method was performed a comparison between the orbit generated by propagating the TLE of the observed object and the orbits generated using two-point IOD and OD based on all available measurements (10 for NORAD ID 47719 and 4 for NORAD ID 23645).

Apogee observation



Near apogee observation





Angular Errors in Perigee observation

	IOD	OD
Apogee	7.194 deg	39.897 deg
Near apogee	139.435 deg	134.339 deg

Considerations:

The IOD method imposes the apogee near to the acquired measurements, so:

- If the measurements are not taken at the apogee, both IOD and OD orbits presents large error.
- If the **measurements** are taken **at apogee**, **both IOD and OD yield consistent orbits**.

Inter-Agency Space Debris Coordination Committee

IT 34.1 – Statistical survey

Conclusions

- ASI, SSAU and CSA have collected measurements for the 10 targets.
  - Can be interesting to **examine the light curves of these objects** and, if possible, **compare them with the ones of satellites launched during the same period that have not changed their period** (if available).
- The list with the 10 targets was passed by ASI to the **WG2** to **simulate the behaviour of fragmentation in Molniya** for objects that have different orbits. This simulation aims to elucidate how these objects, subjected to distinct orbital perturbations over time, respond to such influences.
  - Can be interesting to examine the light curves of all those simulated by WG2 **to understand if they differ from each other or exhibit similarities**.
- No accurate orbital determination of the 10 target objects was performed.
  - Can be interesting to propagate the initial condition at the beginning of the operational **orbit to see what happened from that moment until the perigee flipped**, and hopefully conduct a dynamic analysis.

IT 34.1 – Statistical survey

Considerations

The list with the 10 targets was passed by ASI to the **WG2** to **simulate the behaviour of fragmentation in Molniya** for objects that have different orbits. This simulation aims to elucidate how these objects, subjected to distinct orbital perturbations over time, respond to such influences.

SATELLITE NAME	NORAD ID	LAUNCH DATE	BREAKUP DATE	DEB CAT	DEB LEFT	ASSESSED CAUSE ADDITIONAL INFORMATION
SPUTNIK 29	443	24-Oct-62	29-Oct-62	24	0	PROPULSION MOLNIYA FINAL STAGE
COSMOS 862	9495	22-Oct-76	15-Mar-77	13	5	**DELIBERATE SELF-DESTRUCT**
COSMOS 931	10150	20-Jul-77	24-Oct-77	6	5	**DELIBERATE SELF-DESTRUCT**
COSMOS 903	9911	11-Apr-77	08-Jun-78	6	2	**DELIBERATE SELF-DESTRUCT**
COSMOS 1030	11015	06-Sep-78	10-Oct-78	13	9	**DELIBERATE SELFDESTRUCT**
COSMOS 917	10059	16-Jun-77	30-Mar-79	17	15	**DELIBERATE SELF-DESTRUCT**
COSMOS 1124	11509	28-Aug-79	09-Sep-79	6	6	**DELIBERATE SELF-DESTRUCT**
COSMOS 1109	11417	27-Jun-79	01-Feb-80	20	9	**DELIBERATE SELF-DESTRUCT**
COSMOS 1188	11844	14-Jun-80	26-Aug-80	8	6	**DELIBERATE SELF-DESTRUCT**
COSMOS 1261	12376	31-Mar-81	01-Apr-81	11	11	**DELIBERATE SELF-DESTRUCT**
COSMOS 1191	11871	02-Jul-80	14-May-81	11	11	**DELIBERATE SELF-DESTRUCT**
COSMOS 1305 R/B	12827	11-Sep-81	11-Sep-81	8	8	PROPULSION MOLNIYA FINAL STAGE
COSMOS 1247	12303	19-Feb-81	20-Oct-81	8	7	**DELIBERATE SELF-DESTRUCT**
COSMOS 1285	12627	04-Aug-81	21-Nov-81	25	25	**DELIBERATE SELF-DESTRUCT**
COSMOS 1217	12032	24-Oct-80	12-Feb-83	10	7	**DELIBERATE SELF-DESTRUCT**
COSMOS 1481	14182	08-Jul-83	09-Jul-83	9	8	**DELIBERATE SELF-DESTRUCT**
COSMOS 1456	14034	25-Apr-83	13-Aug-83	4	0	**DELIBERATE SELF-DESTRUCT**
COSMOS 1317	12933	31-Oct-81	25-Jan-84	11	11	**DELIBERATE SELF-DESTRUCT**
COSMOS 1348	13124	07-Apr-82	02-Sep-84	11	11	**DELIBERATE SELF-DESTRUCT**
COSMOS 1278	12547	19-Jun-81	01-Dec-86	3	0	**DELIBERATE SELF-DESTRUCT**

18 DELIBERATE SELF-DESTRUCT FROM 1962 to 1986

Reference:

History of On-orbit Satellite Fragmentations, 16th Edition

Inter-Agency Space Debris Coordination Committee

IT 34.1 – Statistical survey

Conclusions

Propulsion-related breakups, currently the most frequent class, include catastrophic malfunctions during orbital injection or maneuvers, subsequent explosions based on residual propellants, and failures of active attitude-control systems.

Breakups of rocket bodies due to propulsion failures are usually more prolific and produce longer lived debris than the intentional destruction of payloads, often due to the higher altitudes of the malfunctioning rocket bodies rather than the mechanics of the explosive event. Breakups of the Soviet/Russian Blok-DM *Sistema Obespecheniya Zapuska* (SOZ) ullage motors have high probability of fragmentation.

COSMOS 1519-21	14608	29-Dec-83	04-Feb-91	8	3	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1710-12	16446	24-Dec-85	29-Dec-91	17	10	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2054	20399	27-Dec-89	01-Jul-92	14	2	PROPULSION PROTON-K BLOCK DM SOZ
GORIZONT 17	19771	26-Jan-89	17-Dec-92	1	0	PROPULSION PROTON-K BLOCK DM SOZ
GORIZONT 18	20116	05-Jul-89	12-Jan-93	2	0	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2204-06	22067	30-Jul-92	08-Nov-94	4	2	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2282	23174	06-Jul-94	21-Oct-95	2	0	PROPULSION PROTON-K BLOCK DM SOZ
RADUGA 33 R/B	23797	19-Feb-96	19-Feb-96	1	0	PROPULSION PROTON-K BLOCK DM
COSMOS 1883-85	18374	16-Sep-87	01-Dec-96	14	11	PROPULSION PROTON-K BLOCK DM SOZ
ASTRA 1A R/B	19689	11-Dec-88	17-Feb-98	19	18	PROPULSION ARIANE 4 H10 FINAL STAGE
COSMOS 2109-11	21013	08-Dec-90	14-Mar-98	3	3	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1987-89	19755	10-Jan-89	03-Aug-98	16	6	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1650-52	15714	17-May-85	29-Nov-98	4	2	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1970-72	19537	16-Sep-88	09-Mar-99	1	1	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2079-81	20631	19-May-90	28-Mar-99	2	2	PROPULSION PROTON-K BLOCK DM SOZ
GORIZONT 32	23887	25-May-96	13-Dec-99	1	0	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2316-18	23631	24-Jul-95	21-Nov-00	1	0	PROPULSION PROTON-K BLOCK DM SOZ
INTELSAT 515 R/B	19773	27-Jan-89	01-Jan-01	87	86	PROPULSION ARIANE 2 R/B
COSMOS 2139-41	21226	04-Apr-91	16-Jun-01	2	1	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2109-11	21012	08-Dec-90	21-Feb-03	3	3	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1883-85	18375	16-Sep-87	23-Apr-03	42	10	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1970-72	19535	16-Sep-88	04-Aug-03	79	10	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 1987-89	19856	10-Jan-89	13-Nov-03	1	1	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2204-06	22066	30-Jul-92	10-Jul-04	34	12	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2022-24	20081	31-May-89	10-Jun-06	120	42	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2139-41	21220	04-Apr-91	08-Mar-09	33	11	PROPULSION PROTON-K BLOCK DM SOZ

AMC 14 BRIZ-M R/B	32709	14-Mar-08	13-Oct-10	123	122	PROPULSION PROTON-K BRIZ-M STAGE
COSMOS 2434-36	32399	25-Dec-07	18-Aug-11	1	1	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2079-81	20630	19-May-90	17-Nov-11	2	2	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2442-44	33385	25-Sep-08	20-May-14	12	10	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2294-96	23402	20-Nov-94	07-Jun-14	2	2	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2459-61	36406	01-Mar-10	09-Jul-14	13	13	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2431-33	32280	26-Oct-07	13-Aug-14	26	23	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2447-49	33472	25-Dec-08	26-Mar-16	6	6	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2447-49	33473	25-Dec-08	01-Jun-16	12	12	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2424-2426	29680	25-Dec-06	27-Jul-16	9	8	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2464-2466	37143	02-Sep-10	03-Sep-17	10	10	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2459-61	36407	01-Mar-10	22-May-18	20	19	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2417-2419	28920	25-Dec-05	24-Aug-18	2	2	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2464-2466	37144	02-Sep-10	12-Aug-19	24	24	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2424-2426	29682	25-Dec-06	23-Oct-19	3	3	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2456-2458	36116	14-Dec-09	21-Dec-19	7	7	PROPULSION PROTON-K BLOCK DM SOZ
COSMOS 2434-2436	**32398**	**25-Dec-97**	**15-Apr-22**	**1**	**1**	**PROPULSION PROTON-K BLOCK DM SOZ**

63 FRAGMENTATION IN MOLNIYA ORBIT

Inter-Agency Space Debris Coordination Committee

IT 34.1 – Statistical search

Conclusions

- **ASI, SSAU, DLR and CNSA conducted observation for the statistical search** in the week that starts from March 18th, 2024, to March 24th, 2024. In particular, ASI observed for 11 night of which 2 in the joint campaign, while SSAU and DLR observed for three nights in that week and CNSA for five days.
  - Can be interesting **to conduct an analysis on the UTCs** using the measurements of all the agencies to determine the orbits of these objects.
- **ASI performed IOD of the UTCs** to understand if it makes sense and could be possible **to schedule a perigee observation** after initial detection during apogee pass (IOD, scheduling, re-observation from another observatory) for objects with subsequent observations in multiple frames.
  - The results shown that **if the observation of the object is close to the apogee it can be possible to retrieve a reasonable orbit**. The problem is that **is not possible to know a-priori if** the measurement of a not catalogue object is retrieved when **the object is at the apogee**.