

Inter-Agency Space Debris Coordination Committee



IT 34.1

**Feasible options to study Molniya
population of space debris**

IT 34.1

Index

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

- **Internal Task:**
Objective and Task description
- **Molniya 2023 Space-Track population:**
Selection criteria and classification
- **Targets description:**
Molniya missions, Rocket bodies and Debris
- **Planning:**
Optical/RADAR observation strategy
- **Test optical observation:**
Molniya 3-31, Cosmos 1547, Cosmos 2084 and SL-12 (AUX MOTOR)

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Objective and Task description

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

IT objective: Producing an analysis and a list of options, based on the contribution of all WG1 delegations, to:

- Statistically survey the population of objects in Molniya orbit, aiming to understand the trackable population and the unknown population
- Collect data to investigate long term orbital dynamics
- Support forensics of events in Molniya

Task description: This analysis will consider optical and radar instruments both to improve existing and to develop new observing techniques and strategies. The task includes:

- The collection of information, 2023Q1 telecon
- **The planning, IADC41 in June 2023**
- The execution of a coordinated test for the study of the Molniya population, IADC42
- The collection of lessons learned, IADC43

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Molniya 2023 Space-track population

Selection criteria

N = 337
(7 TBA and 3 OLD)



N = 13
(Added from old missions)



N = 21
(Enlarged not in previous lists)



371 objects

Molniya-like objects:

- Inclination [deg]: 67.5 ± 7.5 (typical ~ 62.8 deg)
- Mean Motion [rev/day]: 2 ± 0.5 (typical ~ 2.0 rev/day)
- Eccentricity: 0.65 ± 0.15 (typical ~ 0.72)
- Altitude: 150 km to 40000 km

Added:

- Molniya-1: 22671,23420,24960
- Molniya-3: 11057, 15738
- Oko: 6192, 15952, 16527, 17213, 18103, 18701, 19554, 19608

Enlarged list:

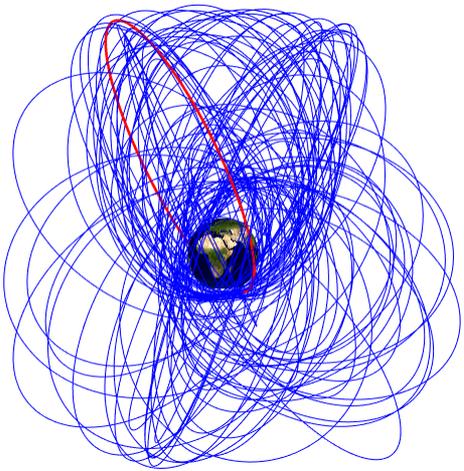
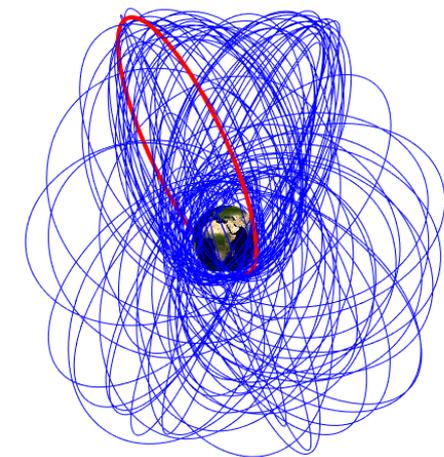
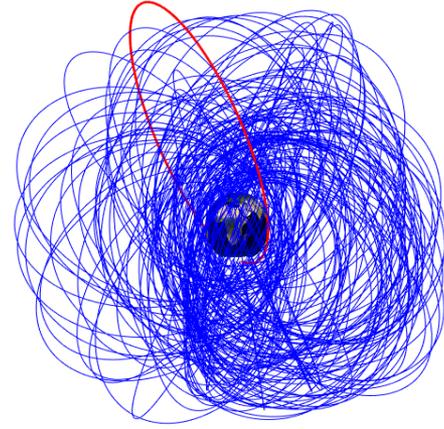
- SL-12 R/B (AUX MOTOR):
16446,18374,19170,19755,19856,20081,20630,20631,21012,21220,
21226,23402,23403,36406,37143
- CZ-3B R/B: 43110,43247
- SL-12 DEB: 42974,48349,48417
- USA 125 DEB: 23947

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Molniya 2023 Space-track population

Classification and main parameters

Parameter	Missions	Rocket bodies	Debris
Number	92	106	152
Inclination	61.6 – 72.6 [deg]	61.8 – 72.7 [deg]	61.1 – 74.2 [deg]
Mean Motion	1.98 – 5.63 [rev/day]	1.96 – 2.49 [rev/day]	1.8 – 2.2 [rev/day]
Eccentricity	0.41 – 0.75	0.51 – 0.73	0.50 – 0.77
Orbit			

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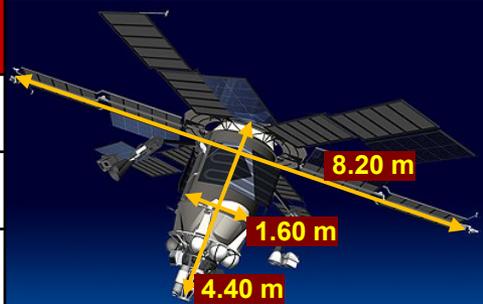


Targets description

Molniya missions

MOLNIYA 1 – 2 – 3

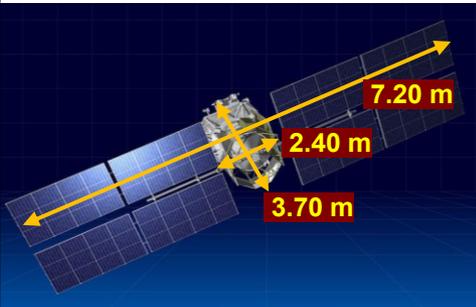
Total targets	34
Molniya-1	19
Molniya-2	3
Molniya-3	12



INFO: Russia military and communication
Molniya-1 (1967 to 1975), Molniya-2 (1971 to 1977) and Molniya-3 (1974 to 2003)

MERIDIAN

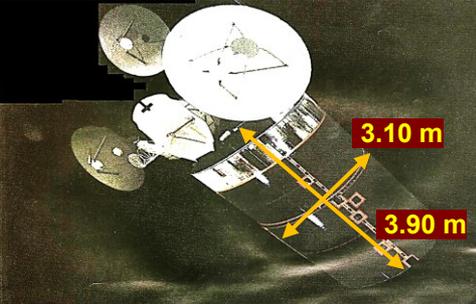
Total targets	7
1 st ver	4
Meridian M ver	3
Active	4



INFO: Russia military and communication
First version (2006 to 2014), Meridian-M version (2019 to 2022)

SDS 1 – 2 – 3

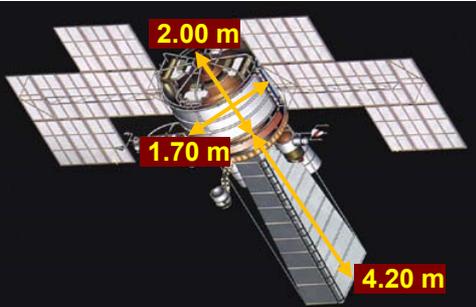
Total targets	3
SDS-1	3
SDS-2	0
SDS-3	0



INFO: USA military and communication
SDS-1 (1976 to 1987), SDS-2 (1989 to 1996) TLE not available and SDS-3 (1998 to 2022)

OKO

Total targets	48
Reentered	33
Reentering	3
Self-destruction	1



INFO: Russia missile early warning
Cosmos (1972 to 2012), Reentering: 16993, 27409, 27613

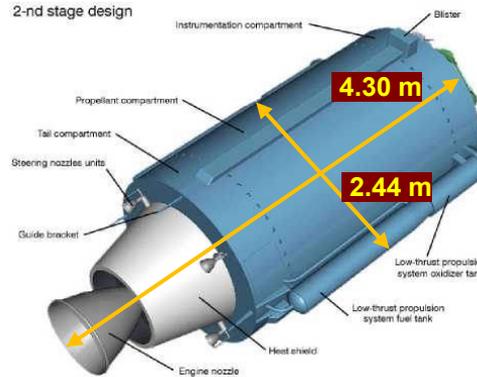
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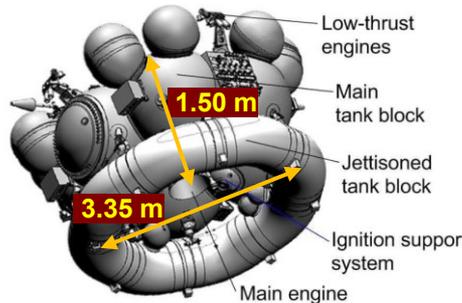
Targets description

Rocket bodies / Debris

SL R/B	87
SL-6 (2 nd stage)	69
SL-12 (2 nd stage)	1
SL-12 (AUX MOTOR)	15
SL-26	2



Other R/B	19
FREGAT	12
DELTA 4, ATLAS 2A	2
TITAN 34B, AGENA D	3
CZ-3B	2



Debris	152
COSMOS	138
SL-6	4
SL-12	3
DELTA 1	1
SOLWIND	2
ARIANE 1	1
THOR ABLESTAR	1
TITAN 34B AGENA	1
USA-125	1

- No info available about shape/dimensions

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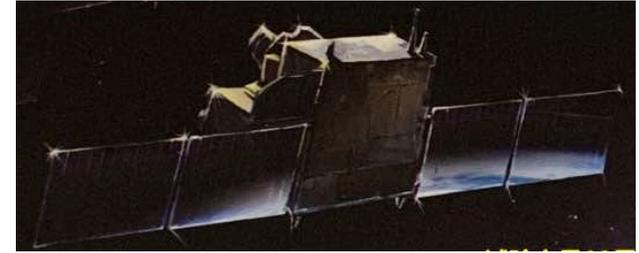
Targets description

Recent / Future targets

Constellation: Shiyao

Objective: to refrain of agricultural monitoring and space environment observation (experimental satellite program)

Planned satellites: 5 HEO (2021 – 2025), 1 partially operational in orbit (NORAD ID: 49258 – SHIYAN 10) and 1 operational (NORAD ID: 54878 – SHIYAN 10 02)



Constellation: Arktika-M

Objective: to monitor high-latitude areas of the Earth (remote-sensing) and emergency communications satellites

Planned satellites: 5 HEO (2021 – 2025), 1 operational in orbit (NORAD ID: 47719)



Constellation: Ekspress

Objective: to provide Ku-band coverage to Russia's Far North

Planned satellites: 4 HEO (2024) and 8 GEO (2025 – 2030)



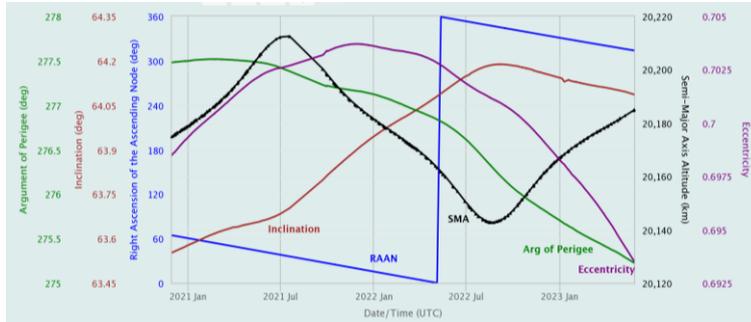
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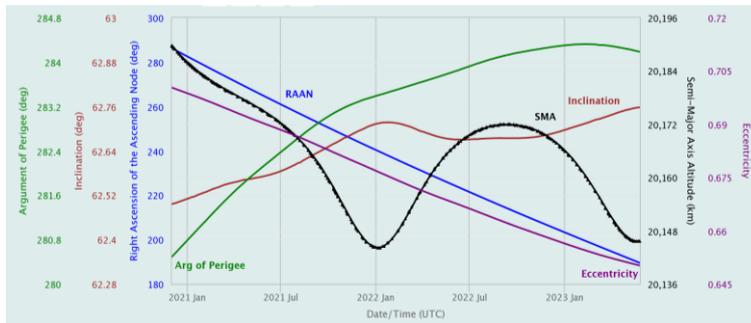
Targets description

SDS orbit evolution

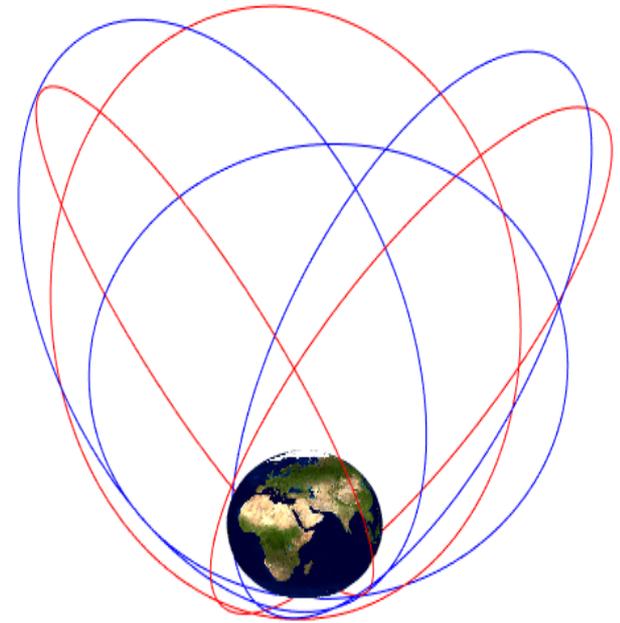
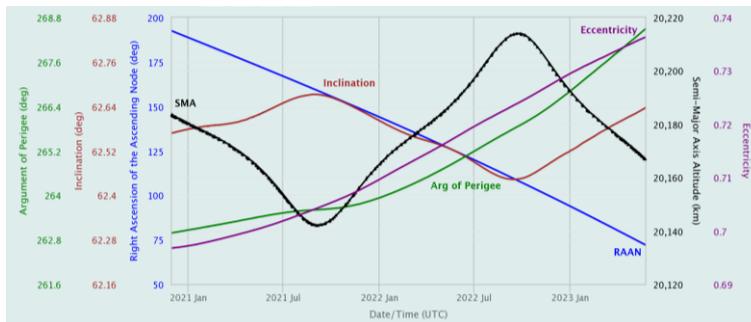
Name	OPS 5805
NORAD ID	12093
1st TLE date	2019/05/07



Name	USA 4
NORAD ID	15226
1st TLE date	2019/07/17



Name	USA 21
NORAD ID	17506
1st TLE date	2019/07/16



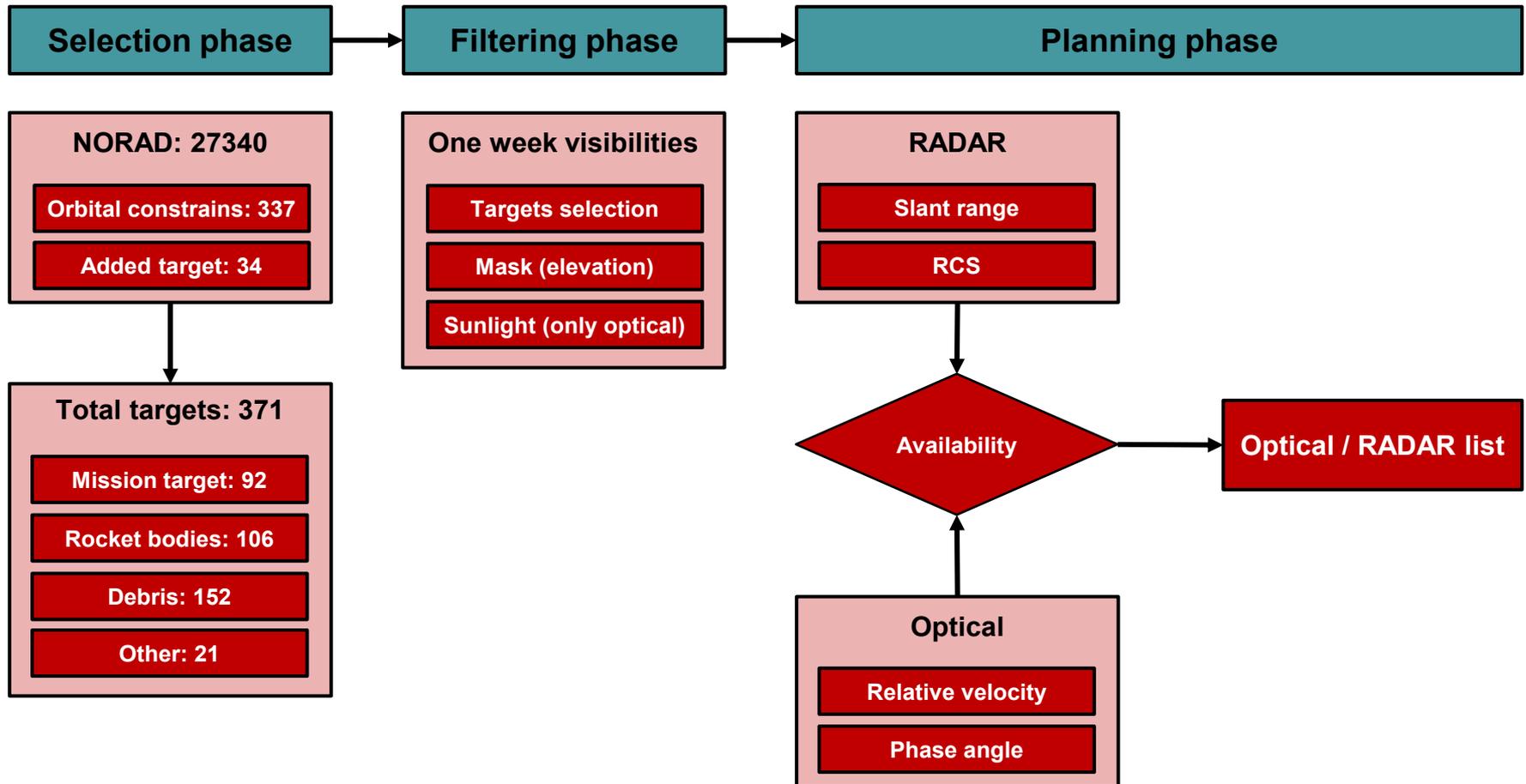
2019 TLE released
2023 TLE released

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Planning

Optical/RADAR targets observation

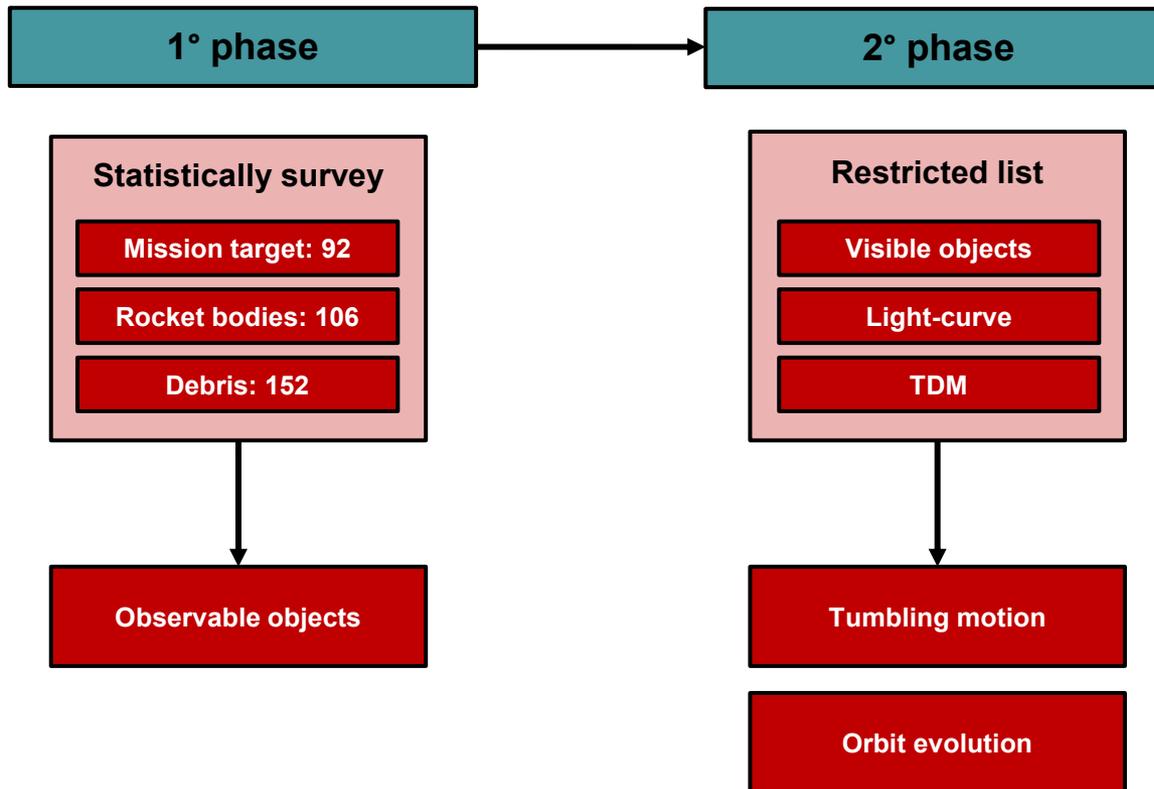


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Planning

Possible strategy



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Molniya observation campaign

Italian optical facilities for IT 34.1



SCUDO observatory



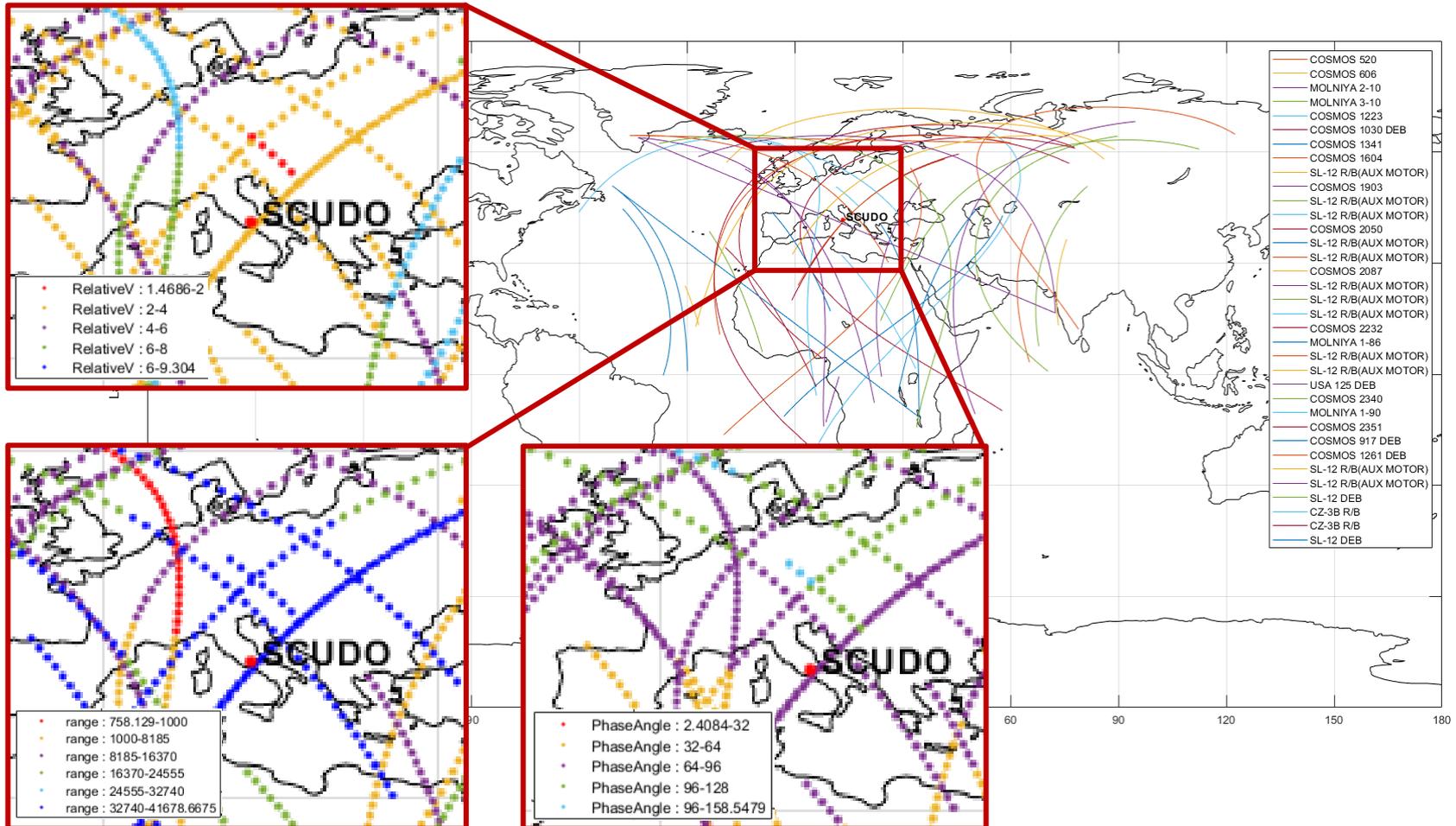
Lens diameter	250 mm	150 mm
Focal length	1200 mm	750 mm
Sensor	sCMOS	sCMOS
Field of View	1.07° x 1.07°	1.27° x 1.07°
QE	95%	60%
Binning	3x3	4x4
Pixel scale	5.69 arcsec/px	10.65 arcsec/px
Location	Colleparado (FR – Italy)	
Latitude	41.76524 deg	
Longitude	13.37503 deg	
Altitude	555 m	

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Optimization strategy

Visibility, relative velocity, phase angle and slant range



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Enlarged list optical observation

Visibilities and observation status

SSN	Sat_Name	30-May-2023	31-May-2023	1-June-2023	2-June-2023	3-June-2023	4-June-2023	5-June-2023	6-June-2023	7-June-2023	8-June-2023	9-June-2023	10-June-2023	Observed
6192	COSMOS 520													
6916	COSMOS 606													
7376	MOLNIYA 2-10													
11057	MOLNIYA 3-10													
12078	COSMOS 1223													
12907	COSMOS 1030 DEB													
13080	COSMOS 1341													
15350	COSMOS 1604													
16446	SL-12 R/B(AUX MOTOR)													
18374	SL-12 R/B(AUX MOTOR)													
18701	COSMOS 1903													
19170	SL-12 R/B(AUX MOTOR)													
19755	SL-12 R/B(AUX MOTOR)													
19856	SL-12 R/B(AUX MOTOR)													
20081	SL-12 R/B(AUX MOTOR)													
20330	COSMOS 2050													
20596	COSMOS 2076													
20630	SL-12 R/B(AUX MOTOR)													
20631	SL-12 R/B(AUX MOTOR)													
20707	COSMOS 2087													
21012	SL-12 R/B(AUX MOTOR)													
21220	SL-12 R/B(AUX MOTOR)													
21226	SL-12 R/B(AUX MOTOR)													
22321	COSMOS 2232													
22671	MOLNIYA 1-86													
23402	SL-12 R/B(AUX MOTOR)													
23403	SL-12 R/B(AUX MOTOR)													
23947	USA 125 DEB													
24761	COSMOS 2340													
24960	MOLNIYA 1-90													
25327	COSMOS 2351													
27884	COSMOS 917 DEB													
27901	COSMOS 1261 DEB													
36406	SL-12 R/B(AUX MOTOR)													
37143	SL-12 R/B(AUX MOTOR)													
42974	SL-12 DEB													
43110	CZ-3B R/B													
43247	CZ-3B R/B													
48349	SL-12 DEB													
48417	SL-12 DEB													

Observed objects	Observable objects	Observation days	Bad weather
21/40	18/18	12 days	5 days

Legend	
	to be observed
	observed
	in visibility but not observed
	observed but not detected
	already observed
	not in visibility
	bad weather

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Molniya observation

Attitude motion

Expectation for a non controlled object

- Achievement of a “flat-spinning” regime, around the major axis of inertia

Molniya main perturbations

- Gravity gradient of the Earth
- Interaction with the magnetosphere
- Aerodynamical drag

Perturbations consequences

- Precession of the spin axis
- Spin period slow-down

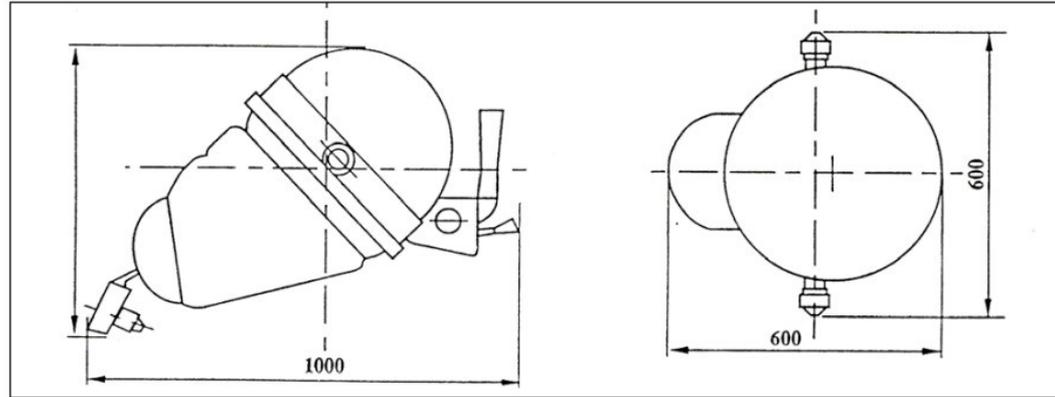
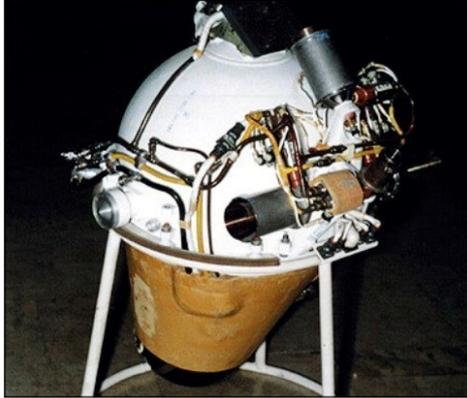
Observing the peculiar tumbling motion of the molniya objects through the years and the evaluation of the differences among their light curves can provide useful information to investigate long term orbital dynamics

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Targets description

SL-12 (AUX MOTOR)



Ref. Orbital Debris Quarterly News (NASA Orbital Debris Program Office), Volume 18, Issue 4, October 2014

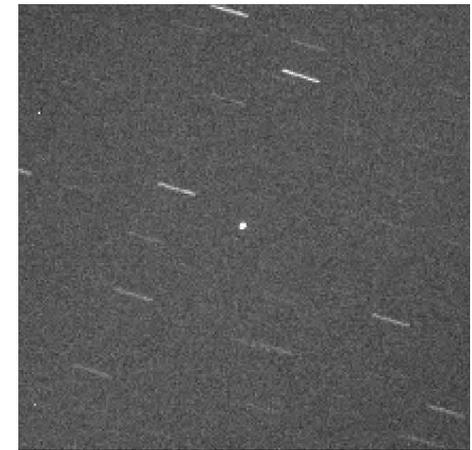
20081
2023/05/30 20:16:14



20631
2023/05/30 19:39:14



37143
2023/05/30 20:39:44



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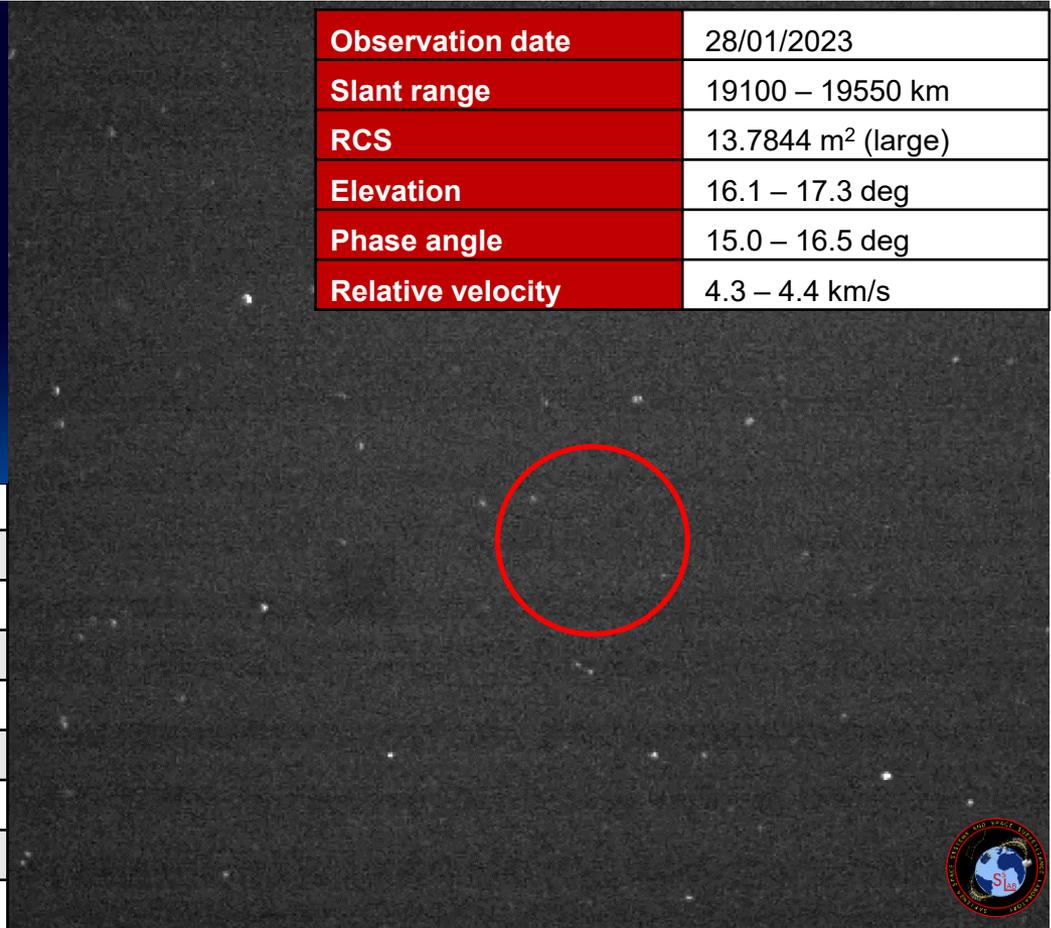
Optical observation

Molniya 3-31



NORAD ID	17328
Int'l Code	1987-008A
Perigee	1,185.7 km
Apogee	39,174.3 km
Inclination	63.6 °
Period	717.6 minutes
Semi major axis	26550 km
RCS	13.7844 m ² (large)
Launch date	January 22, 1987

Observation date	28/01/2023
Slant range	19100 – 19550 km
RCS	13.7844 m ² (large)
Elevation	16.1 – 17.3 deg
Phase angle	15.0 – 16.5 deg
Relative velocity	4.3 – 4.4 km/s

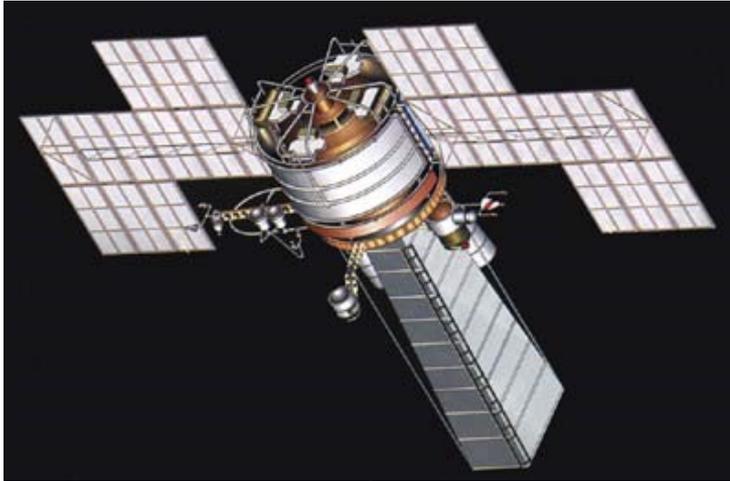


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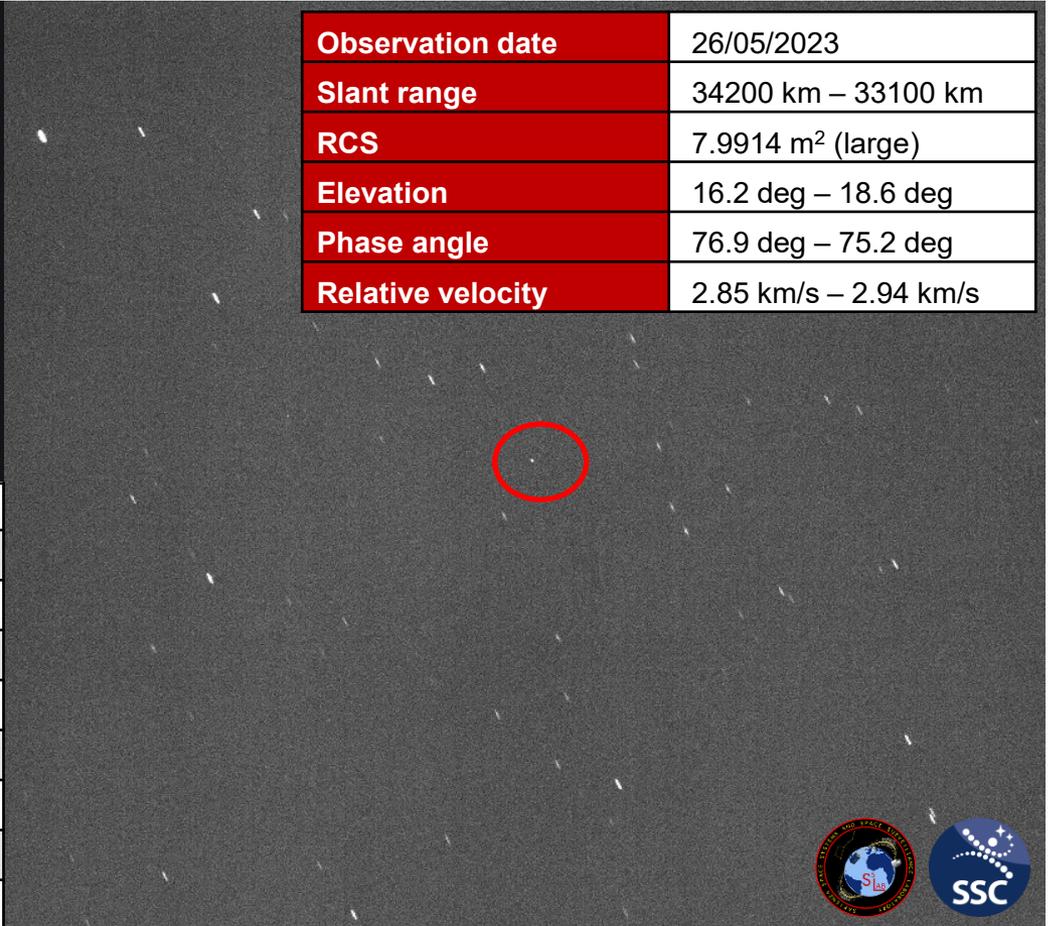
Optical observation

Cosmos 1547



NORAD ID	14884
Int'l Code	1984-033A
Perigee	4,888.8 km
Apogee	35,536.9 km
Inclination	72.6 °
Period	718.9 minutes
Semi major axis	26583 km
RCS	7.9914 m ² (large)
Launch date	April 4, 1984

Observation date	26/05/2023
Slant range	34200 km – 33100 km
RCS	7.9914 m ² (large)
Elevation	16.2 deg – 18.6 deg
Phase angle	76.9 deg – 75.2 deg
Relative velocity	2.85 km/s – 2.94 km/s

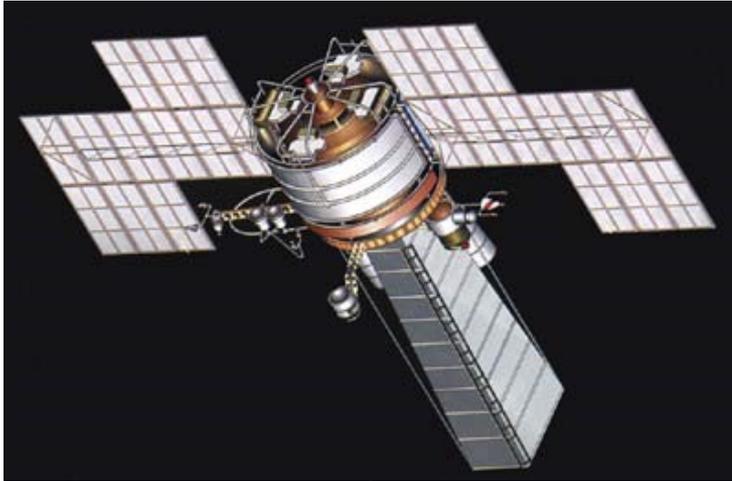


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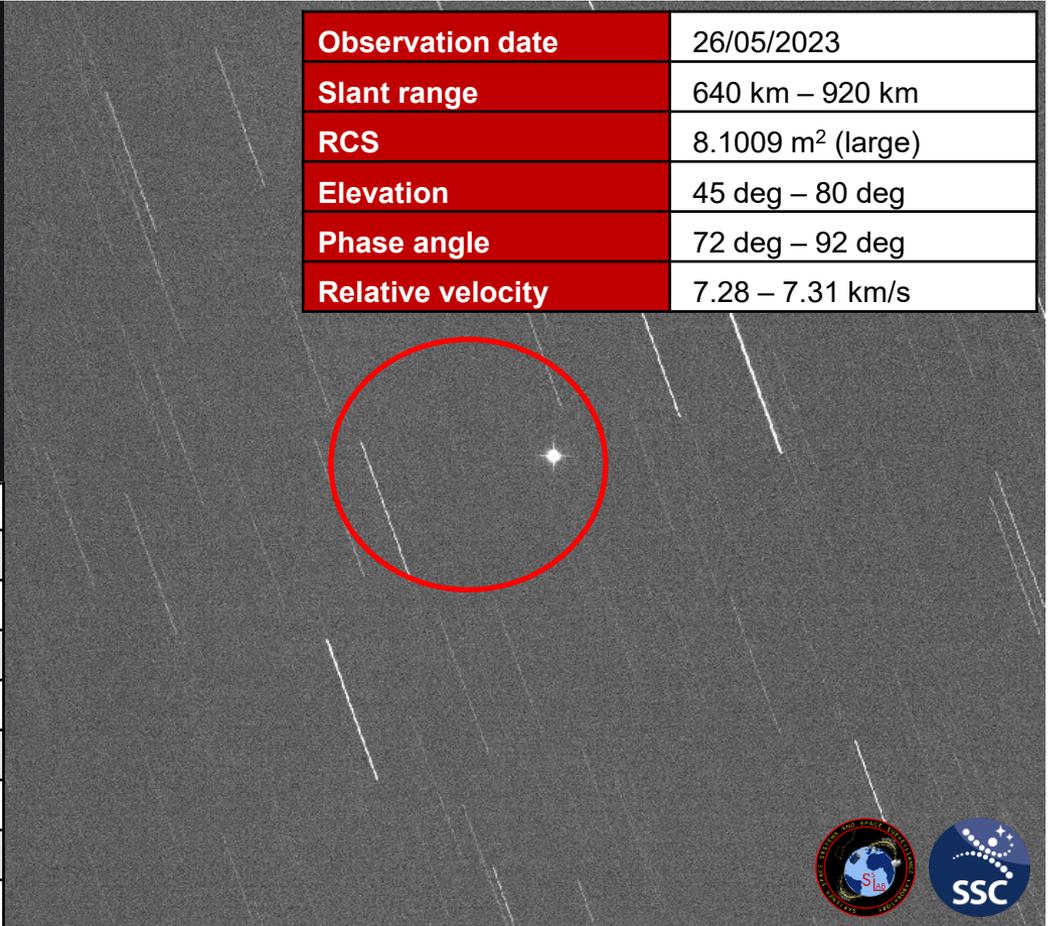
Optical observation

Cosmos 2084



NORAD ID	20663
Int'l Code	1990-055A
Perigee	496.6 km
Apogee	681.3 km
Inclination	62.8 °
Period	96.3 minutes
Semi major axis	6959 km
RCS	8.1009 m ² (large)
Launch date	June 21, 1990

Observation date	26/05/2023
Slant range	640 km – 920 km
RCS	8.1009 m ² (large)
Elevation	45 deg – 80 deg
Phase angle	72 deg – 92 deg
Relative velocity	7.28 – 7.31 km/s



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Conclusion

IT 34.1 - Feasible options to study Molniya population of space debris

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

- **Targets list, description and classification:**

Provided criteria to obtain the targets list and added some objects of previous Molniya mission and from the enlarged list provided by the other delegations. All these objects were described and classified in Molniya missions, Rocket bodies and Debris.

- **Observation coordination:**

Provided a strategy to observe the targets with Optical and/or RADAR facilities. The optimization is based on relative speed and phase angle for the Optical and for RCS (if available) and Slant Range for the RADAR.

- **Test observation:**

Optical observation of Molniya 3-31 from SCUDO observatory (IT) on the 28/01/2023, of Cosmos 1547 and Cosmos 2084 from AWARE observatory (AU) on the 26/05/2023 and of 14/40 objects of the enlarged list.

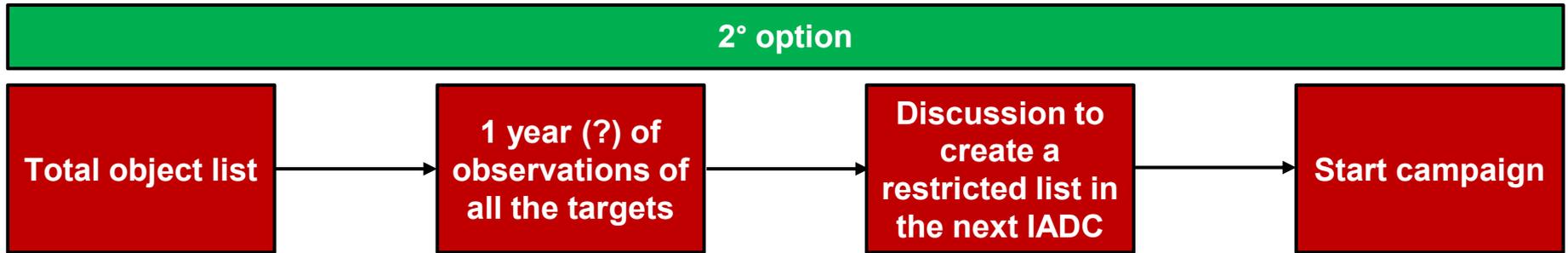
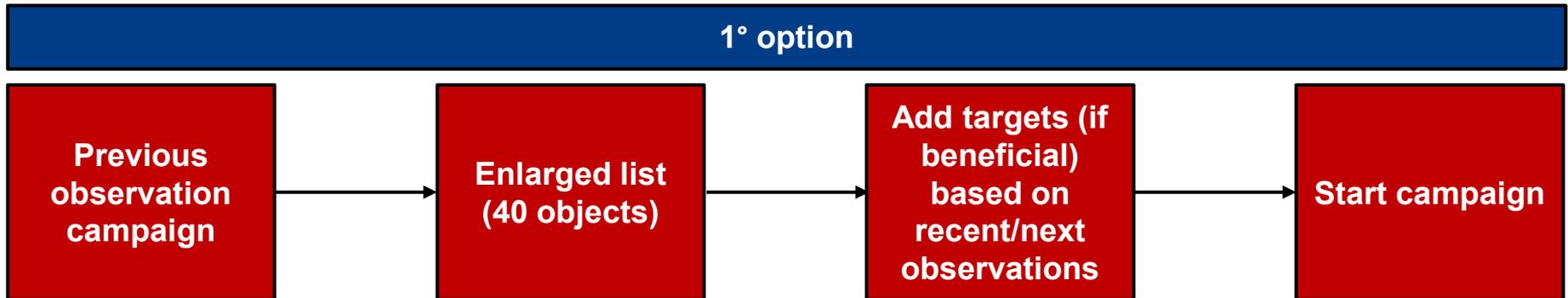
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Next step

IT 34.1 – Discussion for an AI?

IADC42: The execution of a coordinated test for the study of the Molniya population



- 1) Survey
- 2) Collect data

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population of space debris**