

# Inter-Agency Space Debris Coordination Committee



## IT 34.1

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

# IT 34.1

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

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# IT 34.1

## 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]:  $67.5 \pm 7.5$  (typical  $\sim 62.8$  deg)
- Mean Motion [rev/day]:  $2 \pm 0.5$  (typical  $\sim 2.0$  rev/day)
- Eccentricity:  $0.65 \pm 0.15$  (typical  $\sim 0.72$ )
- 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:

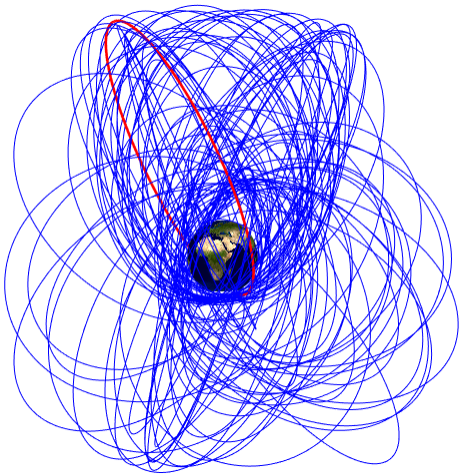
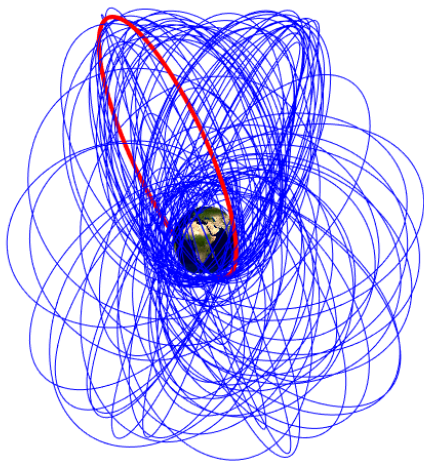
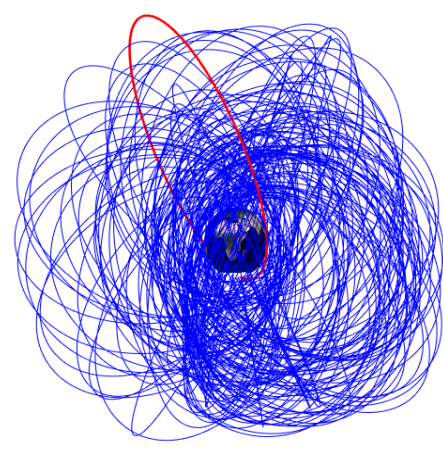
- SL-12 R/B (AUX MOTOR):  
16446, 18374, 19170, 19755, 19856, 20081, 20630, 20631, 21012, 21220, 21226, 23402, 23403, 36406, 37143
- CZ-3B R/B: 43110, 43247
- SL-12 DEB: 42974, 48349, 48417
- USA 125 DEB: 23947

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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			

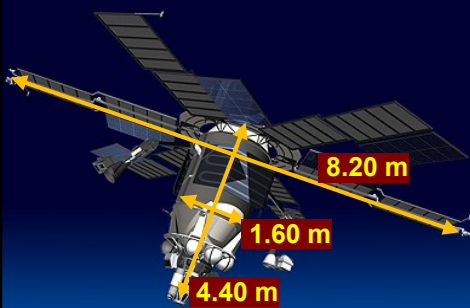
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# Targets description

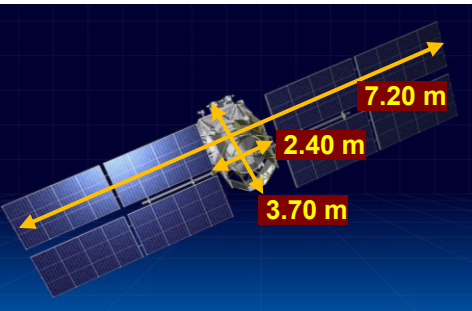
## Molniya missions

### MOLNIYA 1 – 2 – 3

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

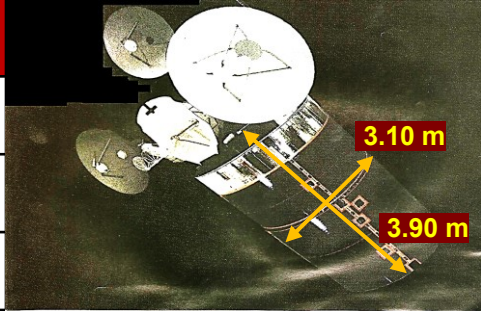
**INFO:** Russia military and communication  
Molniya-1 (1967 to 1975), Molniya-2 (1971 to 1977) and Molniya-3 (1974 to 2003)

### MERIDIAN

Total targets	7	
1 <sup>st</sup> ver	4	
Meridian M ver	3	
Active	4	

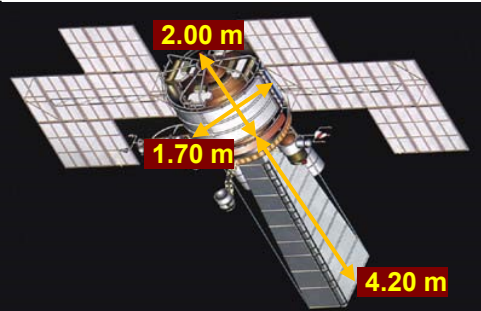
**INFO:** Russia military and communication  
First version (2006 to 2014), Meridian-M version (2019 to 2022)

### 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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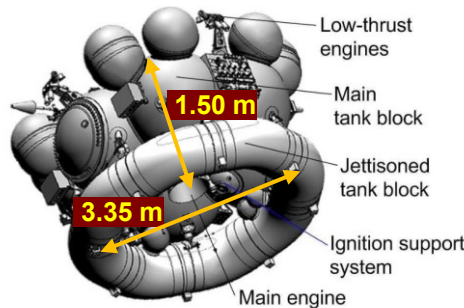
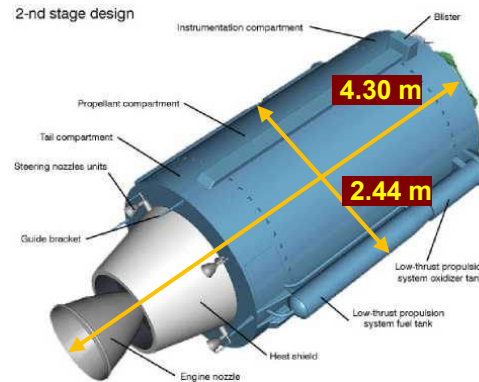


# Targets description

## Rocket bodies / Debris

SL R/B	87
SL-6 (2 <sup>nd</sup> stage)	69
SL-12 (2 <sup>nd</sup> 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
<ul style="list-style-type: none"> <li>No info available about shape/dimensions</li> </ul>	

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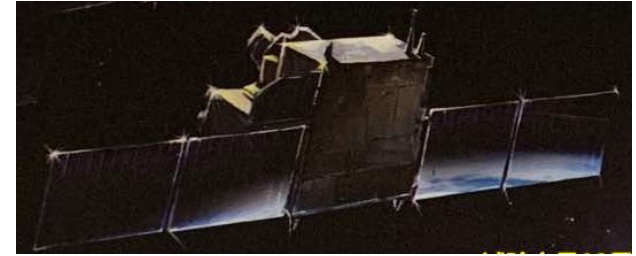
# Targets description

## Recent / Future targets

**Constellation:** Shiyan

**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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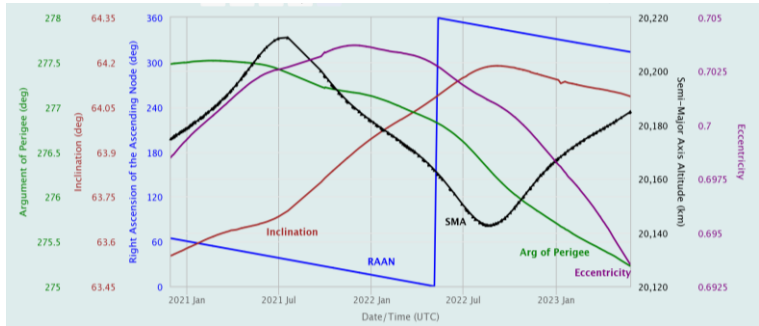




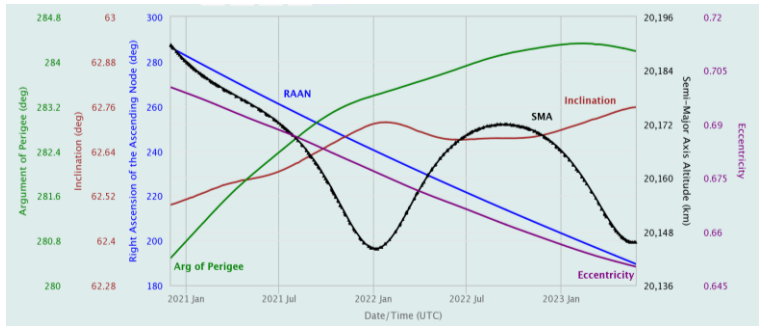
# Targets description

## SDS orbit evolution

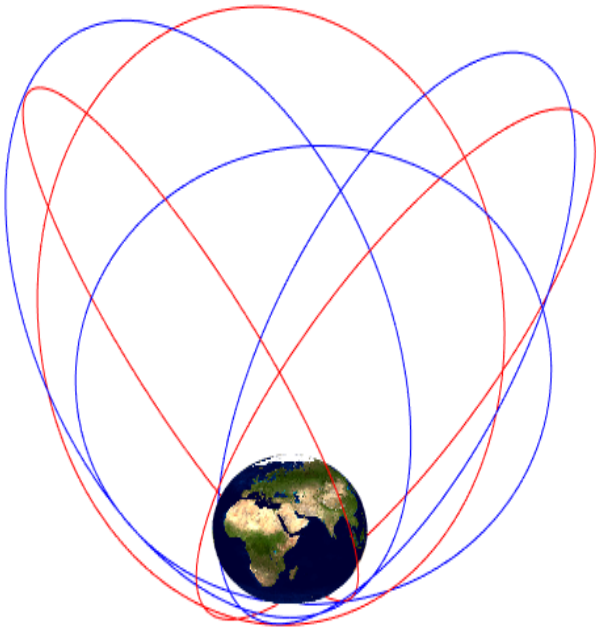
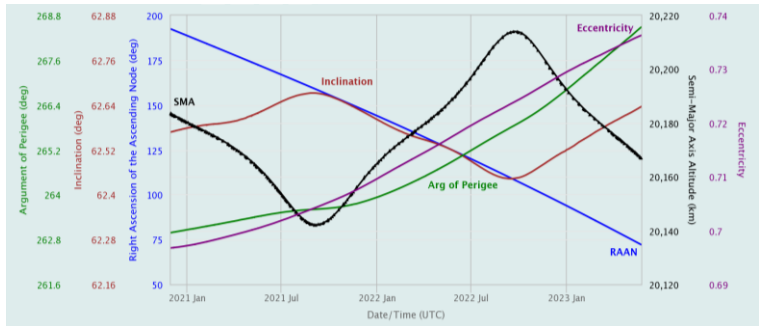
<b>Name</b>	OPS 5805
<b>NORAD ID</b>	12093
<b>1st TLE date</b>	2019/05/07



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



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



2019 TLE released

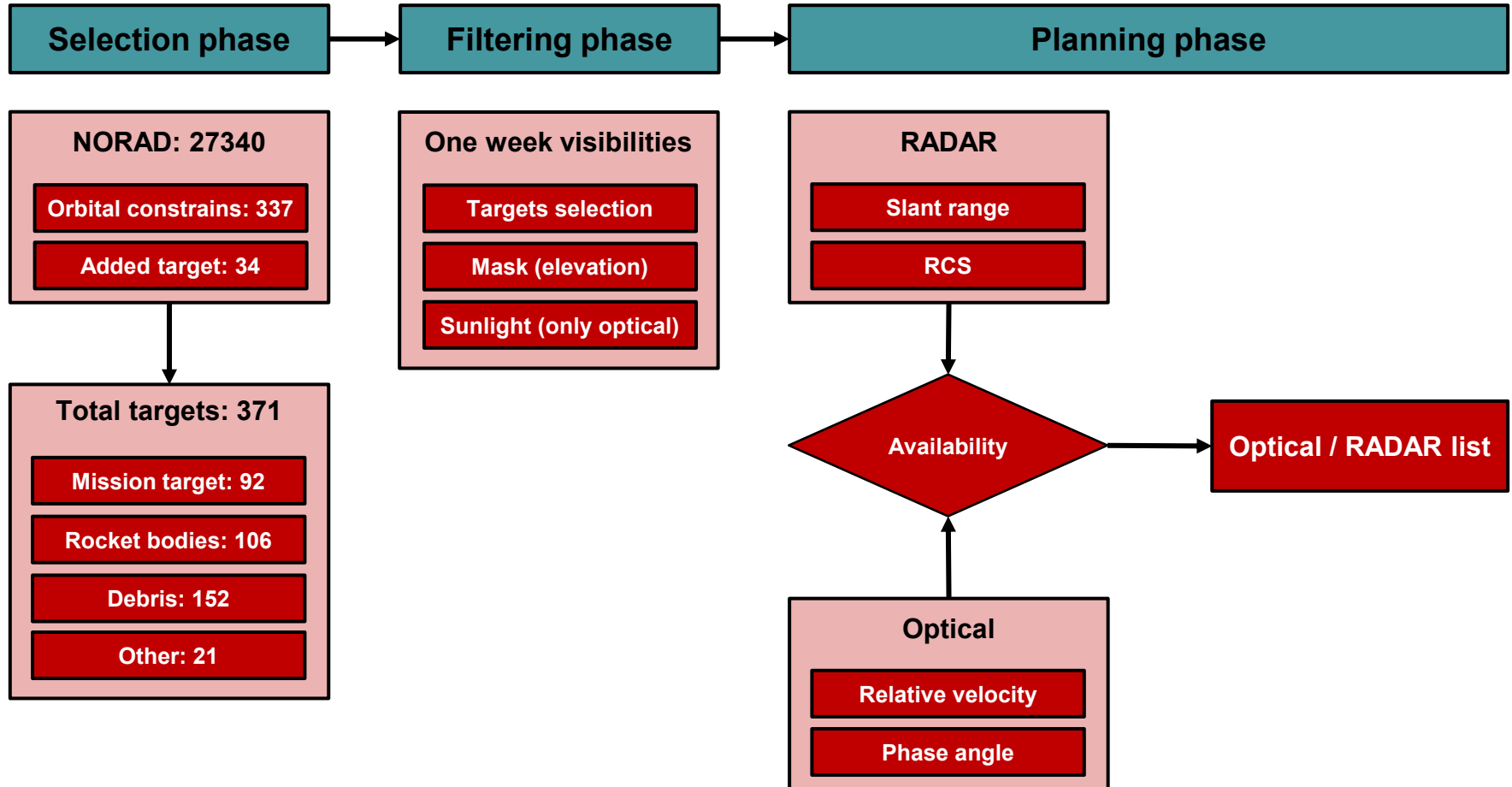
2023 TLE released

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# Planning

## Optical/RADAR targets observation

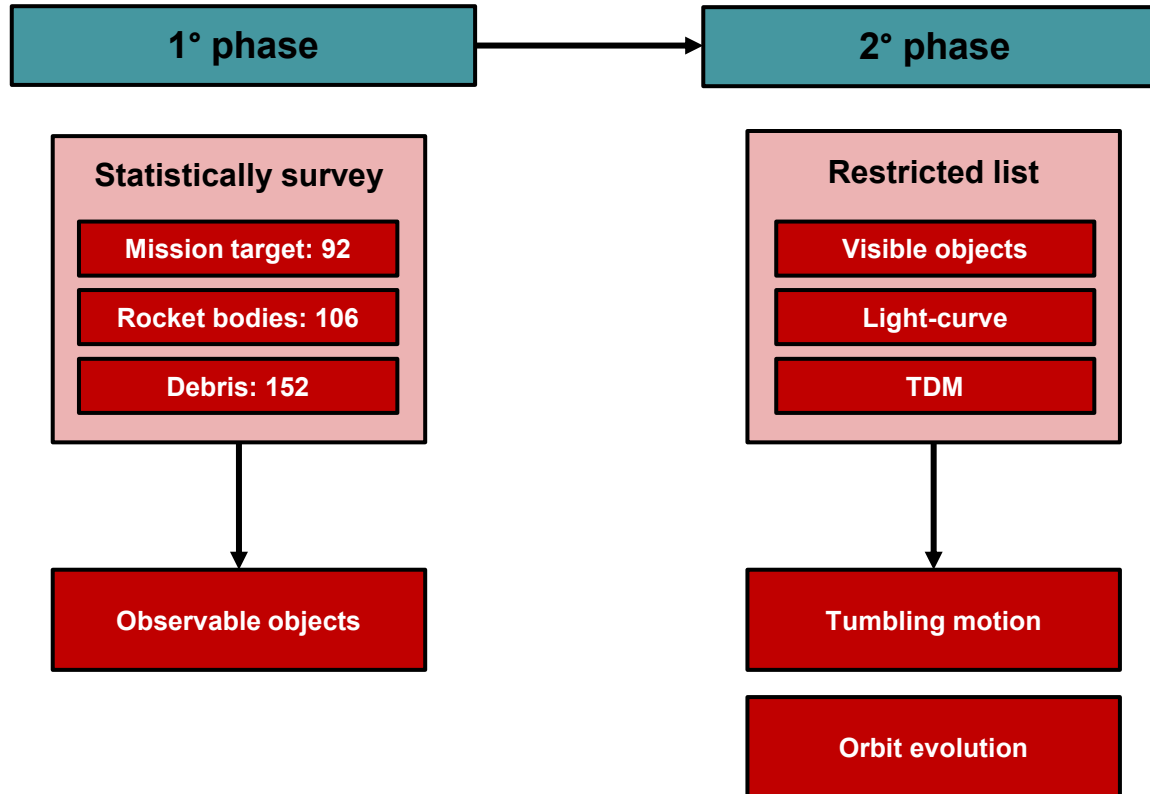


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# Planning

## Possible strategy



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# Molniya observation campaign

## Italian optical facilities for IT 34.1



### SCUDO observatory



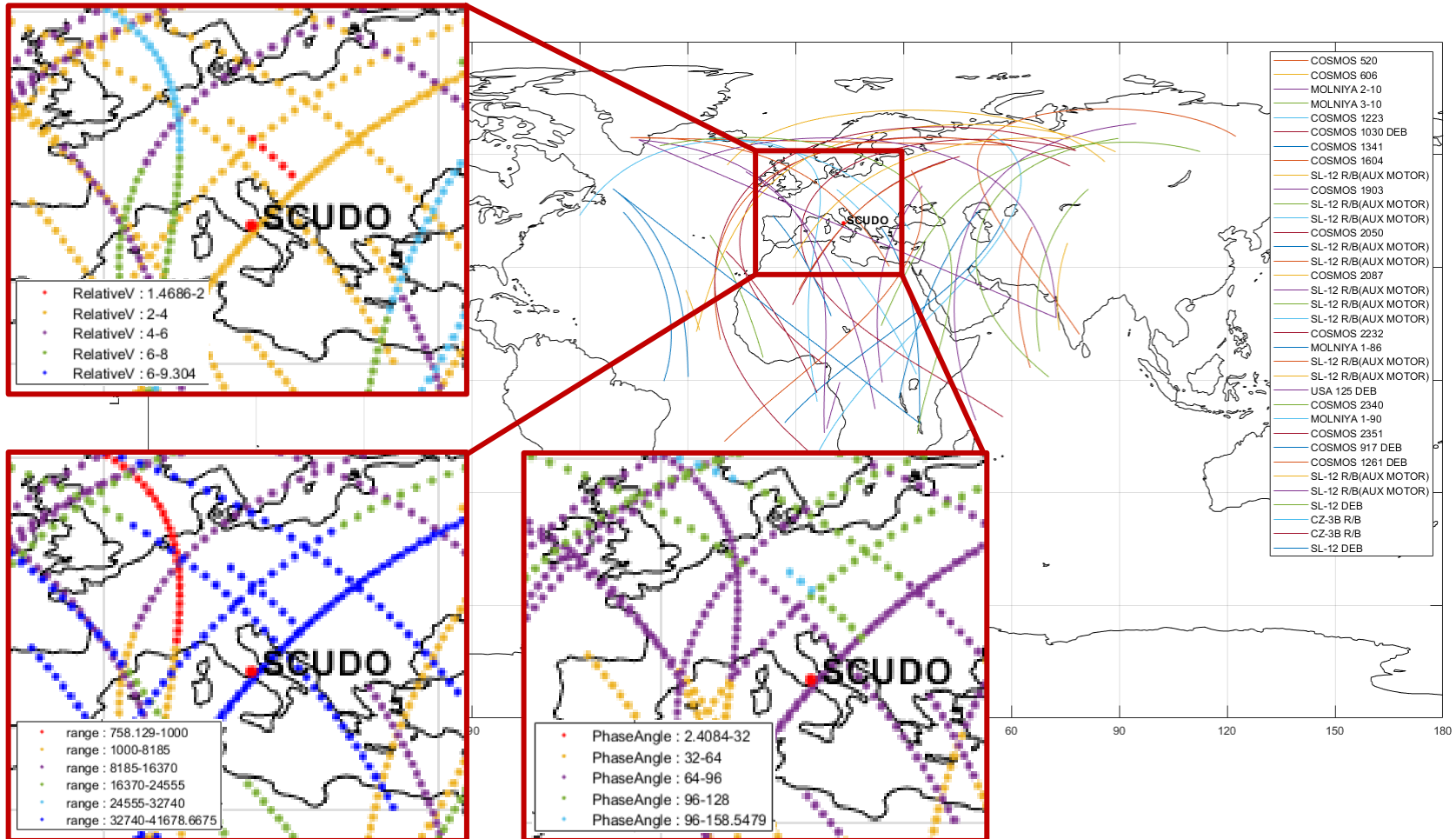
Lens diameter	250 mm	150 mm
Focal length	1200 mm	750 mm
Sensor	sCMOS	sCMOS
Field of View	1.07° x 1.07°	1.27° x 1.07°
QE	95%	60%
Binning	3x3	4x4
Pixel scale	5.69 arcsec/px	10.65 arcsec/px
Location	Colleparado (FR – Italy)	
Latitude	41.76524 deg	
Longitude	13.37503 deg	
Altitude	555 m	

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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

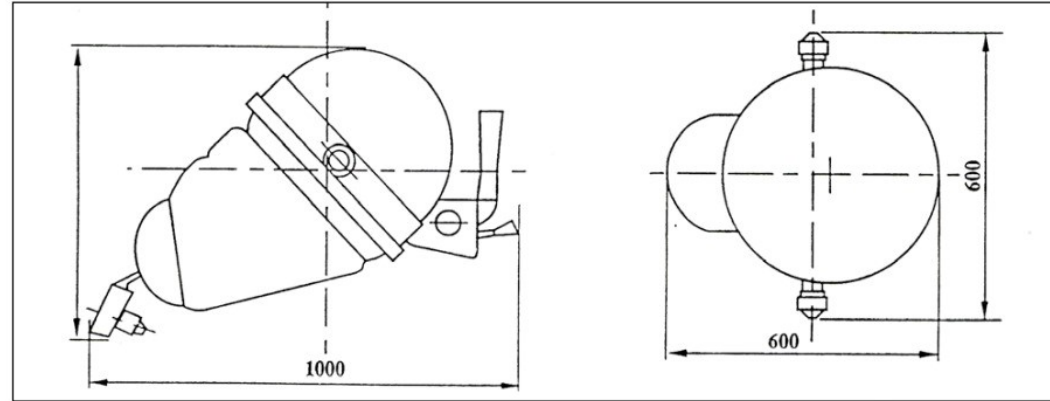
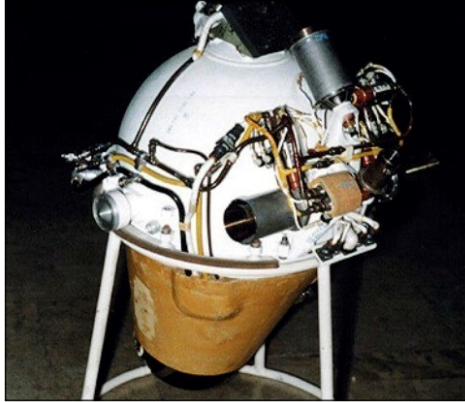
**Observing the peculiar tumbling motion of the molniya objects through the years and the evaluation of the differences among their light curves can provide useful information to investigate long term orbital dynamics**

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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**



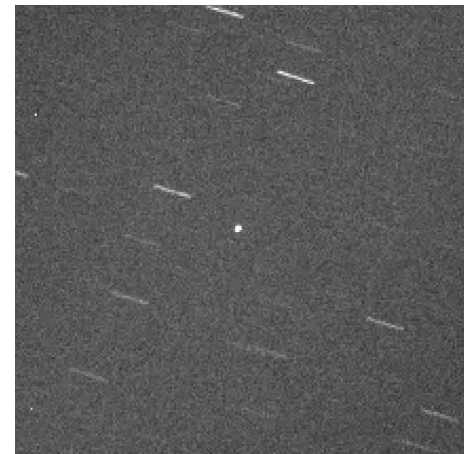
**20631**

**2023/05/30 19:39:14**



**37143**

**2023/05/30 20:39:44**



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# Optical observation

## Molniya 3-31



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

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

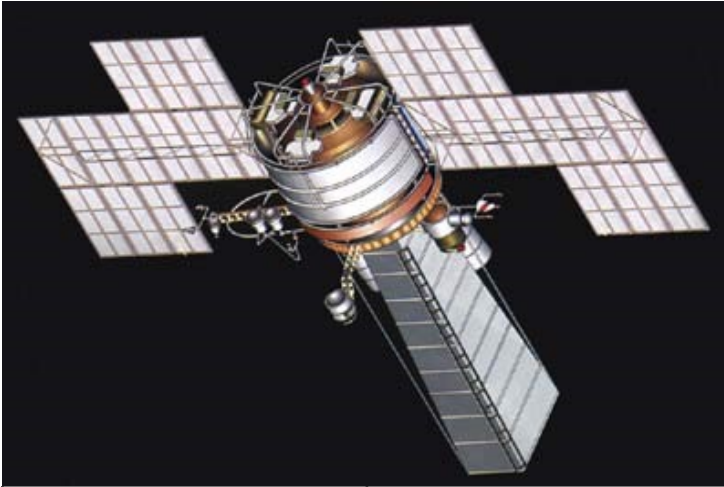
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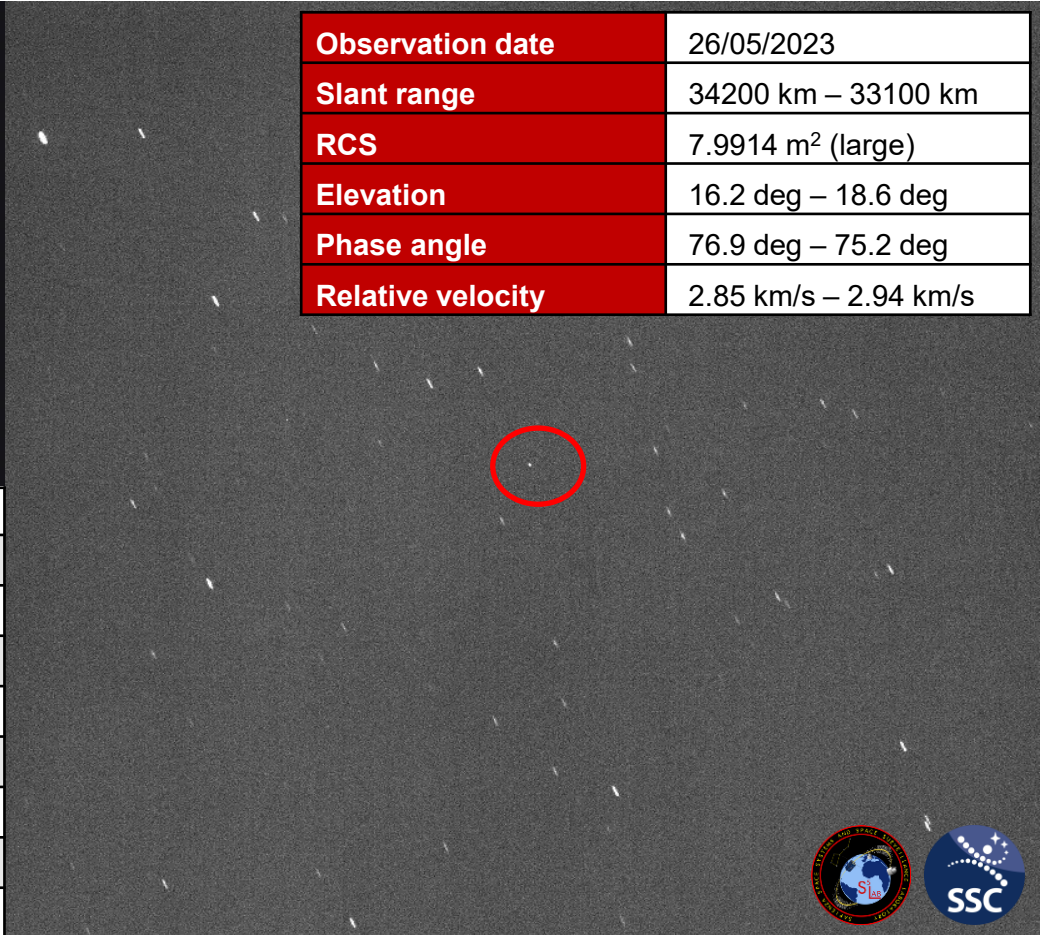
# Optical observation

## Cosmos 1547



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

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

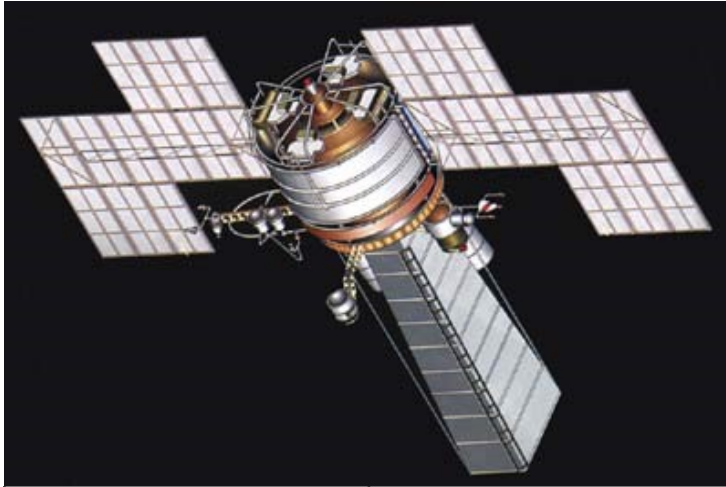


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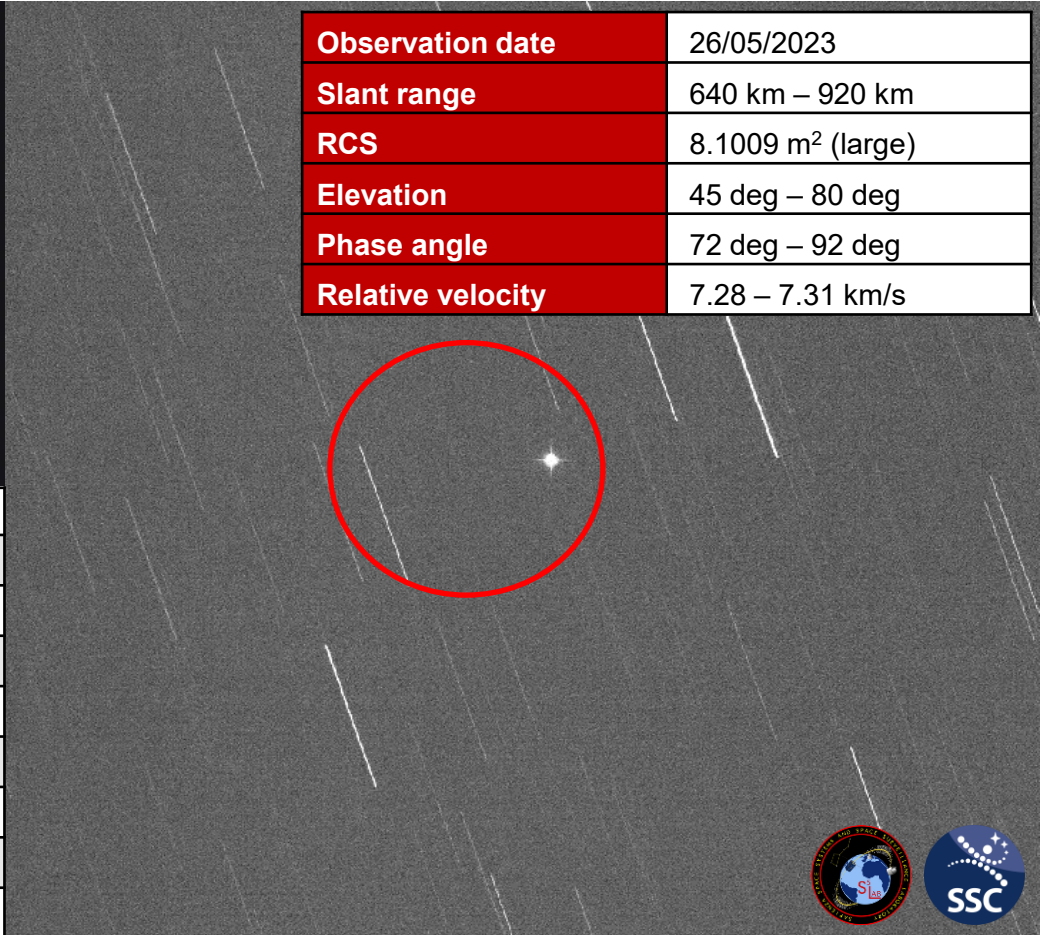
# Optical observation

## Cosmos 2084



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

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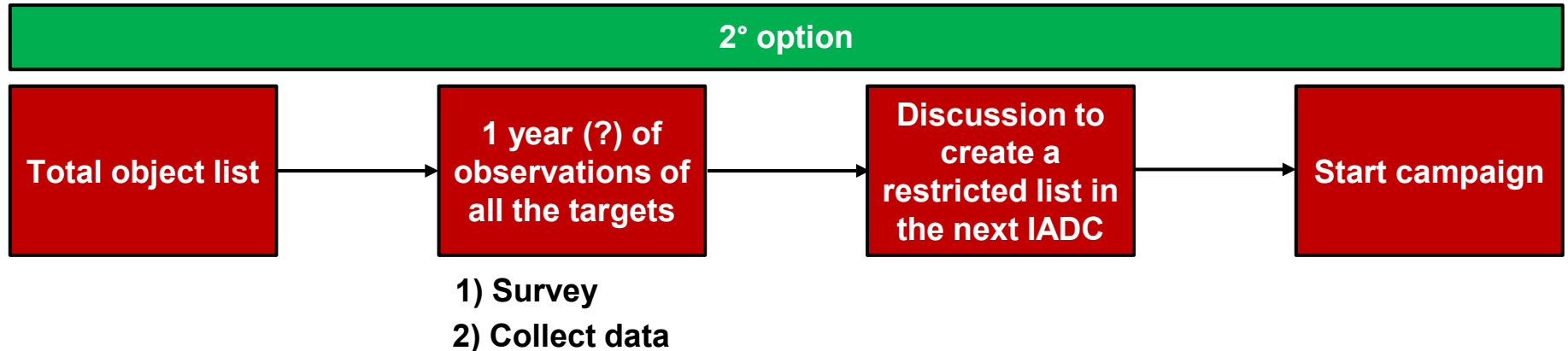
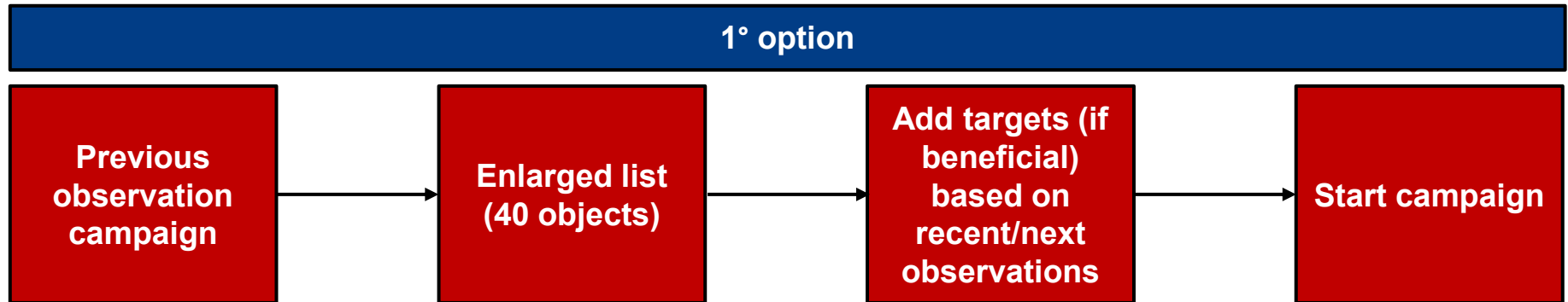




# Next step

## IT 34.1 – Discussion for an AI?

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



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## IT 34.1

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