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COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE

PHYSICAL NATURE AND TECHNICAL ATTRIBUTES OF THE GEOSTATIONARY ORBIT

Study prepared by the Secretariat

Addendum

Note by the Secretariat

1. The Committee on the Peaceful Uses of Outer Space, at its twenty-fifth session from 22 March to 1 April 1982, endorsed the request of the Scientific and Technical Sub-Committee that the study on the physical nature and technical attributes of the geostationary orbit (GSO) (A/AC.105/203 and Add.1-3) continue to be brought up to date as required. The Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, held in Vienna from 9 to 21 August 1982, adopted in its report (A/CONF.101/10) several recommendations and comments concerning the GSO, some of which fell within the scope of its physical nature and technical attributes.

2. The present study has been prepared, in response to the above requests and comments, by the Outer Space Affairs Division with the assistance of Dr. B. Jasani of the Stockholm International Peace Research Institute and of Dr. L. Perek, Dr. P. Lála, and Dr. L. Sehnal of the Astronomical Institute of the Czechoslovak Academy of Sciences.

3. Since the Scientific and Technical Sub-Committee has before it several documents on the geostationary orbit (A/AC.105/203 and Add.1-3; A/CONF.101/BP/7; annual reports by the International Telecommunication Union (ITU) on telecommunication and the peaceful uses of outer space and annual reports by International Telecommunications Satellite Organization (INTELSAT), the contents of the present study have been restricted to three subjects: the present and planned occupation of, alternatives to, and close encounters in the GSO.

I. THE PRESENT AND PLANNED OCCUPATION OF THE GEOSTATIONARY ORBIT

4. According to the Radio Regulations, a "space station" is defined as a station (one or more transmitters or receivers or a combination of transmitters and receivers) located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the earth's atmosphere. A "satellite" is a body which revolves around another body of preponderant mass and which has a motion primarily and permanently determined by the force of attraction of that other body. In principle, it is possible to locate two or more space stations on a single satellite. Therefore a distinction has to be made between a satellite, which is a vehicle or spacecraft, and a space station, which is a group of instruments mounted on that vehicle.

5. Another important term is the "nominal orbital position". This is assigned to a space station by a member administration of ITU and notified to the International Frequency Registration Board (IFRB). Whenever necessary, following notification, nominal orbital positions are co-ordinated with those of other space systems and, upon reaching agreement, registered by IFRB in the Master International Frequency Register. Relevant information is published at all important steps in special sections of the weekly IFRB Circular.

6. In paragraph 62 of the UNISPACE 82 report (A/CONF.101/10) it is stated that, as of 31 December 1981, a total of about 220 satellites were already in operation or notified to ITU as planned for operation in the GSO. Since this statement refers to IFRB documents, the correct term was "space stations" instead of "satellites".

7. A nominal orbital position is filled when the satellite carrying the space station in question is launched, successfully introduced into the GSO and its transmissions started in the assigned frequencies of the radio spectrum. Some nominal positions may not have been filled, and other positions may have been vacated at any given moment. Thus there is always a difference between the number of assigned nominal positions and the number of satellites actually on station.

8. Reasons for not filling a nominal position range from changes in original plans to protracted co-ordination procedures, technical reasons for postponing launch and malfunctions during launch or during operation of the satellite. Reasons for vacating nominal positions are usually connected with terminated activity of the particular spacecraft and with exhausted fuel for station-keeping manoeuvres. Some satellites are being deliberately removed from the GSO towards the end of their active lives. This was the case with several INTELSAT 3 satellites, with Raduga 5, ATS 6, Anik 1, SMS 1 and SMS 2. All of them have been removed to disposal orbits, either beyond or below the GSO. The intention has been reported to remove satellites Symphonie 1 and 2 from the GSO, using their last reserves of cryogenic gas. Such manoeuvres are most useful and recommendable because they help to reduce the danger of possible collisions and damage to expensive active satellites.

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9. Also present in the GSO, in addition to active satellites, are those inactive bodies which have terminated their activities but which have not been removed from the orbit. Some non-functional objects, such as apogee motors, also move in or pass close to the GSO. For practical purposes, a belt of 150 km below and the same distance above the GSO has been considered here.

10. The need to distinguish betwen nominal positions, which are analogous to assigned parking places, and actual presence in the orbit required the listing of geostationary satellites and space objects given below. Table 1 lists all satellites and space objects which are materially present and observed in the orbit or close to it. Objects which only occasionaly pass through the belt of the GSO have not been listed. There are a number of objects in eccentric orbits with apogees beyond the distance of the GSO. Such orbits are subject to perturbations caused by the oblateness of the earth and by the attraction of the sun and the moon, the main effects being the regression of the nodes and the precession of the line of the apsides. Consequently, satellites in such orbits cut through the GSO only during some periods of time, at other times avoiding the neighbourhood of the GSO for several years depending on their inclination and other orbital parameters. Since such orbits contribute relatively little, and intermittently, to the general population of the GSO, they have not been listed in table 1.

11. The headings of table 1 give the international designation of each space object as assigned on behalf of the Committee on Space Research (COSPAR), the launching country and agency in easily understood abbreviations as given in the 1982 report of ITU, the name of the satellite at launch (which frequently differs from the name used in IFRB Circulars), the longitude of the subsatellite point computed from the two-line orbital elements, 1/ the date when the satellite was observed above that longitude, and remarks. The remark "inactive" means that the satellite is not transmitting according to the Table of Artificial Earth Satellites, published by the Royal Aicraft Establishment. 2/ "Drifting" means that the movement of the satellite in the GSO exceeds the motion usually observed with satellites kept at a station. 3/

12. Table 1 shows that, as of 31 December 1982, there were at least 169 trackable objects in the GSO in the following categories:

Non-functional objects	20
Inactive satellites	41
Research, experiment, meteorology	17
Communications	74
National means of verification and/or early warning	17

The uncertainty in the total number of objects in the GSO arises from the fact that some non-functional objects might have escaped detection either because they were small or because they have never transmitted any radio signals or were lost when the signals ceased. Thus, Chobotov 4/ reported that on 27 April 1980 there were 103 non-functional objects and inactive satellites in the GSO, 56 of them with no recent tracking. Out of the 74 communication satellites, more than 20 serve the international community and 4 have been launched by or for developing countries.

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To exactly what extent developing countries benefit from the use of the GSO is difficult to assess accurately. There are a number of bilateral and multilateral agreements for participation in domestic as well as international satellite systems. For participation of developing countries in the INTELSAT system, for example, the reader is referred to the INTELSAT annual report for 1982, which lists 76 developing countries as members and several additional countries as international users.

13. Several space stations and systems were planned to be put into use before the end of 1982 in addition to those of table 1. These are listed in table 2, which was compiled from IFRB Circulars. Out of the 52 entries, 31 are being co-ordinated at present and this may be the reason for the delay. For nine space stations, only advance publication is at hand, possibly indicating that the planning has not yet reached its final stage. The launching of others may have been delayed for technical reasons, or their function is implemented by one or more transponders on satellites already in orbit. Therefore, some, but definitely not all, space stations listed in table 2 will have their own satellites launched in the future.

14. Future plans, as far as they have been notified to ITU, are reflected in table 3 which lists space stations planned to be put into operation in the GSO in the years 1983 to 1987. Total numbers of satellites to be expected in the GSO in the future cannot, however, be established as simple additions of space stations shown in the respective tables. Plans for new space stations are still appearing, thus increasing values in the tables. On the other hand, after the termination of their active lifetimes, satellites become inactive or are even ejected from the GSO, decreasing the numbers of active satellites in the orbit. A parameter which may assist in getting an idea of future occupation of the GSO is the expected duration of use of a space station. This is shown in the last column of table 3, under "period of validity". According to a resolution adopted at the 1979 World Administrative Radio Conference of ITU, the period of validity of assignments of orbital positions must be furnished by the countries and published by IFRB.

15. The total number of all tracked space objects in the GSO was, as of 31 December 1982, 169, of which 108, or less, were active. The total number of nominal positions referred to the same date was, according to the twenty-second report by ITU on telecommunication and the peaceful uses of outer space (1983), 243 with the following break-down: 83 space stations had been registered, 92 were in the co-ordinating process under the relevant ITU Radio Regulations and 68 were advance publications by member administrations of ITU. In addition, the plan for the broadcasting satellite service, adopted at the Geneva Conference in 1977, lists 162 space stations at 36 positions in the orbit.

16. As stated in the study (A/AC.105/203), it is impossible to determine how many satellites can be accommodated in the GSO. It is, however, possible to find out if a specific satellite system, with all physical parameters defined, would interfere with other systems or not.

17. Some early estimates of the total capacity of the GSO gave the number as 180 satellites, corresponding to the requirement, then quoted, for a 2° separation between two neighbouring satellites. That estimate has been surpassed due to

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development of technology. Taking from the preceding paragraph the number of stations already registered, plus a great majority of those being co-ordinated, plus those planned for the broadcasting satellite service, the figure of 180 is considerably exceeded. Nevertheless, the capacity of the GSO is finite, even taking into account the state of technology and the efficiency of use.

II. ALTERNATIVES TO THE GEOSTATIONARY ORBIT

18. In the report of UNISPACE 82 (para. 285), the fact was mentioned that, for certain purposes and locations, it may not be essential to use the GSO. Since increasing concern has been expressed regarding the congestion of the GSO, countries were invited to examine whether or not, for their needs, they could use a satellite in elliptical orbit rather than in the geostationary. The report also states that the feasibility and overall advantages of using elliptical orbits for international communiction merits re-examination.

19. The full examination of alternatives to the GSO would require extensive work which is beyond the scope of the present study. Only basic facts and possibilities are presented here.

20. It is not necessary to consider alternatives for meteorological, remote sensing or scientific satellites in the GSO, because there are few such satellites and they do not contribute significatnly to the congestion of the GSO. Four or five meteorological satellites are enough to provide coverage for the whole earth. On the other hand, communication satellites are very numerous. Furthermore, solar power sttions, if and when they are implemented, would require a relatively large number of space stations to make the supply of energy significant. Alternatives for these two applications are most important for alleviating the congestion in the GSO.

A. Eccentric 12-hour orbits

21. Within three days of the successful launch of the first truly geostationary satellite, Syncom 3, by the United States of America in 1964, an experimental satellite, Cosmos 41, was launched by the Union of Soviet Socialist Republics into a highly eccentric 12-hour orbit. A series of Molniya satellites was initiated in the following year for communication purposes. The inclination of the Molniya orbits is typically 62.8°, which makes communications possible even with locations at very high northern latitudes. The elliptic orbit has an altitude between 400 and 40.000 km, the two apogees each day being situated approximately at longitudes 90°E and 90°W. The apparent movement of the satellite in the sky is very slow near the apogee. One satellite is capable of providing communications for up to nine hours. A set of three or four satellites provides for continuous communications. Figures 1 and 2 show an example of the tracks of four Molniya satellites in the sky, over a 24-hour period, from locations near Prague and near Havana. It is evident that tracking within an area of some 18° x 12° at a comfortable elevation over the horizon is sufficient to provide communications between two fairly distant locations.

22. The orbital inclination near 63° has an additional advantage. It is close to the "critical inclination" of 63.4° at which there is no movement of the perigee in the orbital plane. Thus the Molniya satellites never pass through the GSO even though their orbits have apogees at a distance exceeding that of the GSO. Another advantage is in the relatively low perigee of some 400 km. The drag of the atmosphere and lunisolar perturbations at that altitude shorten the lifetime of the satellites to about 12 to 20 years. Thus, after a time span somewhat exceeding the active lifetime of the satellite, natural decay sets in and there is no problem of too many inactive satellites in the Molniya orbits, as there is in the GSO.

23. A series of USSR Cosmos satellites have similar orbits, as do some of the United States Satellite Data System (SDS) satellites.

B. Eccentric 24-hour orbits

24. By definition, the inclination and eccentricity of the GSO are zero because the orbit lies in the equatorial plane and is circular. If one or both of the two parameters are different from zero, the orbit can still be synchronous, i.e. the period of revolution of the satellite around the earth equals the period of the earth's rotation. The satellite, however, does not appear stationary in the sky, and ground antennae have to perform movements in elevation and azimuth in order to track the satellite. This is the price to pay for the possibility of accommodating a larger number of satellites than the GSO alone permits.

25. As an example, figure 3 shows the track in the sky of a satellite moving in an orbit with inclination $i=0.5°$, eccentricity $e=0.005$, and the perigee situated at the southernmost point of the orbit. The orbit, as seen from a suitable location on the equator, has an almost circular shape (right-hand side of the figure), traversed by the satellite every 24 hours. The left-hand side of the figure shows the orbit as projected onto a meridional plane. The GSO appears as a point, marked by a circle, and the orbit appears as an almost straight line passing fairly close to the GSO.

26. Such an orbit could accomodate several satellites if care were taken of proper station-keeping and maintaining relative positions. If, for example 12 satellites are at regular intervals in the orbit, the closest distance between satellites would be about 200 km, which would be seen from the ground as about 0.3.* By enlarging the orbit through a proper choice of the inclination and eccentricity, this distance could be made as large as 2°, large enough to separate transmission signals from each satellite at the ground station. Such an arrangement would accomodate 12 satellites at a separation of 2°, using up only two locations in the GSO itself.

27. In another application, the orbit can be made as small as to fit within the angular size of the maximum sensitivity lobe of the ground antenna, e.g., a parabolic earth antenna of 1 m diameter designed for the 12 GHz band, permits good reception within an area of 1.6° diameter. The orbit shown in figure 3 is seen under a smaller angle than that from any location on the earth. In such a case, the antenna would receive transmissions from all satellites in the orbit

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simultaneously. The main advantage is a stationary ground antenna. There would be no need for tracking. Another advantage of such a cluster of satellites lies in the possibility of replacing a satellite by a new one without the need for manned missions to replace new antennae or other parts on large space stations. A more suitable orbit for satellite clusters is shown in figure 4. Its orbital elements are the same as in figure 3, with the exception of the location of the perigee. If the perigee is in the GSO, the orbit, seen from the ground, has the form shown in the right-hand part of figure 4. Its projection on the meridional plane, shown in the left-hand part of figure 4, shows that all satellites in the cluster keep a fairly large minimum distance from the GSO, thus substantially reducing the possibility of physical interference with satellites strictly in the GSO.

28. The apparent shape of geosynchronous orbits depends on the location of the observer. The oval in figure 3 would look almost the same from northern latitudes, while it would look somewht flattened from southern latitudes. The nearly straight line in figure 4 would look like a very narrow oval from both northern and southern latitudes.

29. Figures 3 and 4 show only two basic shapes of the multitude of shapes and sizes of geosynchronous orbits. The purpose here was to show the possibilities given by the laws of satellite motion, in particular the possibility of accommodating several satellites in a single orbit with sufficient angular separation, or of keeping all satellites in one geosynchronous orbit at a sufficient distance from the GSO.

III. CLOSE ENCOUNTERS IN THE GEOSTATIONARY ORBITAL BELT

30. Satellites in the GSO are not entirely stationary. Gravitational perturbations, caused by the complex shape of the earth and by the forces exerted by the sun and the moon on the satellites, pull them out of the equatorial plane, thus increasing the inclination of their orbits and, equally important, attracting them towards two stable points in the GSO at about 75°E and 105°W. Satellites can be kept at their stations only by periodic station-keeping manoeuvres. Adequate allowance for these motions is thus required. The range of the motions depends on the state of technology. A typical value is 0.1° or 75 km at present.

31. Inactive satellites either oscillate around one of the stable points in the GSO or drift around the entire orbit. Since inactive satellites attain inclinations of several degrees, they cut through the GSO on their two daily passes with relatively large speeds.

32. There is no required minimum separation between orbital positions of space stations as they are registered by IFRB. Sometimes the same position is assigned to several stations. For example, in the list of geostationary space stations, 5/ there are seven space stations sharing the position at 19°W, six stations at 60°E, five stations at 140°E, and three or four stations appear at several orbital positions. In the plan adopted by the Broadcasting Satellite Conference in Geneva, 1977, up to 13 stations appear at the same orbital position. Even if nominal positions could be subdivided, slots of not more than 0.1° would result. Satellites would come very close together at the borders of the slots.

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33. The fact that satellites sharing the same nominal orbital position come periodically close together has been observed and reported. According to a paper presented at the 33rd Congress of the International Astronautical Federation, Paris, 1982, 6/ a sample of GSO encounters for 21 satellites over a period of six months in the second half of 1981 showed that there were 120 predicted encounters within a 50 km miss distance. Several close approach predictions were in the 1 to 5 km range, which resulted in collision avoidance manoeuvres being made. As an example, Fltsatcom 1, 1978-016A, operating at longitude 100°W, had eight close encounters with SBS 1, 1980-091A, five of them between 2.6 km and 6.0 km and five additional close encounters with four other satellites. A finite probability of collision existed at móst of these encounters because of inaccuracies in determining satellite positions and orbits. Accoding to another report, 7/ it was estimated in early May 1980 that satellites 1978-016A and 1973-040A would soon pass close to each other. On 4 May the predicted distance was 9.4 km and a few days later the predicted miss distance was reduced to only 3.5 km. The uncertainty in determining the accurate positions and speed was larger than the miss distances: 10.0 and 20.0 km at the respective two approaches. In order to avoid a possible collision, Fltsatcom 1, 1978-016A, performed an evasive manoeuvre.

34. The relative velocity at encounters may vary from almost zero to very high speeds. Typically, it is of the order of about 500 km/h if the inclinations of the orbits are 1-2° and it attains double that value for inclinations around 5°. At these speeds, a collision with even a very small piece of debris is usually fatal and results in a sudden loss of the satellite. With present tracking technology it is possible to detect debris of about 10 cm size in low orbits and of 1 m size in the GSO. Thus not all potential collisions in the GSO can be predicted and avoided by evasive manoeuvres. A collision might have been the cause of damage to solar panels on GEOS 2 and also the cause of serious damage to several satellites outside the GSO.

35. In any discussion on the use of the geostationary orbit it is important to focus on issues such as the increasing saturation of this orbit and the increasing probability of collisions between satellites in this orbit. These issues have been dealt with above. However, an understanding of such problems would not be complete without an examination of actual missions of various types of satellites in the geostationary orbit. From table 1 it can be seen that there are mainly three applications for which the orbit is used, namely, for monitoring the earth's environment and its weather and climate, for communications, and for the detection of the launches of intercontinental ballistic missiles and verification of disarmament agreements. Some of the latter satellites are reported to carry sensors for monitoring missile tests. Although the majority of the meteorogolical and environmental satellites are launched and used by the civilian agencies of various countries, this is not the case with the communications and the verification/missile detection satellites. The former type of satellites are launched by both civilian and military space agencies whereas the latter are launched exclusively by the military agencies of some States. Thus, more than a third of all space objects in the GSO are the result of military activities. Therefore, the impact on the GSO of military activities is not insignificant and presumably could increase in the future as more and more countries perceive the need for the use of outer space for such military purposes.

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36. In addition to the issue of congestion of the geostationary orbit, it is very important to realize that serious difficulties could arise from collisions between spacecraft in this orbit. The example cited earlier of two close encounters of satellite 1973-40A with other satellites helps to illustrate the dangers that exist in the way this orbit is being used at present. Satellites which are used for verification of arms control agreements or for continuously monitoring the earth's surface to detect the launches of intercontinental ballistic missiles, and would thus give an early warning of a surprise attack by such missiles, form the basis for feelings of confidence and stable relationships between States. Their status is, therefore, an extremely sensitive one. A collision with such a satellite, or even with a military communications satellite, could arouse fears that an anti-satellite weapon had been used. In fact such fears have been aroused already on several occasions. This has to be viewed in the context of the development and even deployment of such systems. Moreover, as time goes on the probability of collision will increase because we can expect that there will be many more nations orbiting spacecraft in the GSO and because future satellites may be even larger than those currently deployed.

37. The international community might wish, upon assessing the importance of a safe and orderly conduct of space activities and of building up feelings of confidence among States, to investigate the matter and to consider the adoption of measures increasing the safety of space operations as well as protecting the environment. Such measures might deal with recommendations to restrict the amount of debris in outer space, to remove, whenever feasible, inactive satellites from orbital lanes used for important activities and to regulate the shared use of an orbital position in the GSO.

Notes

1/ Two-line orbital elements, issued daily by the NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

2/ Table of Artificial Earth Satellites, published by the Royal Aircraft Establishment, Farnborough, United Kingdom of Great Britain and Northern Ireland.

3/ A/AC.105/203, p. 5.

4/ V. A. Chobotov, "The collision hazard in space", The Journal of the Astronautical Sciences, 1982, vol. 30, p. 191.

5/ Twenty-second report by ITU on telecommunication and the peaceful uses of outer space, Geneva, 1983.

6/ M. G. Wolfe, V. Chobotov and F. E. Bond, "Man-made space debris implications for the future".

7/ N. L. Johnson, "The crowded sky", Spaceflight, 1982, vol. 24, p. 446.

ANNEX

Table 1. Artificial satellites and space objects in the geostationary orbit as of 31 December 1982

COSPAR No.	Country Agency	Name	Orbital position	Date and remarks
1963-031A	USA	Syncom 2		inactive, drifting
1964-047A	USA	Syncom 3		inactive, drifting
1965-028A	USA	Early Bird		inactive, drifting
1966-110A	USA	ATS 1	164.5E	10 Jan 83, drifting to 162 E
1967-001A	USA/IT	Intelsat 2 F-2		inactive, drifting
1967-026A	USA/IT	Intelsat 2 F-3		inactive, drifting
1967-094A	USA/IT	Intelsat 2 F-4		inactive, drifting
1967-111A	USA	ATS 3	105.4 W	5 Dec 82
1968-063A	USA	BMEWS I-1		inactive
1968-081C	USA	ERS-21		inactive
1968-081D	USA	LES 6	90.5 W	29 Oct 82, inactive
1968-081E	USA	non-functional	179.6 W	6 Dec 82, drifting
1969-013A	USA	Tacsat 1		inactive
1969-036A	USA	BMEWS 2		inactive
1969-069A	USA	ATS 5	70.2 W	7 Dec 82
1969-101A	G	Skynet 1A	98.6 W	10 Oct 80, inactive, drifting
1970-021A	NATO	NATO 1	108.3 W	28 Oct 82, inactive
1970-032A	USA/IT	Intelsat 3 F-7		inactive
1970-069A	USA	BMEWS 4		inactive
1971-000E		non-functional		
1971-006A	USA/IT	Intelsat 4 F-2	5.1 E	30 Nov 82, inactive, drifting
1971-009A	NATO	NATO 2	107.7 W	29 Nov 82, inactive
1971-039A	USA	IMEWS 2	89.2 E	2 Dec 82, inactive, at an orbit 60-100 km below GSO
1971-039B	USA	non-functional	35.1 W	19 Nov 82, drifting
1971-095A	USA	DSCS 1	105.4 W	6 Dec 82, inactive
1971-095B	USA	DSCS 2	69.7 W	31 Dec 81, inactive
1971-116A	USA/IT	Intelsat 4 F-3	46.0 W	30 Nov 82, leased service
1972-003A	USA/IT	Intelsat 4 F-4	1.1 W	27 Nov 82
1972-041A	USA/IT	Intelsat 4 F-5	37.6 W	26 Nov 82, inactive
1972-101A	USA	BMEWS 5		inactive
1973-013A	USA	BMEWS 6		inactive
1973-023A	CAN	Anik A2	140.7 E	6 Dec 82, inactive, drifting, at an orbit 100 to 170 km beyond GSO
1973-040A	USA	IMEWS 4	2.7 W	21 Nov 82, drifting, at an orbit 70 to 180 km beyond GSO
1973-058A	USA/IT	Intelsat 4 F-7	53.0 W	4 Dec 82
1973-100A	USA	DSCS 3	38.9 W	15 Jun 82, inactive, drifting
1973-100B	USA	DSCS 4	60.3 E	30 Nov 82
1974-017A	URS	Cosmos 637	139.8 E	6 Dec 82, inactive, drifting
1974-017F	URS	non-functional	157.0 E	5 Dec 82, drifting
1974-022A	USA	Westar 1	78.9 W	23 Nov 82
1974-039C	USA	non-functional	30.9 W	20 Nov 82, drifting
1974-075A	USA	Westar 2	79.0 W	21 Nov 82
1974-093A	USA/IT	Intelsat 4 F-8	179.2 E	2 Dec 82
1974-094A	G	Skynet 2B	5.7 E	3 Nov 82
1974-101A	F/SYM	Symphonie 1	11.2 W	29 Nov 82
1975-038A	CAN	Anik A3	114.0 W	24 Oct 82
1975-042A	USA/IT	Intelsat 4 F-1	174.1 E	27 Nov 82
1975-055A	USA	BMEWS		
1975-077A	F/SYM	Symphonie 2	11.6 W	10 Nov 82
1975-091A	USA/IT	Intelsat 4A F-1	18.5 W	14 Nov 82
1975-097A	URS	Cosmos 775	53.3 E	10 Jun 82, inactive
1975-097F	URS	non-functional	17.6 E	23 Nov 82, drifting
1975-100A	USA	GOES 1	129.2 W	2 Jan 83, re-activated

Table 1. (cont.)

COSPAR No.	Country Agency	Name	Orbital position	Date and remarks
1975-117A	USA	RCA Satcom 1	135.1 W	6 Dec 82
1975-118A	USA	IMEWS 5	13.4 E	20 Nov 82, drifting
1975-118C	USA	non-functional	117.6 W	17 Jan 82, drifting
1975-118D	USA	non-functional		
1975-123A	URS	Raduga 1	92.9 E	24 Jan 82, inactive
1975-123F	URS	non-functional	153.6 E	13 Oct 82
1976-004A	CAN	Anik C2	132.7 W	5 Dec 82
1976-010A	USA/IT	Intelsat 4A F-2	21.5 W	19 Nov 82
1976-017A	USA	Marisat 1	14.9 W	6 Dec 82
1976-023A	USA	LES 8	107.2 W	3 Dec 82
1976-023B	USA	LES 9	104.5 W	5 Dec 82
1976-023F	USA	non-functional	171.1 W	3 Jun 81, drifting
1976-029A	USA	RCA Satcom 2	119.2 W	21 Nov 82
1976-035A	NATO	NATO 3A	17.8 W	1 Dec 82
1976-042A	USA	Comstar 1	95.0 W	30 Nov 82
1976-053A	USA	Marisat 2	76.2 E	18 Nov 82
1976-059A	USA	IMEWS 6	84.5 E	15 Nov 82, slowly drifting, at an orbit 36 to 50 km beyond GSO
1976-059C	USA	non-functional	143.9 E	26 Nov 82, drifting
1976-073A	USA	Comstar 2	95.1 W	20 Nov 82
1976-092A	URS	Raduga 2	72.6 E	24 Feb 82, inactive
1976-101A	USA	Marisat 3	176.2 E	5 Dec 82
1977-005A	NATO	NATO 3B	21.1 W	1 Dec 82
1977-007A	USA	IMEWS 7	68.1 E	17 Jul 82
1977-007C	USA	non-functional	76.2 W	29 Nov 82
1977-014A	J	Kiku 2 ETS 2	99.3 E	22 Sep 82
1977-018A	INS	Palapa 2	54.8 E	20 Nov 82
1977-034B	USA	DSCS 2-8	174.4 E	2 Dec 82
1977-034C	USA	non-functional	114.3 W	27 Aug 82, drifting at 70 to 2 700 km beyond GSO
1977-038A	USA	RH 2		
1977-041A	USA/IT	Intelsat 4A F-4	34.6 W	30 Nov 82
1977-048A	USA	GOES 2	108.4 W	4 Dec 82
1977-065A	J	Himawari 1	160.2 E	3 Dec 82
1977-071A	URS	Raduga 3	99.4 E	26 Nov 82, inactive
1977-080A	I	Sirio 1	24.1 W	28 Nov 82
1977-108A	ESA	Meteosat 1	10.7 E	1 Jan 83, used as a relay
1977-114A	USA	RH 3		
1977-118A	J	CSE Sakura 1	135.6 E	17 Aug 82
1978-002A	USA/IT	Intelsat 4A F-3	179.0 E	6 Dec 82
1978-016A	USA	Fltsatcom 1	99.3 W	2 Dec 82
1978-035A	USA/IT	Intelsat 4A F-6	174.1 E	2 Dec 82
1978-038A	USA	RH 4		
1978-039A	J	BSE Yuri	85.9 E	18 Jul 82
1978-044A	ESA	OTS 2	5.0 E	1 Jan 83
1978-058A	USA	IMEWS 8		
1978-062A	USA	GOES 3	90.9 W	10 Jan 83
1978-068A	USA	Comstar D-3	86.9 W	6 Dec 82
1978-071A	ESA	GEOS 2	34.9 E	1 Jan 83
1978-073A	URS	Raduga 4	39.8 E	2 Dec 82, inactive
1978-106A	NATO	NATO 3C	48.9 W	27 Oct 82, slowly drifting
1978-113A	USA	DSCS 2-11	135.3 W	3 Dec 82
1978-113B	USA	DSCS 2-12	65.5 E	1 Dec 82

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Table 1. (cont.)

COSPAR No.	Country gency		Orbital position	Date and remarks
1978-116A	CAN	Anik B-1	109.0 W	3 Dec 82
1979-009A	J	ECS Ayame	15.1 W	13 Sep 82, inactive, drifting
1979-015A	URS	Ekran 3	78.2 E	3 Dec 82, inactive, drifting
1979-038A	USA	Fltsatcom 2	71.9 E	1 Dec 82
1979-053A	USA	IMEWS 9	83.2 W	6 Dec 82
1979-053C	USA	non-functional	20.6 E	23 Nov 82, drifting
1979-062A	URS	Gorizont 2	89.8 E	5 Dec 82, inactive
1979-072A	USA	Westar 3	91.0 W	6 Dec 82
1979-086A	USA	IMEWS 10		ecc. orbit, drifting
1979-086C	USA	non-functional		
1979-087A	URS	Ekran 4	83.6 E	26 Jul 82, inactive
1979-098A	USA	DSCS 13	129.5 W	5 Dec 82
1979-098B	USA	DSCS 14	12.8 W	30 Nov 82
1979-098C	USA	non-functional	82.3 W	14 Sep 82, drifting
1979-105A	URS	Gorizont 3	61.0 E	21 Jul 82, inactive
1979-105E	URS	non-functional	59.4 E	16 Jun 82, drifting
1980-004A	USA	Fltsatcom 3	22.5 W	30 Nov 82
1980-016A	URS	Raduga 6	44.9 E	4 Dec 82, inactive
1980-018A	J	Ayame 2	101.2 W	28 Sep 82, drifting, inactive
1980-049A	URS	Gorizont 4	13.7 W	30 Nov 82
1980-060A	URS	Ekran 5	51.4 E	18 Nov 82, inactive
1980-074A	USA	GOES 4	135.3 W	19 Nov 82
1980-074C	USA	non-functional		drifting
1980-081A	URS	Raduga 7	24.6 W	3 Dec 82
1980-087A	USA	Fltsatcom 4	171.4 E	23 Nov 82
1980-091A	USA	SBS 1	100.0 W	3 Dec 82
1980-098A	USA/IT	Intelsat 5 F-2	27.5 W	13 Oct 82
1980-104A	URS	Ekran 6	57.7 E	4 Dec 82
1981-018A	USA	Comstar 4	126.9 W	2 Dec 82
1981-025A	USA	IMEWS 11	134.6 W	3 Dec 82
1981-027A	URS	Raduga 8		
1981-049A	USA	GOES 5	75.0 W	28 Nov 82
1981-050A	USA/IT	Intelsat 5 F-1	60.2 E	4 Dec 82
1981-057A	ESA	Meteosat 2	0.7 W	30 Nov 82
1981-057B	IND	ISCOM Apple		
1981-061A	URS	Statsionar-Ekran 7	98.8 E	5 Dec 82
1981-069A	URS	Raduga 9	36.7 E	17 Nov 82
1981-073A	USA	Fltsatcom 5	44.7 W	30 Nov 82
1981-076A	J	GMS Himawari 2	139.5 E	25 Nov 82
1981-096A	USA	SBS 2	97.0 W	5 Dec 82
1981-102A	URS	Raduga 10	85.4 E	1 Dec 82
1981-107A	USA	IMEWS 12		
1981-107C	USA	non-functional		
1981-114A	USA	RCA Satcom 3R	131.1 W	6 Dec 82
1981-119A	USA/IT	Intelsat 5 F-3	24.9 W	25 Nov 82
1981-122A	ESA	Marecs 1	25.9 W	1 Jan 83
1982-004A	USA	RCA Satcom 4	82.8 W	5 Dec 82
1982-009A	URS	Statsionar-Ekran 8	98.8 E	7 Oct 82
1982-014A	USA	Westar 4	99.0 W	3 Dec 82
1982-017A	USA/IT	Intelsat 5 F-4	27.5 W	25 Jan 83
1982-019A	USA	IMEWS 13	72.1 W	3 Dec 82
1982-020A	URS	Gorizont 5	54.1 E	17 Jan 83
1982-031A	IND	INSAT 1A	73.6 E	24 Jun 82, activity lost
1982-044A	URS	Cosmos 1366	79.3 E	23 Jan 83

Table 1. (cont.)

COSPAR No.	Country Agency	Name	Orbital position	Date and remarks
1982-058A	USA	Westar 5	123.1 W	6 Dec 82
1982-082A	CAN	Anik D-1	104.5 W	5 Dec 82
1982-093A	URS	Ekran 9	99.1 E	20 Jan 83
1982-097A	USA/IT	Intelsat 5 F-5	62.7 E	25 Jan 83
1982-103A	URS	Gorizont 6	90.4 E	14 Jan 83
1982-103E	URS	non-functional	122.9 E	6 Jan 83
1982-105A	USA	RCA Satcom 5	143.0 W	25 Jan 83
1982-106A	USA	DSCS 2-15	13.2 W	24 Jan 83
1982-106B	USA	DSCS 2-16	105.3 W	19 Jan 83
1982-106D	USA	IUS (non-f.)	30.3 E	12 Jan 83, drifting
1982-110B	USA	SBS 3	94.1 W	17 Jan 83
1982-110C	CAN	Anik C3	117.7 W	18 Jan 83
1982-113A	URS	Raduga 11	34.3 E	17 Jan 83

Table 2. Space stations planned for use before the end of 1982

Nominal position		Country Agency	Name	Period of validity
172	W	F/MRS	Marecs B	
170	W	URS	GALS 4	
170	W	URS	Loutch P-4	
170	W	URS	Statsionar 10	
170	W	URS	Volna 7	
81.7	W	USA	USASAT 5C	
34.5	W	USA/IT	Intelsat MCS Atl E	10 years
34.5	W	USA/IT	Intelsat 5 Atl 4	
26.5	W	URS	GALS 1	
25	W	URS	Volna 1	
25	W	URS	Statsionar 8	
25	W	F/SIR	Sirio 2	
24.5	W	USA/IT	Intelsat MCS Atl D	10 years
21.5	W	USA/IT	Intelsat 5 Atl 5	10 years
21.5	W	USA/IT	Intelsat MCS Atl C	10 years
18.5	W	USA/IT	Intelsat 5 Atl 2	
18.5	W	USA/IT	Intelsat MCS Atl A	
14.4	W	URS	Potok 1	10 years
14	W	URS	Loutch 1	
14	W	URS	Volna 2	
12.5	W	F	Marots B	
11.5	W	F/SYM	Symphonie 3	
10	E	F	Eutelsat 1	
14	E	NIG	National System	
19	E	ARS	Arabsat 1	
20	E	NIG	National System	
20	E	F/SIR	Sirio 2	
26	E	ARS	Arabsat 2	
26	E	IRN	Zohreh 2	
34	E	IRN	Zohreh 1	
40	E	F/MRS	Marecs D	
41	E	IRN	Zohreh 4	
45	E	URS	GALS 2	
45	E	URS	Loutch P2	
45	E	URS	Statsionar 9	
45	E	URS	Volna 3	
47	E	IRN	Zohreh 3	
53	E	URS	Volna 4	
60	E	USA/IT	Intelsat MCS Indn B	
64.5	E	F/MRS	Marecs C	
70	E	CHN	STW 2	
80	E	URS	Potok 2	10 years
85	E	URS	GALS 3	
85	E	URS	Loutch P3	
85	E	URS	Volna 5	
90	E	URS	Loutch 3	
90	E	URS	Statsionar 6	
90	E	URS	Volna 8	20 years
125	E	CHN	STW 1	
140	E	URS	Loutch 4	
140	E	URS	Statsionar 7	
140	E	URS	Volna 6	

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Table 3. Space stations planned for 1983 and future years

Year	Nominal position	Country Agency	Name	Period of validity
1983	168 W	URS	Potok 3	10 years
	139 W	USA	US Satcom 1-R	10 years
	95 W	USA	Telestar 3A	10 years
	27.5 W	USA/IT	Intelsat MCS Atl B	
	19 W	D	TV-Sat	7 years
	8.5 W	URS	Statsionar 11	15-20 years
	13 E	F	Eutelsat I-2	
	40 E	URS	Statsionar 12	15-20 years
	76 E	URS	GOMSS	15 years
	94 E	IND	INSAT 1B	
	95 E	URS	CSDRN	20 years
	99 E	URS	Statsionar T2	15-20 years
	108 E	INS	Palapa B1	
	113 E	INS	Palapa B2	
	118 E	INS	Palapa B3	
	130 E	J	CS - 2A (launched 4 Feb)	6 years
	135 E	J	CS - 2B	6 years
1984	172 W	USA	TDRS West	
	135 W	USA	USGCSS Phase 3 E Pac	10 years
	119 W	USA	Spacenet 1	10 years
	108 W	CAN	Musat A	
	87 W	USA	Telstar 3B	10 years
	79 W	USA	TDRS Central	
	79 W	USA	USASAT 7D	10 years
	75.4 W	CLM	Satcol 1A	10 years
	75.4 W	CLM	Satcol 1B	10 years
	75 W	CLM	Satcol 2	10 years
	53 W	USA/IT	Intelsat 4A Atl 3	11 years
	41 W	USA	TDRS East	
	27.5 W	USA/IT	Intelsat 5A Atl 2	10 years
	24.5 W	USA/IT	Intelsat 5A Atl 1	10 years
	24 W	URS	Prognoz 1	20 years
	19 W	F	TDF 1	10 years
	16 W	URS	WSDRN	20 years
	12 W	USA	USGCSS Phase 3 Atl	10 years
	10 W	F	Telecom 1A	10 years
	7 W	F	Telecom 1B	10 years
	6 W	G	Skynet	8 years
	1 W	USA/IT	Intelsat 4A Atl 2	
	12 E	URS	Prognoz 2	20 years
	17 E	ARS	SABS	
	35 E	URS	GALS 6	20 years
	35 E	URS	Prognoz 3	20 years
	57 E	USA/IT	Intelsat 5 Indn 3	10 years
	57 E	USA/IT	Intelsat MCS Indn	10 years
	60 E	USA	USGCSS Phase 3 Indn	10 years
	66 E	USA/IT	Intelsat 5 Indn 4	10 years
	66 E	USA/IT	Intelsat MCS Indn D	10 years
	80 E	URS	Prognoz 4	20 years
	80 E	URS	Statsionar 13	15-20 years
	95 E	URS	Statsionar 14	15-20 years
	110 E	J	BS - 2	7 years
	130 E	URS	GALS 5	20 years

Table 3. (cont.)

Year	Nominal position		Country Agency	Name	Period of validity
1984	130	E	URS	Statsionar 15	15-20 years
	174	E	USA/IT	Intelsat 5 Pac 1	10 years
	175	E	USA	USGCSS Phase 3 W Pac	10 years
	179	E	USA/IT	Intelsat 5 Pac 2	10 years
1985	160	W	URS	ESDRN	20 years
	127	W	USA	Comstar D-4	7 years
	116.5	W	MEX	Ilhuicahua 2	10 years
	114	W	CAN	Telesat D2	10 years
	113.5	W	MEX	Ilhuicahua 1	10 years
	109	W	CAN	Telesat C3	10 years
	106	W	USA	GSTAR 1	10 years
	91	W	USA	Advanced Westar 1	10 years
	74	W	USA	USASAT 7A	10 years
	70	W	B	SBTS A-1 (Brazil)	10 years
	70	W	USA	USASAT 7C	8 years
	66	W	USA	USASAT 8A	10 years
	65	W	B	SBTA A-2 (Brazil)	10 years
	19	W	F	L-SAT	10 years
	0	E	G	Skynet A	8 years
	4	E	F	Telecom 1C	10 years
	156	E	AUS	ANSCS 1	10 years
	160	E	AUS	ANSCS 2	10 years
	164	E	AUS	ANSCS 3	10 years
	179	E	USA/IT	Intelsat MCS Pac A	
1986	141	W	MEX	Ilhuicahua 3	10 years
	103	W	USA	GSTAR 2	10 years
	62	W	USA	USASAT 8B	10 years
	31	W	G	Unisat	10 years
	31	W	G	Unisat 1 Atl	10 years
	19	W	I	Sarit	7 years
	19	W	LUX	LUX-SAT	
	19	W	SUI	Helvesat	7 years
	5	W	S	Tele-X	7 years
	15	E	ISR	AMS 1, 2	
1987	145	W	MEX	Ilhuicahua 4	10 years
	58	W	USA	USASAT 8C	10 years

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Captions

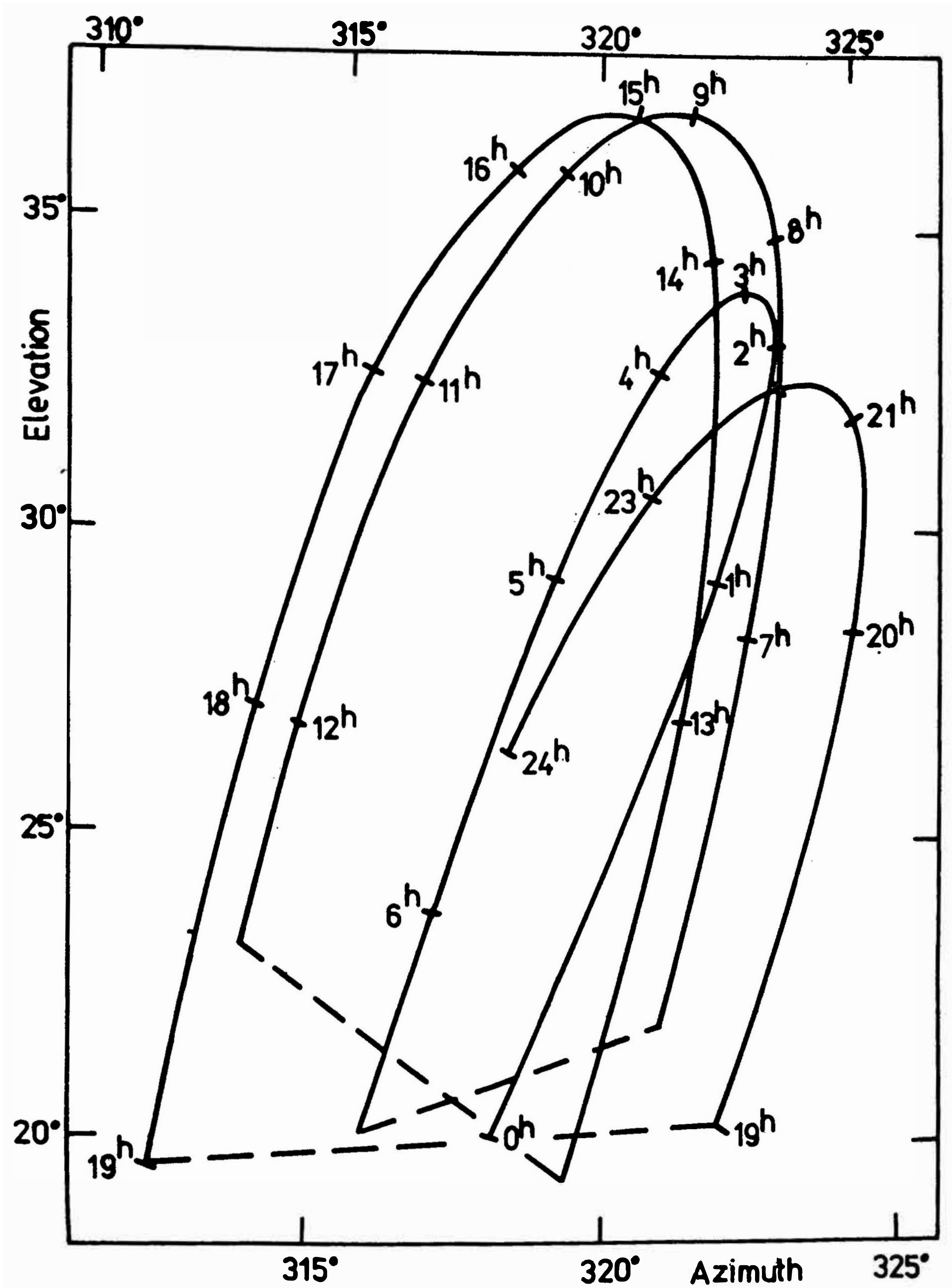
Figure 1. Tracks (full lines) on the sky of four Molniya satellites as seen from a location near Prague, Czechoslovakia, for a period of 24 hours. In this example the antenna was switched over to the next satellite at 6:30, 12:30, and 19:00 UT (broken lines).

Figure 2. The same as in Figure 1 but seen from a location near Havana, Cuba, for the same period of 24 hours.

Figure 3. A geosynchronous orbit appearing on the sky as an almost circular oval (right). The projection of the orbit onto the meridional plane (left).

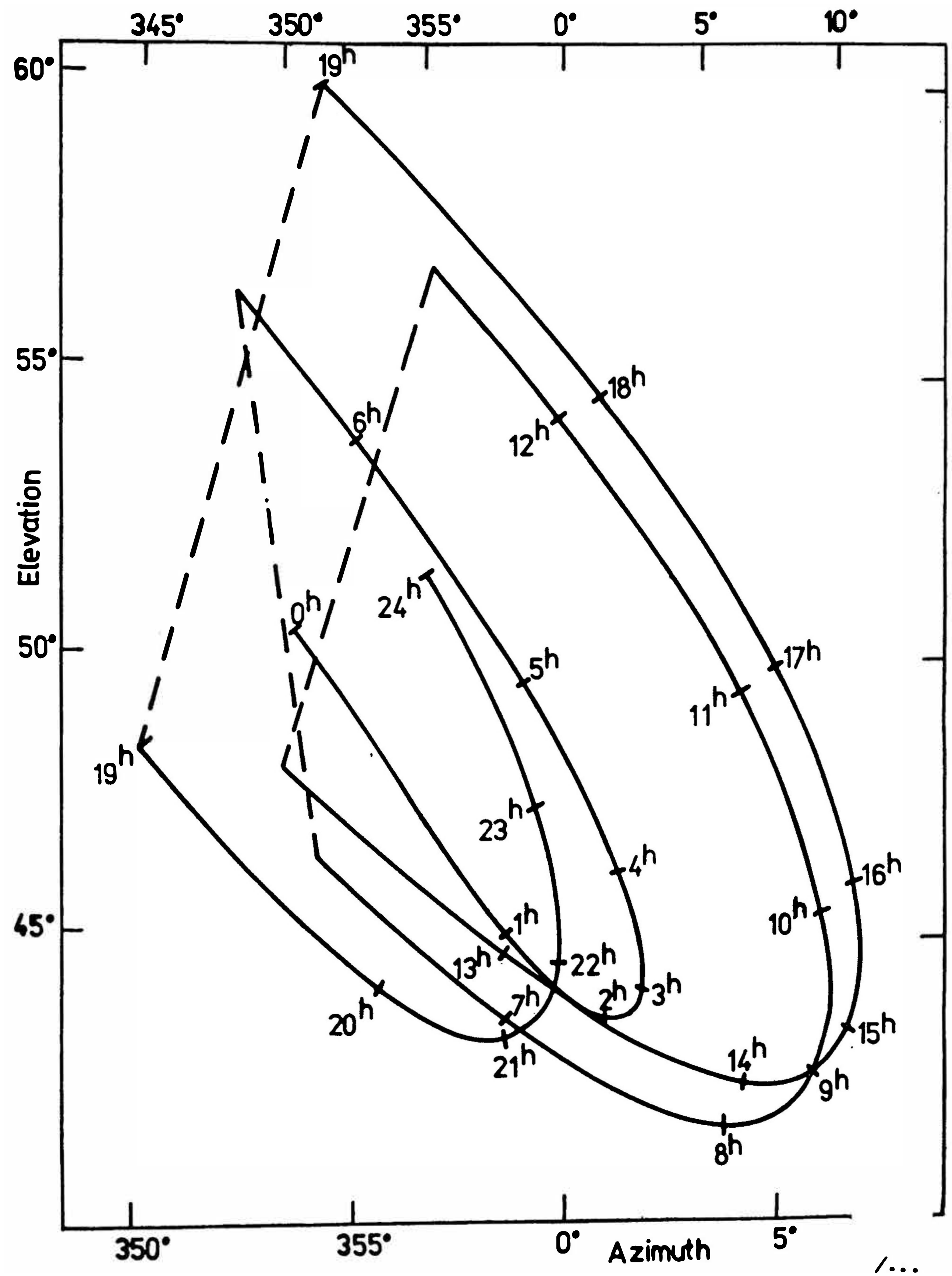
Figure 4. A geosynchronous orbit appearing as an almost straight-line on the sky (right). A projection on a meridional plane (left) showing that the geosynchronous orbit keeps at all times a certain distance from the geostationary orbit.

Figure 1


310°
315°
320°
325°
35°
30°
25°
20°
Elevation
15h
9h
16h
10h
8h
14h
3h
2h
4h
17h
11h
21h
23h
5h
1h
7h
20h
18h
12h
13h
24h
6h
0h
19h
19h
315°
320°
Azimuth
325°

/...

Figure 2


345°
350°
355°
0°
5°
10°
60°
55°
50°
45°
Elevation
19h
6h
18h
12h
0h
24h
5h
17h
11h
19h
23h
4h
16h
10h
1h
13h
22h
3h
2h
20h
7h
15h
21h
14h
9h
8h
350°
355°
0°
Azimuth
5°

/...

Figure 3

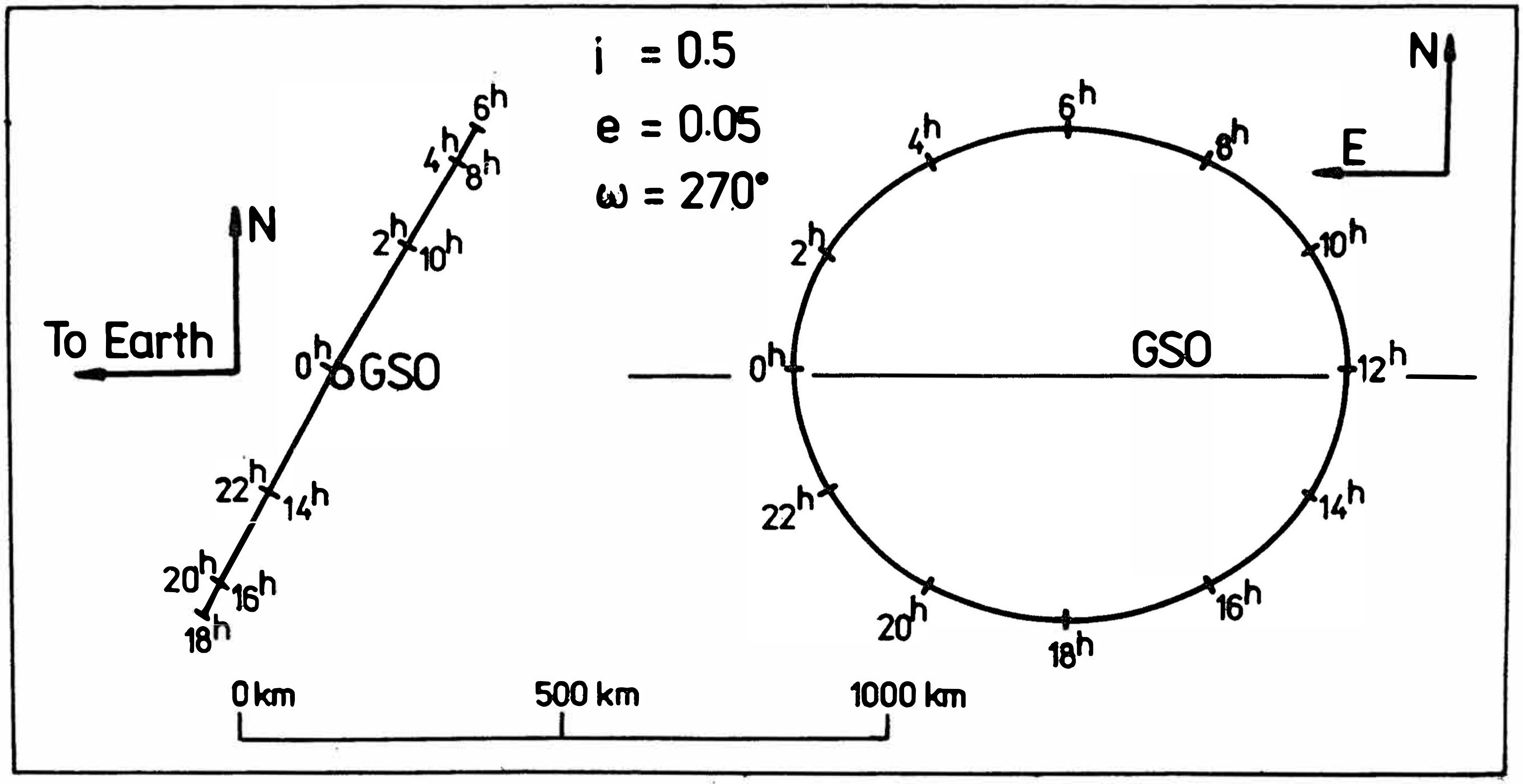
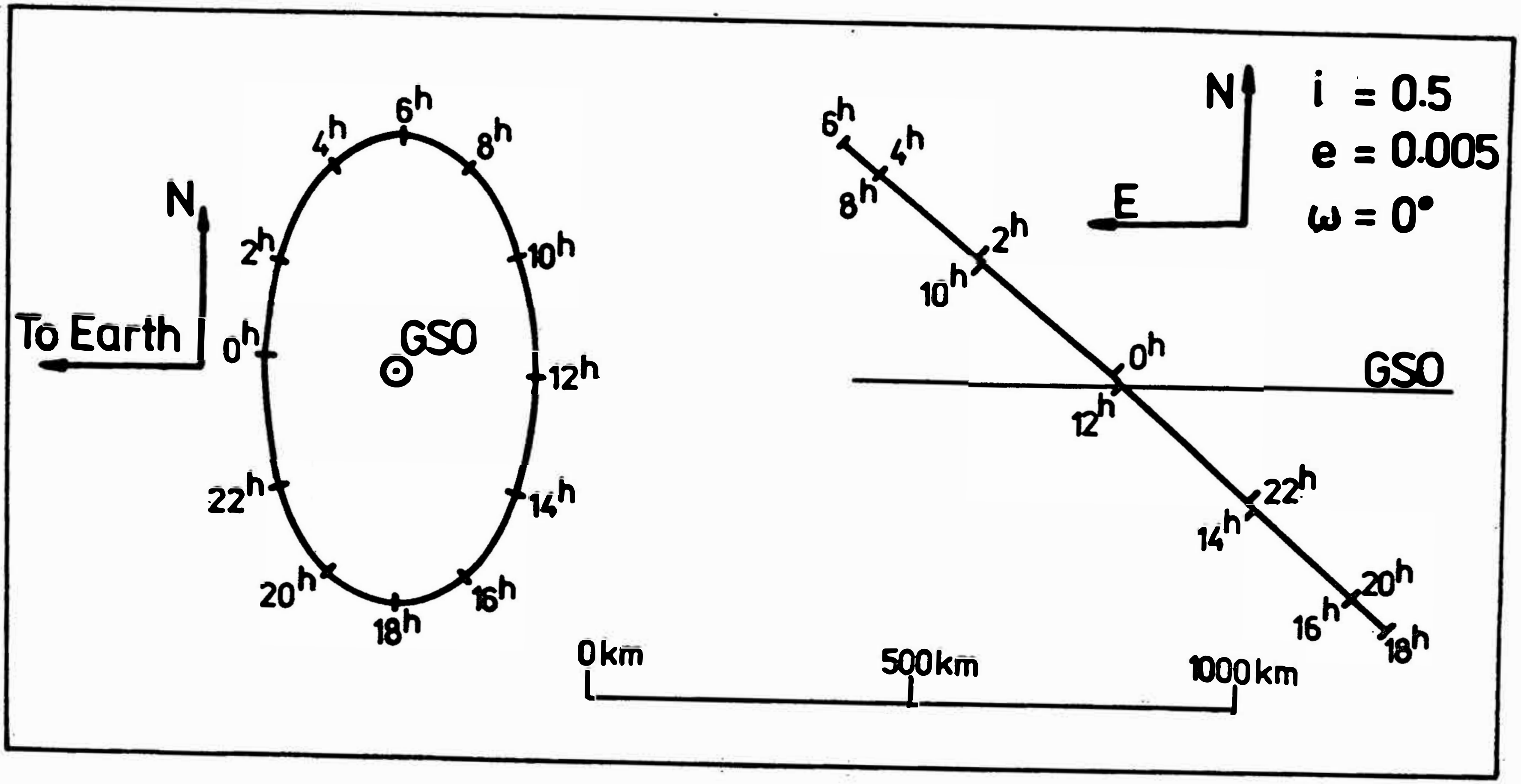

i = 0.5
e = 0.05
ω = 270°
N
To Earth
GSO
0h
2h
4h
6h
8h
10h
14h
16h
18h
20h
22h
N
E
GSO
0h
2h
4h
6h
8h
10h
12h
14h
16h
18h
20h
22h
0 km
500 km
1000 km

Figure 4


N
To Earth
GSO
0^h 2^h 4^h 6^h 8^h 10^h 12^h 14^h 16^h 18^h 20^h 22^h
N
E
$i = 0.5$
$e = 0.005$
$\omega = 0°$
GSO
0 km
500 km
1000 km