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Committee on the Peaceful Uses of Outer Space

Disposal of satellites in geosynchronous orbit

Report by the Secretariat

Contents

V.99-91115 (E)

I. Introduction

1. At its forty-second session, the Committee on the Peaceful Uses of Outer Space agreed[1] that the Scientific and Technical Subcommittee, at its thirty-seventh session, should review international application of the International Telecommunications Union (ITU) standards and Inter-Agency Space Debris Coordination Committee (IADC) recommendations concerning the disposal of satellites in geosynchronous orbit at the end of their useful life. It also recommended that, to facilitate the review by the Subcommittee, the Secretariat should compile relevant data on space objects in geosynchronous orbit.

2. The present report was prepared by the Secretariat in response to the request by the Committee. It incorporates information received from the Canadian Space Agency (CSA), the Centre National d'Etudes Spatiales (CNES) of France, the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and Intelsat. The Secretariat wishes to express its appreciation to the Astronomical Institute of the Czech Academy of Sciences, Czech Republic, the European Space Operations Centre (ESOC) of the European Space Agency (ESA) in Darmstadt, Germany, and Johnson Space Center of the National Aeronautics and Space Administration (NASA) in Houston, United States of America for their valuable assistance in the preparation of the present report.

II. Standards and recommendations on geosynchronous satellite disposal

3. During the 1980s, ITU began addressing the issue of end-of-mission disposal and supersynchronous graveyard orbits. In 1986, the ITU International Consultative Committee for Radio (CCIR) assigned question 34.4 to Study Group 4 to examine six questions associated with the potential for physical interference in geosynchronous Earth orbit (GEO) and with the removal of spacecraft from GEO. After many years of fact-finding and scientific discussion, ITU concluded that some measures to limit the growth of the geosynchronous satellite population were prudent.

4. Specifically, it was recommended that:[2]

(a) As little debris as possible should be released into the geostationary satellite orbit (GSO) during the placement of a satellite in orbit;

(b) Every reasonable effort should be made to shorten the lifetime of debris in the transfer orbit;

(c) A geostationary satellite at the end of its life should be transferred, before complete exhaustion of its propellant, to a supersynchronous graveyard orbit that does not intersect the GSO;

(d) The transfer to the graveyard orbit should be carried out with particular caution in order to avoid radio frequency interference with active satellites;

(e) The following footnote should be considered part of this recommendation: "Further studies are required to define what constitutes an effective graveyard orbit".

5. By the time the ITU recommendations were published, more than 90 spacecraft had already been manoeuvreed out of GEO into a wide variety of disposal orbits, following the precedent set by Intelsat in 1977. In the early 1980s, the written policy of Intelsat was to desynchronize unusable spacecraft 40 to 50 km upward, but a decade later it had raised the minimum altitude to 150 km (see chapter III).

6. Although ITU did not explicitly recommend a specific super-synchronous disposal (graveyard) orbit, its definition of GSO "as a mean radius of 42,164 ± 300 km and extending to 15 degrees north and south latitude" dictated a minimum perigee of the disposal orbit 300 km above GSO.[3]

7. At the twelfth meeting of IADC in Houston in March 1995, action item 12.6 was assigned to Working Group 4 (Mitigation) to review the 1993 ITU recommendation on GSO spacecraft disposal orbits. After extensive scientific debate, IADC, representing the world's leading space agencies, reached a consensus on a new formulation for determining the minimum altitude of disposal orbits, one based upon clearly identified factors.[4]

8. The IADC recommendation recognized that the vast majority (over 97 per cent) of operational GSO spacecraft maintain perigees and apogees within 75 km of GSO. Furthermore, regions extending 125 km on either side of this operational zone were needed as spacecraft translation corridors to permit initial station acquisition and subsequent relocations. To ensure that the upper operational zone and the translation corridor would not intersect with disposal orbits, buffer zones of 35 km and 10-200 km were established to account for orbital perturbations by gravitational forces and solar radiation forces, respectively. The simplified formula is given as

$$\Delta H = 235 + 1000 \times C_R \times A/m,$$

where ΔH is the minimum altitude of the disposal orbit perigee above GSO in kilometres, C_R is the solar radiation pressure coefficient (usually with a value between 1 and 2), A is the average cross-sectional area and *m* is the mass of the satellite. This means that for a spacecraft with an A/*m* of 0.01 m^2/kg, the minimum perigee of disposal orbit should be 245 km above GSO altitude and for spacecraft with 0.10 m^2/kg and $C_R = 2$, it should be 435 km.

III. Examples of the GSO disposal policy

9. In order to prepare the present report, the Secretariat requested satellite operators to provide information on their general policy regarding the disposal of satellites in GSO and on the status of spacecraft they operated near GSO. The substantive responses are summarized below.

A. Intelsat

10. Intelsat has self-imposed policies and procedures to properly decommission "expended" satellites and to prevent the generation of space debris. The existing policies and procedures on general satellite designs, launch operations, satellite operations, satellite anomalies and satellite decommissioning are:

1. General satellite design

Intelsat satellite procurement documentation specifies designs that minimize outgassing and space debris generation during transfer orbit deployments and in-orbit operations.

Intelsat uses satellite designs that are self-contained and generate no orbital debris.

Satellites are equipped, when possible, with measurement devices to assist in determining end-of-propellant conditions.

2. Launch operations

A dialogue is maintained with United States Space Command. Intelsat furnishes launch information and orbital parameters upon request.

3. Satellite operations

Detailed satellite propellant budgets are maintained, including a record of all manoeuvres. Mathematical models are employed to calculate propellant usage and predict remaining reserves. These models are continually updated with flight data.

A propellant uncertainty margin is used to hold back on-board propellant reserves and guarantee that satellites are not stranded in-orbit.

Multiple ground stations are used to track and command satellites in order to provide full redundancy during in-orbit operations or emergency conditions.

Satellite telemetry is continually monitored and compared against preset limits. Alarms are used to alert ground teams of any anomalies.

Battery capacity and power subsystem performance is continually monitored on all satellites. Emergency procedures are in place to "shed load" when low battery or power conditions are noted.

Contingency plans and procedures are available for emergency response: on-call engineering staff are available for immediate 24-hour consultation.

Intelsat abides by standard protocols during orbital relocations and coordinates all activities with the other satellite owners/operators.

4. Satellite anomalies

Contingency plans call for immediate orbit raising and decommissioning of any satellite that is likely to be stranded in the geosynchronous orbital arc. The Director of Satellite Engineering Support and Processes has the authority to make this decision; no other approvals or authorizations are required.

5. Satellite decommissioning

At decommissioning, all satellites are placed into a safe, passive mode. This includes depressurization and venting of propellant systems as part of orbit raising, discharge of batteries and turning off of all radio frequency units to preclude interference with any other satellite owner/operators.

For older satellites, sufficient propellant is held back to raise the orbit to a minimum altitude of 150 km above geosynchronous at decommissioning. This manoeuvre is normally done in multiple parts over several days to guarantee a good parking orbit. For newer satellites, starting with Intelsat VI, a minimum decommissioning altitude of 300 km has been adopted. Because of conservative propellant budgeting, Intelsat normally exceeds the targeted decommissioning altitude.

B. Canadian Space Agency

11. Canada does not have an official GSO disposal policy. It is however considered to be good business judgement to protect present and future spacecraft and respective orbital positions by moving retired objects out of the way. The Canadian space operator Telesat nominally aims for a disposal orbit at 300 kilometres, but there are technical factors that will affect the amount of displacement achieved.

12. The resulting displacement value for retired satellites is generally positive, but in several cases it is less than 300 kilometres (see tables in the annex). The Canadian Government satellite CTS/Hermes (1976-004A) was not controlled by Telesat. It was initially stationed at 116 degrees west longitude, but was later moved to 142 degrees to conduct some experiments with Australia. The control of the satellite was lost on 24 November 1979 while at this position. As a result, it was not possible to move it into proper disposal orbit.

C. Centre National d'Etudes Spatiales

13. The French space agency CNES is focusing its attention on enhancing the understanding of the current debris environment and on the establishment of a French standard to provide space project managers with guidelines on how to reduce risk levels. For satellites in geosynchronous orbit, CNES has applied, since 1983, de-orbiting measures for satellites under its control, except for satellites that failed during their operational mission (e.g. Telecom 1B, 1985-035B). CNES has already adopted the recommendation of IADC concerning the minimum altitude of the disposal orbit for geostationary satellites. A list of disposed satellites is included in tables in the annex.

D. European Space Agency

14. The European Space Agency (ESA) had studied as early as 1979 the collision risk in the geostationary ring and has proposed the use of a disposal orbit in order to protect operational geostationary satellites. The first ESA satellite to be removed from the geostationary orbit was ESA-GEOS 2 (1978-071A) in January 1984. In 1989, ESA objectives in the field of space debris were formulated and approved by its Council. They included a policy to reorbit its geostationary satellites at the end of their operational life to a disposal orbit located at least 300 km above the geostationary orbit. The ESA paper entitled "Space debris mitigation handbook" contains the IADC recommendation on the reorbiting of geostationary satellites at the end of their operational life. A list of disposed satellites is included in tables in the annex. As a consequence of a spacecraft anomaly, the satellite Olympus 1 (1989-053A) could only be transferred to a disposal orbit below the geostationary orbit.

E. EUMETSAT

15. As a general practice, EUMETSAT removes non-functioning spacecraft from the geostationary arc wherever possible. EUMETSAT activity in this area is not governed by a formal policy, but it generally aims to follow the best practice observed by other satellite operators. A list of disposed satellites is included in tables in the annex.

IV. Situation near the geostationary orbit

16. The situation in the region of geostationary orbit, as of about 1 July 1999, is presented in figures and tables in the annex. The number of spacecraft, upper stages and end-of-life (EOL) manoeuvres is given in figures 1 and 2 and in table 1, which were provided by the NASA Johnson Space Center. From 1963 to 1999, as many as 573 spacecraft and almost 200 upper stages were launched near GSO. By mid-1999, the number of operational GSO spacecraft was estimated at 270, and more than 160 spacecraft had been removed from GSO. Dates of EOL manoeuvres, when available, are given in tables 2 to 5.

17. Tables 2 to 5 are based on the document "Classification of geostationary objects, issue 1", issued by

ESOC in August 1999; information was checked and amended using information provided by other sources (see paragraph 2). The completeness of lists of objects near GSO is limited by several factors. In the first place, orbital elements of some objects are not publicly available. In the second place, objects smaller than about 1 metre in size cannot be routinely detected and catalogued. Orbital elements appear in the NASA Two-Line Elements (TLE) and are processed by ESOC and Information System for the Characterization of Objects in Space (DISCOS). The ESOC document mentioned above contains a detailed analysis of available orbital elements for objects in and near the geostationary orbit.

18. The tables in the present report include only spacecraft, not rocket stages and other debris. Spacecraft are divided into different categories according to their minimal distance from the geosynchronous orbit. The objects listed in table 2 fully conform to the ITU standard of minimal 300 km disposal distance from GSO. The objects listed in tables 3 and 4 do not cross the GSO altitude, but they are not at a safe distance from it, and orbital perturbations might cause changes in their orbits which would change their category in the future. Some objects are disposed below the GSO altitude (table 4). Finally, objects listed in table 5 are currently crossing the geostationary orbit and are potentially dangerous to active satellites there.

19. In the column labelled “status” in tables 2 to 5, the general category and corresponding number from the ESOC document “Classification of geostationary objects” are given for easy identification. Active satellites in the C category, which are under the regime of full longitude and inclination control (C1) or only longitude control (C2) have not been taken into account. The fact that a satellite has terminated its useful life is, in principle, determined by the decision of its owner or operator. In the absence of published statements, an indication of the inactivity of satellites is the discontinuation of station-keeping manoeuvres and the drift of satellites from their original nominal positions. It may, however, happen that a satellite is repositioned from one nominal position into another one by putting it into a drift orbit.

20. Most of the objects under consideration are in drift orbits, category D, and are apparently not under station keeping. The mean deviations of their perigees and apogees from the geostationary radius of 42,164 km have been listed as well as their inclinations. The remaining objects are listed under the L category, which means that they are librating (oscillating) around the so-called eastern stable point at 75 degrees east longitude (L1 category), western stable point at 107 degrees west longitude (category L2) or even around both points (L3 category). The libration orbits are rather complicated. They are very close to the nominal GSO altitude, and some cross the GSO twice daily while others cross it only at some phases of their libration period. Therefore their perigee and apogee altitudes have not been listed. Objects of indeterminate status, category Ind, have not been included. Some of the objects in that category might be active; for others, additional information would be needed, possibly provided by their owners or operators, to determine their status.

V. Conclusions

21. The ITU standards and IADC recommendations have been developed quite recently and are not mandatory. It is therefore very difficult to evaluate their international application. Most satellite operators are aware of the seriousness of the situation near GSO and have acknowledged the wisdom of taking some mitigation measures. Because of technical and managerial problems, however, even self-imposed guidelines are not being followed in many cases. For geostationary orbit-protection measures to become effective, a broad international consensus should be reached on the guidelines, and systematic monitoring of their implementation seems to be necessary.

Notes

[1] Official Records of the General Assembly, Fifty-fourth Session, Supplement No. 20 (A/54/20), para. 44.

[2] “Environmental protection of the geostationary-satellite orbit.” In 1993-ITU-R recommendations, ITU-R S series, ITU-R S.1003 (Geneva, Fixed Satellite Service, 1993).

[3] Ibid.

[4] *Fifteenth Inter-Agency Space Debris Coordination Committee Meeting Proceedings, 9-12 December 1997* (Houston, NASA Johnson Space Center, 1998).

Annex

Statistical data

Figure 1
Spacecraft and upper stages placed near the geostationary satellite orbit

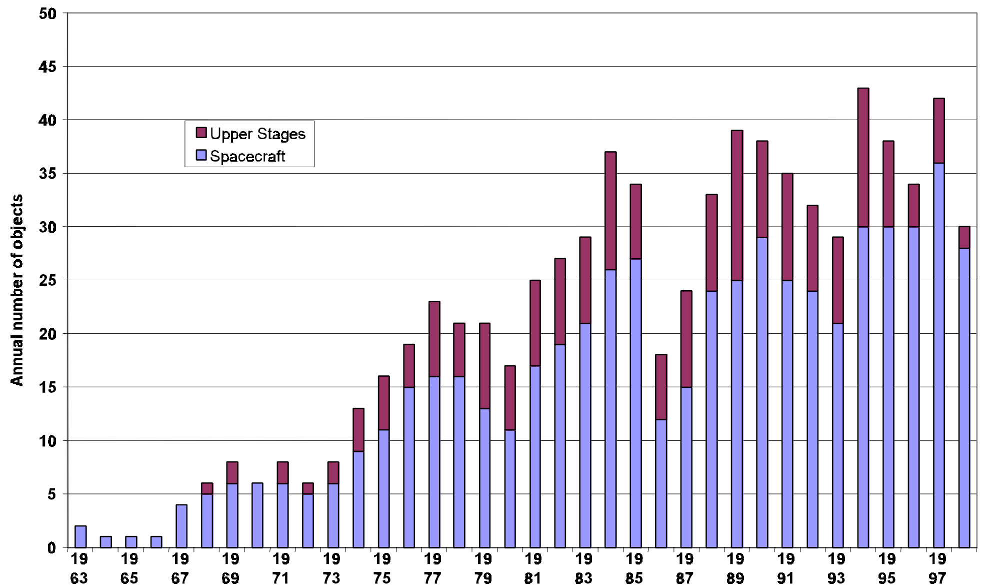

Figure 2
New spacecraft and end-of-life manoeuvres

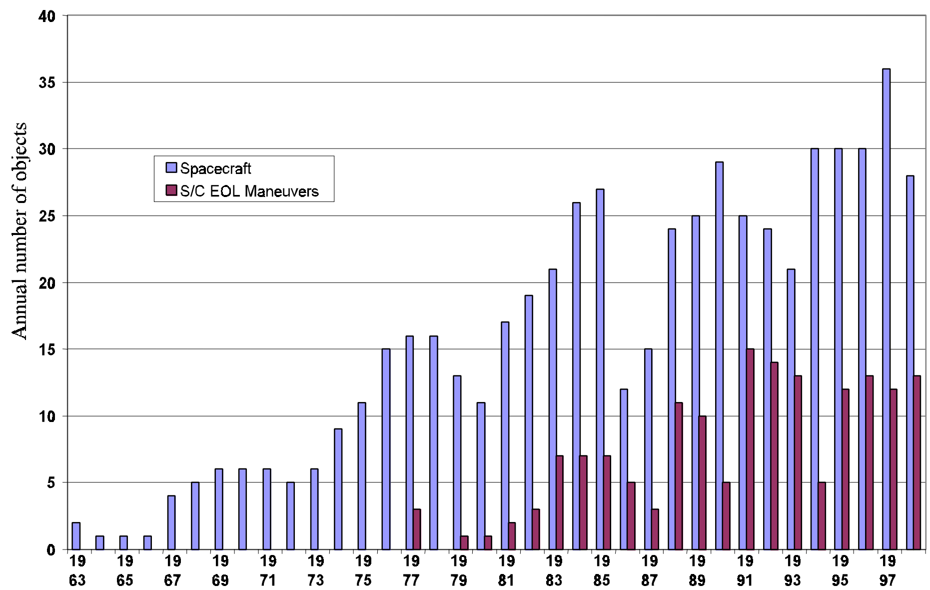

Table 1
Statistics of geostationary satellite orbit operations

Year	*Spacecraft*	*S/C EOL Manoeuvres*	*Upper Stages*
1963	2	0	0
1964	1	0	0
1965	1	0	0
1966	1	0	0
1967	4	0	0
1968	5	0	1
1969	6	0	2
1970	6	0	0
1971	6	0	2
1972	5	0	1
1973	6	0	2
1974	9	0	4
1975	11	0	5
1976	15	0	4
1977	16	3	7
1978	16	0	5
1979	13	1	8
1980	11	1	6
1981	17	2	8
1982	19	3	8
1983	21	7	8
1984	26	7	11
1985	27	7	7
1986	12	5	6
1987	15	3	9
1988	24	11	9
1989	25	10	14
1990	29	5	9
1991	25	15	10
1992	24	14	8
1993	21	13	8
1994	30	5	13
1995	30	12	8
1996	30	13	4
1997	36	12	6
1998	28	13	2
Total	**573**	**162**	**195**

Table 2

Spacecraft with perigees more than 300 km above the geostationary satellite orbit

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.-	1969-045A	Intelsat 3 F-4 (34)	3699 km	3965 km	6.1	1977
D.401	1970-003A	Intelsat 3 F-6 (36)	398 km	755 km	5.18	1977
D.111	1971-006A	Intelsat 4 F-2 (42)	344 km	470 km	15.29	1983
D.110	1972-090A	Telesat 1 (Anik 1)	352 km	468 km	13.89	1982
D.39	1973-100A	DSCS 3	629 km	872 km	16.04	1990
D.31	1973-100B	DSCS 4	491 km	1089 km	15.52	1993
D.94	1974-033A	SMS 1	411 km	533 km	17.33	1981
D.15	1976-053A	Marisat 2	720 km	1824 km	14.36	1996
D.9	1977-005A	NATO 3B	1272 km	1656 km	13.22	1993
D.22	1977-034A	DSCS 7	957 km	1123 km	15.20	1981
D.11	1977-034B	DSCS 8	1266 km	1566 km	14.87	1990
D.117	1977-118A	Sakura 1 (CS-1)	366 km	405 km	13.37	1985
D.87	1978-106A	NATO 3C	482 km	535 km	10.78	1992
D.2	1978-113A	DSCS 11	1741 km	1950 km	14.94	1993
D.84	1978-113B	DSCS 12	502 km	541 km	12.78	1992
D.89	1979-038A	Fleetsatcom 2	421 km	564 km	12.81	1992
D.13	1979-098A	DSCS 13	1327 km	1400 km	12.59	1993
D.82	1979-098B	DSCS 14	525 km	570 km	12.43	1995
D.98	1980-049A	Gorizont 4	443 km	492 km	13.73	1988
D.114	1980-098A	Intelsat 5 F-2 (502)	320 km	467 km	8.19	1998
D.112	1981-050A	Intelsat 5 F-1 (501)	383 km	421 km	8.70	1997
D.103	1981-057A	Meteosat 2	318 km	562 km	9.84	1991
D.93	1981-073A	Fleetsatcom 5	435 km	513 km	12.97	1986
D.6	1981-122A	Marecs 1	1012 km	2056 km	9.59	1996
D.88	1982-020A	Gorizont 5	358 km	634 km	13.03	1989
D.7	1982-106A	DSCS 15	1509 km	1528 km	9.99	1997
D.47	1982-113A	Raduga 11	554 km	916 km	11.84	1989
D.5	1983-016A	Ekran 10	1375 km	1700 km	13.35	1985
D.113	1983-058A	ECS 1	371 km	425 km	7.57	1996
D.81	1983-066A	Gorizont 7	494 km	603 km	11.30	1989
D.108	1983-081A	Sakura 2B (CS-2B)	390 km	439 km	8.74	1990
D.75	1983-088A	Raduga 13	527 km	671 km	11.36	1987
D.80	1983-118A	Gorizont 8	468 km	675 km	10.97	1988
D.28	1984-023A	Intelsat 5 F-8 (508)	858 km	772 km	6.38	1994
D.18	1984-028A	Ekran 12	1182 km	1266 km	12.40	1988
D.108	1984-081A	ECS 2	390 km	448 km	6.87	1993
D.83	1984-081B	Telecom 1A	379 km	686 km	6.79	1992
D.17	1984-090A	Ekran 13	1176 km	1295 km	11.65	1989
D.29	1984-093C	Leasat 2	681 km	936 km	11.82	1996
D.90	1984-113C	Leasat 1	354 km	629 km	6.23	1992
D.3	1985-024A	Ekran 14	1532 km	1685 km	11.38	1988
D.25	1985-028C	Leasat 3	618 km	1290 km	13.15	1996
D.50	1985-076D	Leasat 4	677 km	739 km	8.41	1988
D.120	1985-087A	Intelsat 5A F-12 (512)	305 km	350 km	4.12	1998
D.20	1986-038A	Ekran 15	1011 km	1145 km	10.27	1988

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.86	1986-082A	Raduga 19	474 km	558 km	8.74	1993
D.23	1986-090A	Gorizont 13	954 km	1096 km	8.78	1991
D.16	1987-028A	Raduga 20	1136 km	1370 km	9.23	1991
D.40	1987-040A	Gorizont 14	635 km	864 km	10.27	1992
D.19	1987-073A	Ekran 16	1082 km	1111 km	9.10	1989
D.14	1987-109A	Ekran 17	1100 km	1455 km	7.71	1993
D.74	1988-012A	Sakura 3A	570 km	650 km	2.52	1996
D.54	1988-028A	Gorizont 15	564 km	836 km	7.72	1992
D.8	1988-036A	Ekran 18	1447 km	1554 km	8.61	1990
D.24	1988-051A	Meteosat 3	933 km	985 km	5.49	1995
D.21	1988-108A	Ekran 19	936 km	1154 km	6.97	1997
D.26	1989-020B	Meteosat 4	911 km	834 km	4.30	1995
D.102	1989-048A	Raduga 1-01	371 km	518 km	6.39	1996
D.107	1990-077A	Yuri 3A (BS-3A)	375 km	456 km	1.07	1998
D.116	1991-046A	Gorizont 23	354 km	420 km	4.77	1992
D.105	1991-060A	Yuri 3B (BS-3B)	406 km	436 km	1.85	1999
D.85	1991-074A	Gorizont 24	447 km	595 km	4.47	1998

Table 3
Spacecraft with perigees between 0 and 300 km above the geostationary satellite orbit

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.37	1968-116A	Intelsat 3 F-2 (32)	195 km	1326 km	15.45	1977
D.152	1969-069A	ATS 5	195 km	247 km	15.19	1984
D.161	1971-116A	Intelsat 4 F-3 (43)	130 km	237 km	13.74	1983
D.180	1972-003A	Intelsat 4 F-4 (44)	106 km	143 km	13.23	1983
D.220	1972-041A	Intelsat 4 F-5 (45)	26 km	65 km	13.91	1983
D.175	1973-023A	Telesat 2 (Anik 2)	66 km	201 km	13.07	1982
D.124	1973-058A	Intelsat 4 F-7 (47)	296 km	343 km	13.28	1983
D.190	1974-022A	Westar 1	72 km	139 km	12.76	1983
D.184	1974-075A	Westar 2	97 km	139 km	12.56	1986
D.173	1974-093A	Intelsat 4 F-8 (48)	116 km	158 km	11.89	1985
D.198	1974-101A	Symphonie	68 km	107 km	14.74	1983
D.153	1975-011A	SMS 2	166 km	265 km	14.52	1982
D.213	1975-038A	Telesat 3 (Anik 3)	39 km	87 km	12.03	1984
D.136	1975-042A	Intelsat 4 F-1 (41)	235 km	338 km	11.91	1987
D.200	1975-077A	Symphonie 2	57 km	113 km	14.84	1985
D.194	1975-091A	Intelsat 4A F-1 (411)	74 km	119 km	11.87	1986
D.160	1975-117A	RCA Satcom 1	80 km	303 km	11.99	1984
D.164	1976-010A	Intelsat 4A F-2 (412)	139 km	191 km	12.04	1985
D.129	1976-017A	Marisat 1	265 km	338 km	13.50	1997
D.96	1976-029A	Satcom 2	229 km	708 km	11.77	1985
D.183	1976-035A	NATO 3A	13 km	229 km	12.97	1992
D.179	1976-042A	Comstar 1A	104 km	150 km	11.86	1987
D.217	1976-066A	Palapa 1	38 km	63 km	11.65	1988
D.202	1976-073A	Comstar 1B	66 km	100 km	11.72	1994
D.205	1977-014A	KIKU 2	54 km	95 km	14.26	1991
D.209	1977-018A	Palapa 2	42 km	88 km	10.85	1991
D.148	1977-041A	Intelsat 4A F-4 (413)	179 km	290 km	11.00	1989
D.135	1977-065A	Himawari 1	230 km	349 km	13.74	1989
D.192	1978-002A	Intelsat 4A F-3 (414)	84 km	121 km	10.52	1988
D.123	1978-044A	OTS 2	283 km	358 km	12.30	1991
D.128	1978-068A	Comstar 1C	214 km	395 km	10.41	1986
D.140	1978-071A	ESA-GEOS 2	220 km	286 km	14.27	1984
D.177	1978-116A	Telesat 4 (Anik)	106 km	151 km	9.95	1986
D.197	1979-072A	Westar 3	69 km	114 km	8.91	1990
D.133	1980-074A	GOES 4	140 km	450 km	12.40	1988
D.178	1980-091A	SBS 1	103 km	150 km	9.60	1991
D.156	1981-076A	Himawari 2	152 km	254 km	12.07	1989
D.228	1981-096A	SBS 2	23 km	55 km	8.73	1996
D.221	1981-114A	Satcom 3R	22 km	66 km	6.50	1991
D.151	1981-119A	Intelsat 5 F-3 (503)	140 km	313 km	7.89	1998
D.159	1982-004A	Satcom 4	172 km	214 km	5.87	1991
D.171	1982-014A	Westar 4	121 km	162 km	5.94	1991
D.132	1982-017A	Intelsat 5 F-4 (504)	177 km	414 km	7.90	1995
D.130	1982-058A	Westar 5	228 km	370 km	5.65	1992

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.222	1982-082A	Telesat 5 (Anik D1)	13 km	74 km	6.26	1991
D.195	1982-110B	SBS 3	61 km	129 km	6.01	1995
D.191	1982-110C	Telesat 6 (Anik C3)	83 km	123 km	6.07	1997
D.144	1983-006A	Sakura 2A	198 km	292 km	9.29	1991
D.185	1983-030A	Satcom 1R	79 km	152 km	5.06	1992
D.125	1983-047A	Intelsat 5 F-6 (506)	288 km	339 km	6.53	1998
D.121	1983-059B	Telesat 7 (Anik C2)	154 km	498 km	5.94	1998
D.226	1983-065A	Galaxy 1	23 km	57 km	4.20	1994
D.154	1983-077A	Telstar 3A	112 km	310 km	4.37	1996
D.145	1983-094A	Satcom 2R	178 km	307 km	3.48	1995
D.165	1983-105A	Intelsat 5 F-7 (507)	129 km	197 km	6.86	1996
D.118	1984-005A	Yuri 2A	294 km	396 km	8.60	1989
D.181	1984-080A	Himawari 3	95 km	153 km	8.45	1995
D.172	1984-093D	Telstar 3C	121 km	157 km	3.46	1997
D.182	1984-101A	Galaxy 3	88 km	156 km	3.50	1995
D.115	1984-113B	Telesat 8 (Anik D2)	265 km	509 km	4.74	1995
D.169	1984-114A	Spacenet 2	96 km	195 km	1.85	1998
D.149	1985-048B	Morelos 1	214 km	241 km	4.16	1994
D.188	1985-048D	Telstar 3D	105 km	118 km	3.20	1999
D.170	1985-076B	Aussat-1	122 km	166 km	5.02	1993
D.157	1986-003B	Satcom K1	186 km	220 km	2.15	1997
D.109	1986-007A	Raduga 18	127 km	702 km	9.43	1991
D.137	1986-016A	Yuri 2B	205 km	351 km	6.78	1992
D.174	1986-026A	Gstar 2	115 km	155 km	3.34	1997
D.193	1987-029A	Palapa 5	76 km	127 km	2.73	1998
D.138	1987-070A	KIKU 5	216 km	315 km	6.05	1997
D.122	1987-095A	TV-Sat 1	265 km	376 km	8.07	1989
D.63	1988-018B	Telecom 1C	251 km	1081 km	3.21	1996
D.201	1988-071A	Gorizont 16	25 km	143 km	7.06	1991
D.131	1988-086A	Sakura 3B	270 km	323 km	1.63	1997
D.127	1988-098A	TDF 1	291 km	320 km	2.47	1996
D.163	1988-109A	Skynet 4B	153 km	178 km	5.53	1998
D.119	1989-004A	Gorizont 17	261 km	423 km	6.68	1997
D.155	1989-020A	JCSAT 1	188 km	229 km	1.67	1998
D.126	1989-027A	TELE-X	287 km	330 km	1.98	1998
D.167	1989-041A	Superbird A	125 km	171 km	6.57	1991
D.142	1989-052A	Gorizont 18	100 km	393 km	6.26	1996
D.92	1990-063A	TDF 2	267 km	681 km	0.66	1999
D.-	1993-015A	UFO 1	253 km	322 km	22.90	1993
D.158	1993-039A	Galaxy 4	121 km	1274 km	0.93	1998

Table 4
Spacecraft below the geostationary satellite orbit with apogees between 0 and -400 km

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.290	1968-081A	OV 2-5	-709 km	- 3 km	13.12	
D.294	1974-039A	ATS 6	-599 km	-346 km	14.74	1980
D.240	1985-015A	Arabsat 1A	- 73 km	-10 km	6.53	1992
D.258	1988-034A	Kosmos 1940	-207 km	-14 km	7.45	1988
D.256	1989-041B	DFS 1 Kopernikus 1	-168 km	-49 km	2.82	1995
D.283	1989-053A	Olympus 1	-381 km	-228 km	5.47	1993

Table 5

Spacecraft crossing the geostationary satellite orbit

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.402	1964-047A	Syncom 3	- 43 km	72 km	8.55	
L2.21	1965-028A	Intelsat 1 F-1 Early Bird			13.41	
D.236	1966-110A	ATS 1	-59 km	25 km	13.91	
D.235	1967-001A	Intelsat 2 F-2 (22)	-46 km	98 km	14.42	
L3.5	1967-026A	Intelsat 2 F-3 (23)			13.79	
L2.24	1967-094A	Intelsat 2 F-4 (24)			14.25	
L41.3	1968-081C	ERS-21 (OV 5-4)			13.58	
L2.19	1968-081D	LES 6			13.57	
L1.3	1968-081C	OV 5-4			13.58	
L1.1	1969-011A	Intelsat 3 F-3 (33)			6.09	1979
D.403	1969-013A	Tactical Comsat 1	- 38 km	15 km	14.52	
L2.6	1969-101A	Skynet 1A			14.65	
L2.9	1970-021A	NATO 1			14.38	
L42.1	1970-032A	Intelsat 3 F-7 (37)			0.85	
D.295	1970-055A	Intelsat 3 F-8 (38)	-1960 km	863 km	13.48	Failed to GEO
L2.8	1971-009A	NATO 2			15.18	
L2.10	1971-095A	DSCS 1			15.15	
L3.1	1971-095B	DSCS 2			15.05	1993
D.259	1974-017A	Kosmos 637	- 314 km	31 km	14.77	
L1.42	1974-060A	Molniya S1			15.17	
L1.68	1974-094A	Skynet 2B			14.25	
L1.47	1975-097A	Kosmos 775			15.15	
L2.15	1975-100A	GOES 1			14.60	
L1.13	1975-123A	Raduga 1			15.04	
L2.18	1976-004A	CTS 1 (Hermes)			14.89	Failed 1979
L2.11	1976-023A	LES 8			13.00	
L2.2	1976-023B	LES 9			12.99	
L1.15	1976-092A	Raduga 2			15.01	
L1.26	1976-107A	Ekran 1			14.98	
L1.48	1977-071A	Raduga 3			14.84	
L1.54	1977-080A	Sirio 1			12.54	
L1.31	1977-092A	Ekran 2			14.79	
L1.65	1977-108A	Meteosat 1			14.32	
L1.69	1978-035A	Intelsat 4A F-6 (416)			10.51	
L1.43	1978-039A	Yuri 1 (BSE 1)			14.14	
L2.7	1978-062A	GOES 3			12.65	1995
L1.46	1978-073A	Raduga 4			14.55	
D.-	1978-118A	Gorizont 1	-13938 km	13946 km	25.10	Failed to GEO
L1.33	1979-015A	Ekran 3			14.33	
L1.12	1979-035A	Raduga 5			14.29	
L1.17	1979-062A	Gorizont 2			13.99	
L1.25	1979-087A	Ekran 4			14.08	
L1.44	1979-105A	Gorizont 3			13.79	
L2.33	1980-004A	Fleetsatcom 3			11.66	
L1.41	1980-016A	Raduga 6			13.90	

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
D.405	1980-018A	Ayame 2	-3002 km	1053 km	1.39	Failed to GEO
L41.2	1980-060A	Ekran 5			11.33	
L2.27	1980-081A	Raduga 7			13.57	
L1.30	1980-104A	Ekran 6			13.50	
D.238	1981-027A	Raduga 8	-375 km	315 km	13.51	
L2.17	1981-049A	GOES 5			9.83	
D.208	1981-057B	APPLE	-25 km	158 km	12.83	1984
L1.34	1981-061A	Ekran 7			13.24	
L1.49	1981-069A	Raduga 9			13.16	
L1.11	1981-102A	Raduga 10			13.04	
D.196	1982-009A	Ekran 8	-30 km	217 km	12.93	1984
D.404	1982-031A	Insat 1A	- 225 km	149 km	0.07	1984
L1.9	1982-044A	Kosmos 1366			12.80	
L1.38	1982-093A	Ekran 9			12.43	
L2.25	1982-103A	Gorizont 6			12.04	
L2.3	1982-105A	RCA Satcom 5			6.35	
L1.10	1983-028A	Raduga 12			11.46	
L2.16	1983-041A	GOES 6			8.78	
D.232	1983-059C	Palapa 3	5 km	50 km	7.01	Failed 1995
		(included here because the orbit is very close to GSO)				
L1.61	1983-089B	Insat 1B			7.54	1993
D.233	1983-098A	Galaxy 2	- 3 km	45 km	4.09	1994
L1.36	1983-100A	Ekran 11			11.73	
L1.14	1984-016A	Raduga 14			10.77	
L1.5	1984-022A	Kosmos 1540			11.76	
L1.7	1984-031A	Kosmos 1546			10.66	
L1.66	1984-035A	China 15			9.43	
L1.24	1984-041A	Gorizont 9			10.50	
L1.59	1984-063A	Raduga 15			10.55	
L2.22	1984-078A	Gorizont 10			10.24	
L3.7	1985-007A	Gorizont 11			9.84	
L2.30	1985-016A	Kosmos 1629			10.02	
L1.71	1985-035B	Telecom 1B			8.78	Failed 1988
D.239	1985-048C	Arabsat 1B	- 83 km	5 km	5.84	
L2.26	1985-070A	Raduga 16			9.60	
L2.14	1985-076C	ASC-1			3.79	
L1.20	1985-102A	Kosmos 1700			9.32	
D.229	1985-107A	Raduga 17	-11 km	75 km	9.37	1992
L1.37	1986-010A	China 18			8.32	
L2.36	1986-027A	Kosmos 1738			9.34	
L1.45	1986-044A	Gorizont 12			8.84	
L3.9	1987-084A	Kosmos 1888			7.74	
L2.31	1987-091A	Kosmos 1894			7.85	
L1.22	1987-096A	Kosmos 1897			7.64	
L2.20	1987-100A	Raduga 21			7.86	
L1.16	1988-014A	China 22 (STTW-1 2)			4.70	
L1.19	1988-063A	INSAT 1C			7.43	

Status	*COSPAR ID*	*Name*	*Perigee*	*Apogee*	*Inclination*	*EOL man.*
L1.3	1988-066A	Kosmos 1961			7.04	
L1.62	1988-095A	Raduga 22			6.86	
L1.53	1989-030A	Raduga 23			6.49	
L1.50	1989-081A	Gorizont 19			6.14	
L1.39	1989-098A	Raduga 24			6.06	
L2.35	1989-101A	Kosmos 2054			5.90	
L1.29	1990-011A	China 26 (STTW-2A)			3.09	
L2.23	1990-016A	Raduga 25			5.80	
L1.23	1990-054A	Gorizont 20			5.55	
L1.4	1990-061A	Kosmos 2085			5.47	
L1.27	1990-112A	Raduga 26			5.12	
L1.35	1990-116A	Raduga 1-02			5.12	
L1.6	1991-010A	Kosmos 2133			4.00	
L1.58	1991-014A	Raduga 27			5.29	
L3.3	1991-064A	Kosmos 2155			4.70	
L3.8	1991-079A	Kosmos 2172			4.45	
L2.29	1992-059A	Kosmos 2209			3.91	
L1.64	1992-088A	Kosmos 2224			2.66	
L2.13	1993-077A	Telstar 401			1.99	Failed
L1.40	1994-012A	Raduga 31			2.63	
L2.28	1994-038A	Kosmos 2282			1.53	
L1.2	1994-069A	Elektro			2.42	
D.264	1994-080A	DFH 3 (China 44)	- 572 km	185 km	3.18	Failed to GEO
L2.34	1994-082A	LUCH			1.07	
L2.4	1995-057A	UFO 6 (USA 114)			3.68	
D.305	1997-027B	INSAT 2D	-2620 km	179 km	1.46	Failed 1997
L2.32	1997-041A	Cosmos 2345			0.22	
L1.21	1997-070A	Kupon 1			1.09	Failed 1997
L1.8	1998-025A	Cosmos 2350			1.34	