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General Aspects of the Mission Helios 1 and 2

Introduction to a Special Issue on Initial Scientific Results of the Helios Mission

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Abstract. The two spacecraft HELIOS 1 and 2 have been launched to investigate the innermost part of the interplanetary space and the solar influences on the interplanetary medium. The spacecraft are nearly identical. However, they are spinning oppositely to one another, HELIOS 1's spin vector pointing toward north, HELIOS 2's toward south.

The orbits are highly eccentric to allow perihelion distances of 0.3095 and 0.290 AU respectively. The large eccentricity leads to a wide range of differential angular velocity values between spacecraft and sun. This improves the possibility to separate spatial and temporal effects. The solar equatorial node is only a few degrees apart from the apside line of HELIOS 1. Therefore, this orbit is nearly symmetrical with respect to the ±7.5 degree range of colar latitudes which is covered by HELIOS. The perihelion of HELIOS 2 is over the northern hemisphere. Since the orbital velocity is high there, this spacecraft is over the northern hemisphere for only 52 days out of the 186 days which constitute the orbital period.

At perihelion, not only the orbital velocity but also the latitudinal velocity is very high in case of HELIOS 1. This makes possible nearly simultaneous measurements over corresponding regions of the northern and southern solar hemisphere.

The relative constellations of the two spacecraft offer several collinear positions suitable for the investigation of phenomena travelling outward from the sun.

The long periods near outer conjunction (each two months or more) have been used to sound the solar corona.

Key words: HELIOS mission – Interplanetary space – Solar wind.

1. Overall Scientific Objectives of the HELIOS Mission

HELIOS is an American-German mission to investigate the innermost parts of the interplanetary space.

Each of the two spin stabilized spacecraft carries ten on-board experiments (Table 1), namely
5 experiments to investigate the behaviour of the interplanetary plasma:

- protons, alpha particles and electrons of the solar wind, their energy spectrum, their three dimensional directional distribution
- three component magnetic fields from DC up to 5 Hz
- magnetic field oscillations up to 2 kHz
- electric field oscillations and waves up to 3 MHz

3 experiments to investigate cosmic rays:

- mass and energy spectrum of cosmic ray particles
- determination of their directional distribution
- monitoring the solar X-ray activity
- registration of galactic or extragalactic gamma ray bursts (HELIOS 2 only)

2 experiments to investigate micrometeoroides

- registration of the intensity and the polarization of the zodiacal light at 16°, 31° and 90° with respect to the orbital plane
- counting the number of dust particles hitting a target
- determination of the mass, the velocity and the chemical composition of micrometeoroides.

Moreover HELIOS is being used to perform additional investigations:

- the analysis of the precisely measured orbit (range, range rate) possibly will yield improved parameters of Einstein's theory of gravitation
- near the outer conjunction, when the signals from the spacecraft received on earth penetrate through the solar corona the polarization of the signals (Faraday effect) is a source of information on the state of the solar corona and on its general behaviour
- analyzing range, range rate and DRVID (Differentiated Ranging Versus Integrated Doppler) near the outer conjunction gives information on coronal properties
- analyzing the signal bandwidth is also being used for coronal investigations.

2. Short Description of the Spacecraft

Each of the two spacecraft is shaped like a spool (cf. Fig. 1). The spin axis is perpendicular to the orbital plane (±1 degree), with spin rate 60±1 rpm. The spin vector is pointing toward north at HELIOS 1 and toward south at HELIOS 2. The major part of the experiments and the electronics devices of the probe are installed in the central compartment. The oblique panels bear the solar cells. The magnetometers are mounted on booms in order to keep those sensitive devices clear of disturbances from the spacecraft. The electric field experiments make use of a radial antenna boom (32 m tip to tip), which was not deployed before launch. Therefore, it is not visible in the picture.

Table 1. HELIOS experiments

Exp. 1	Plasma Particles	H. Rosenbauer R. Schwenn	MPI für Physik und Astrophysik, Inst. für extraterr. Physik Garching
Exp. 2	Flux Gate Magnetometer	G. Musmann F.M. Neubauer	Inst. für Geophysik und Meteorologie, TU Braunschweig
Exp. 3	Flux Gate Magnetometer	F. Mariani N.F. Ness	Universita de l'Aquila, Italy NASA-GSFC Greenbelt, Md.
Exp. 4	Search Coil Magnetometer	G. Dehmel F.M. Neubauer	Inst. für Nachrichtentechnik Inst. für Geophysik und Meteorologie, TU Braunschweig
Exp. 5a	Plasma Waves	D.A. Gurnett	Univ. of Iowa, Dep. of Physics and Astronomy, Iowa City
Exp. 5b	Plasma Waves	P.J. Kellogg	Univ. of Minnesota, School of Physics and Astronomy, Minneapolis
Exp. 5c	Radio Waves	R.R. Weber	NASA-GSFC Greenbelt, Md.
Exp. 6	Cosmic Rays	H. Kunow	Inst. für Reine und Angewandte Kernphysik, Univ. Kiel
Exp. 7	Cosmic Rays	J.H. Trainor	NASA-GSFC Greenbelt, Md.
Exp. 8	Low Energy Cosmic Rays	E. Keppler	MPI für Aeronomie, Inst. für Stratosphärenphysik, Katlenburg-Lindau
Exp. 9	Zodiacallight Photometer	C. Leinert	MPI für Astronomie Heidelberg
Exp. 10	Micrometeorite Analyzer	E. Grün	MPI für Kernphysik Heidelberg
Exp. 11	Celestial Mechanics	W. Kundt W.G. Melbourne	Inst. für Theoretische Physik I Univ. Hamburg JPL Pasadena, Cal.
Exp. 12	Coronal Sounding	G.S. Levy H. Volland P. Edenhofer	JPL Pasadena, Cal. Radioastronomisches Institut Univ. Bonn DFVLR Oberpfaffenhofen

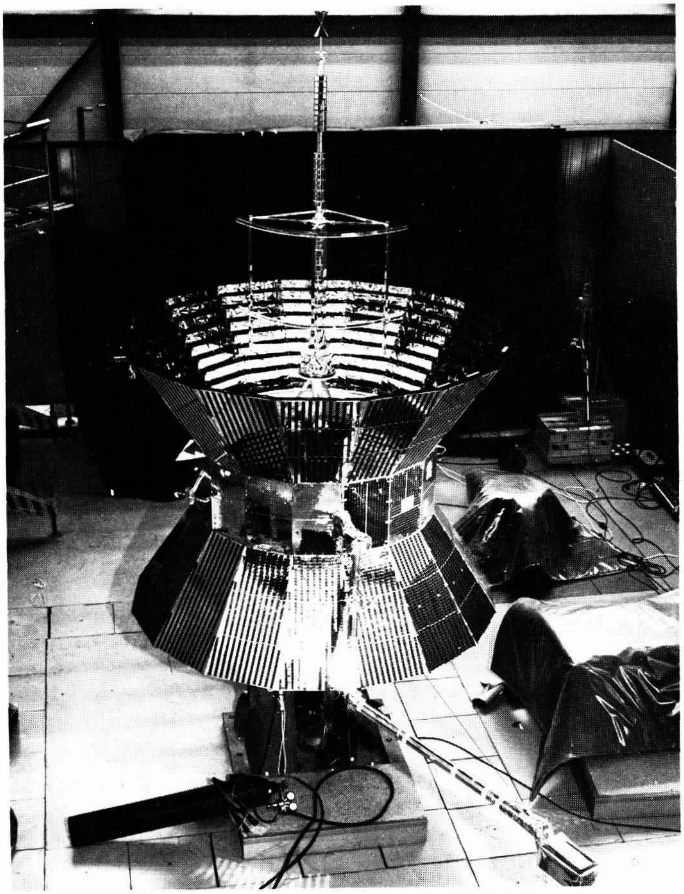


Fig. 1. One of the two HELIOS spacecraft almost ready for launch

Due to a failure on HELIOS 1 only one of the two antenna branches has been deployed. Additionally the undeployed antenna segment has caused a shortage to spacecraft ground. Therefore, this antenna is only a monopole on HELIOS 1, whereas it is a dipole on HELIOS 2. On HELIOS 1 the signal and the signal to noise ratio are reduced accordingly.

In order to allow low energy electron measurements to be performed without too much disturbance by the spacecraft potential, this potential should be low and as nearly spherical as possible. Of course, this objective could only roughly be obtained, because the shape of the spacecraft is by far not spherical. Additionally thermal control requires the surface irradiated by the sun to be highly reflecting. Without further preparation it consists of quartz i.e. it is insolating. In order to reduce the problem of undefined charging up to an unknown potential configuration almost 2/3 of the irradiated surface of the central compartment has been covered by an electrically conducting thin layer of InO connected to the spacecraft structure. All parts not irradiated by the sun were painted with conductive black paint. Thus tolerable conditions were achieved.

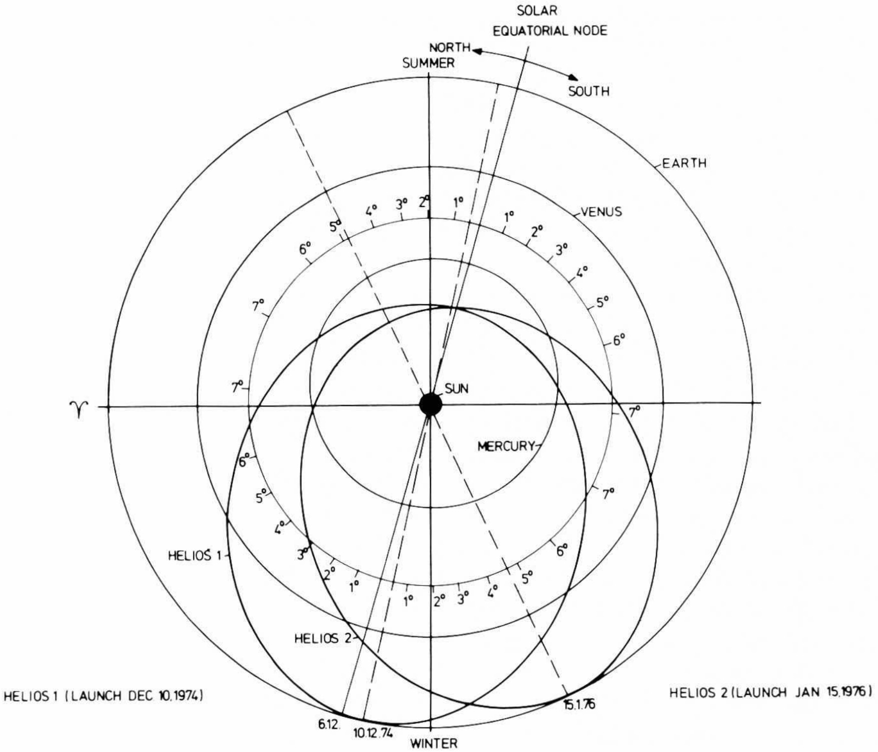


Fig. 2. The sidereal orbits of the innermost planets and of the two HELIOS spacecraft. The scale around the sun-centered circle indicates solar latitude within the ecliptic. Both spacecraft are south of the solar equator when to the right of the solar equatorial node line, and north when to the left

For a more detailed description of the experiments and their on-board environment see Porsche et al. (1975).

3. The Orbital Elements and Special Aspects of the Orbits of HELIOS 1 and 2

HELIOS 1 was launched 10 December 1974 to a perihelion at 0.3095 AU, HELIOS 2 on 15 January 1976 to a perihelion at 0.290 AU. The ecliptical orbital elements are:

	HELIOS 1 (15 January 1975)	HELIOS 2 (21 January 1976)
a	96801835 km	95263193 km
e	0.528140	0.544499
i	23°.447343	23°.434197
Ω	0°.061130	0°.046530
ω	257°.449079	293°.822262
m	247°.558122	191°.106336

The orbits of both spacecraft are Kepler ellipses with high eccentricity. Both inclinations are very small, the orbits being nearly ecliptical. Since the angle between the line of apsides of HELIOS 1 and the node line of the solar equator is only about 4 degrees, HELIOS 1 is about half of the time over the southern and half of the time over the northern hemisphere of the sun. The perihelion as well as the aphelion occur at latitudes of less than 1 degree south resp. north. Therefore, HELIOS 1 is in an almost ideal orbit to compare the northern and southern regions of the sun between ± 7.5 degrees latitude (inclination of the sun's equator).

The solar rotation must be included in this discussion. The differential angular velocity between sun and earth is about $2.4 \cdot 10^{-6}\ \mathrm{s}^{-1}$. During the perihelion phase of HELIOS 1 the differential velocity decreases to about $1.2 \cdot 10^{-6}\ \mathrm{s}^{-1}$, (whilst the inertial velocity is increasing from 20.5 km/s at aphelion to 66 km/s at perihelion), i.e. during the perihelion phase spatial variations of solar events in interplanetary space can be studied with double resolution as compared to the earth. Simultaneously the latitudinal velocity of HELIOS 1 is highest at perihelion. Its maximum value is 0.9 degree per day. Within 17 days of the perihelion phase the latitudinal change is 12 degrees.

The orbit of HELIOS 2, although similar with respect to the main orbital elements offers quite different opportunities. The angle between the line of apsides and the sun's equatorial node line is approximately 40°. The orbit is no longer symmetrical with respect to north-south. The spacecraft is staying north of the sun's equator for only 52 days and south for the rest of each orbit, i.e. for almost 134 days. All measurements close to the sun originate from northern positions of the spacecraft. The latitudinal velocity does not reach such a high maximum value as with HELIOS 1.

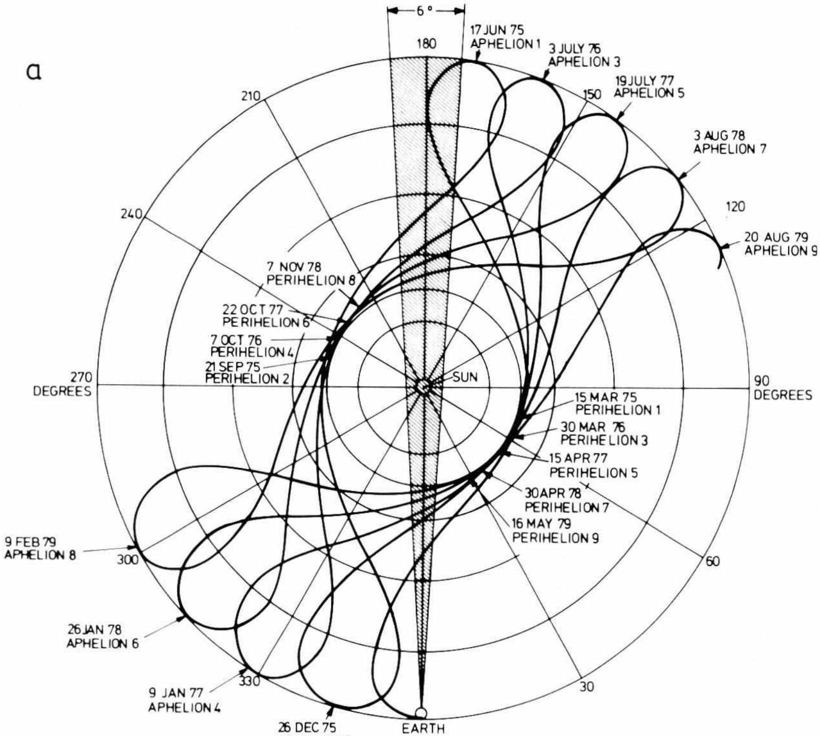
Very important for the mission are the conjunction periods i.e. the time intervals during which the sun-earth-spacecraft angle is smaller than 3 degrees. Fig. 3 gives the orbits of the two spacecraft in a sun-earth centered coordinate system. Both spacecraft had to overcome long blackout periods when in the far-earth part of the orbits. During such periods data transmission is heavily disturbed or impossible. The disturbance is caused by plasma influences of the corona on the S-band signals of the spacecraft.

This influence which has caused considerable loss of on-board data, has been turned into an advantage on the other hand by taking the opportunity to analyze the influence of the corona on the telemetry signals. The constellations were really unique. The earth-HELIOS 1 line was within $12\ R_\odot$ from the sun's center between April 14 and June 8, 1975, which is more than two solar rotations. As seen from the earth the spacecraft did not cross the earth-sun line (Fig. 3a), during this time.

Fig. 3a and b. Sun-Earth centered orbits of HELIOS 1 (Fig. 3a) and HELIOS 2 (Fig. 3b). Note the long periods when the spacecraft are near conjunction behind the sun i.e. when data transmission is restricted and when sounding of the solar corona is possible

HELIOS 1

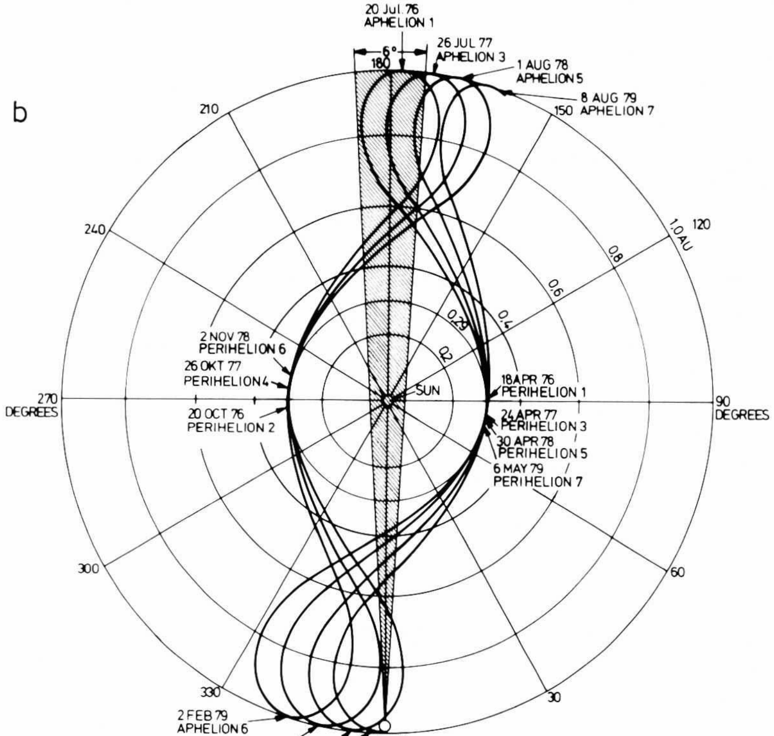
a



10 DEC 74 07 11 01, 49 GMT LAUNCH

HELIOS 2

b



15 JAN 76 05 34 00 36 GMT LAUNCH

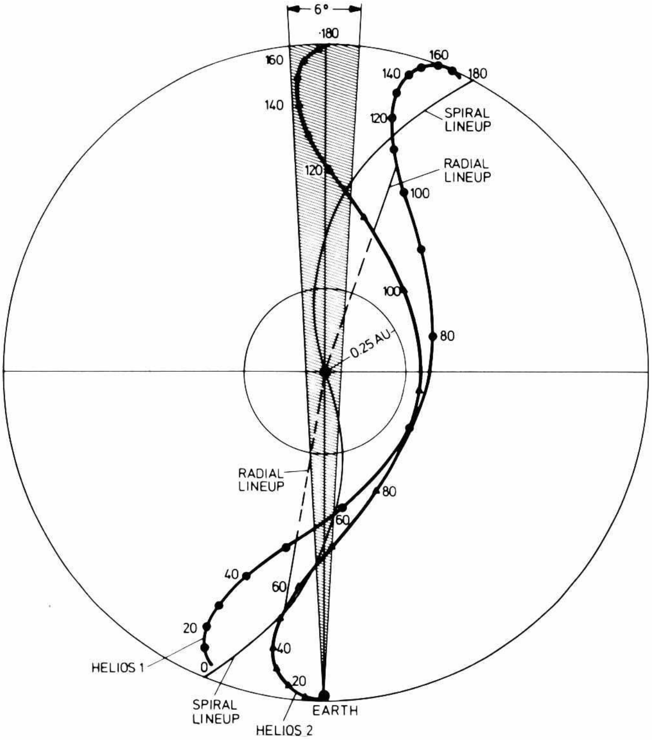


Fig. 4. Sun-Earth centered orbits of HELIOS 1 and HELIOS 2 during the first revolution of HELIOS 2. Numbers give days from launch of HELIOS 2. Note the linear and magnetic-spiral lineup configurations

The conjunction phases of HELIOS 2 (Fig. 3b), are May 8 to Aug. 3, 1976 including about 10 days when the spacecraft was physically behind the solar disc, moving from west to east and vice versa, and 21 May to 18 July 1977 including a full (geometrical) blackout of 16 days. Unfortunately due to a defect on board, range and range-rate (two way doppler) measurements are no longer possible during this last long-lasting conjunction period. No spacecraft before has experienced conjunctions of a comparable length of time. Therefore a really new type of investigations in a coronal region neither accessible by earth bound optical observations nor by in situ measurements, has become possible.

The short conjunction phases, occuring every second orbit, e.g. 24 Aug. to 5 Sep. 1975 for HELIOS 1 and 15 Sep. to 1 Oct. 1976 for HELIOS 2, are also used for corona soundings of course. But compared with the long conjunction phases they allow only snapshot-like investigations.

Figure 4 shows the section of the mission from launch to the first aphelion of HELIOS 2 together with the simultaneous part of the orbit of HELIOS 1. The geometry is very favorable in the following respect: During each orbit the two spacecraft run through two pairs of orbit points, where they are lined up radially with the sun. These constellations allow to analyze the same plasma travelling radially outward from the sun under different environmental conditions with respect to pressure, magnetic field strength, etc. in order to investigate plasma propagation in interplanetary space. Similar constellations between one of the two HELIOS spacecraft and earth satellites (e.g. IMP 7, 8) also are used for the same studies. However since the two HELIOS spacecraft are equipped identically, their data can be compared more directly than in the case where data from different experiments on different spacecraft have to be dealt with. Moreover, the close flyby to the sun gives special importance to the corresponding close lineups.

Similar to the radial lineup constellations, there occur constellations where the two HELIOS spacecraft (or at least one of them and an earth satellite) are lined up on the same magnetic field line. Figure 4 shows two such spirals valid for a solar wind speed of 400 km/s. This enables experimenters to investigate and analyze particles travelling along the same magnetic field line under different environmental conditions.

4. *Acknowledgement.* This introductory article to a special HELIOS issue of the Journal would not have been possible without the detailed work of all HELIOS experimenters and of the HELIOS operations team at GSOC and at many ground stations. I gratefully acknowledge all those efforts and contributions.

Reference

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