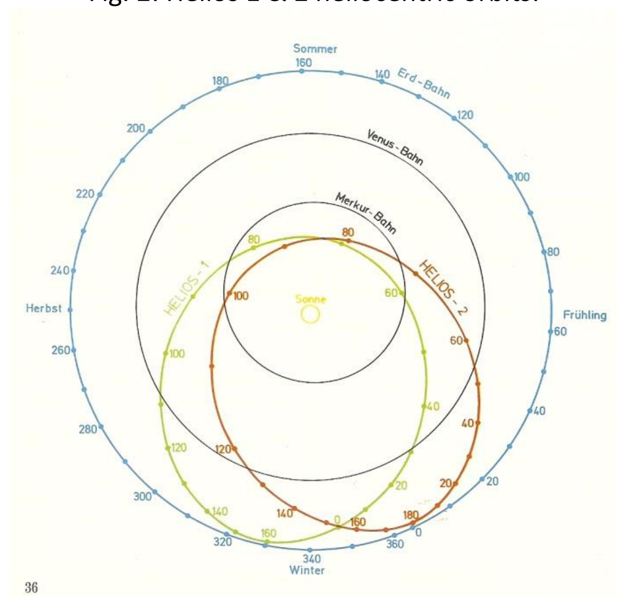
The Helios Mission, Sun-days of German Spaceflight

In commemoration of the 40th anniversary of the Helios-1 Launch

Helios-1 roared off to a spectacular climb into the night sky from the launch pad at Cape Kennedy, Florida on 10. December 1974, 02:11 a.m. EST. The 351 kg solar probe was carried by NASA's heavy-lift Titan III E / Centaur D1-T rocket with a TE 364-4 kick stage into a heliocentric orbit and only three months later approached the sun as close as 46 million km (0.309 AU) for the first time in history (Fig.1: Launch).

< Fig. 1: Helios-1 launch on 10th December 1974 From Cape Kennedy at 02:11 a.m. EST on a Titan III E / Centaur D1-T rocket with a TE 364-4 kick stage, a spectacular night launch!

Fig. 2: Helios 1 & 2 heliocentric orbits:



This launch was also was a big boost for the German aerospace engineers: The Helios project had been negotiated between Chancellor Ludwig Erhard and President Lyndon B. Johnson in 1966 in a political deal to compensate for US military deployment cost at Germany ("*So let us go about the business of mankind*" – President L.B. Johnson said in a welcome address to Chancellor L. Erhard during their visit at Cape Kennedy on 27th Sept. 1966). An agreement was finally signed in 1969 to carry out a joint interplanetary mission consisting of two solar probes in heliocentric orbits to be launched in 1974/76 (Fig. 2: Orbit).

Helios-1, its original planned mission duration time was only 18 months, could be operated as an extended mission until 16. March 1986. This unexpected long duration of more than 10 years for HE-1 and the excellent functioning of the scientific instruments enabled the scientists to collect field- and particle data covering almost an entire solar cycle of 11 years and further enhance and correlate their measurements with the two Voyager spacecraft (Voyager-1 launch on 15th Sept 1977, Voyager-2 launched earlier on 20th Aug 1977) having similar field- and particle instrumentation, thus covering the whole space environment between 0.3 AU and beyond the Earth orbit (< 1AU).

Helios-2 was launched on 15th January 1976 and came even closer to the sun with a distance of only 43 million km (0.290 AU). Helios-2 was lost after fulfilling its primary mission due to transmission problems in December 1981. Until then correlative measurements, i.e., two-dimensional field- and particle propagation could be gathered by the two asynchronously orbiting probes within the 1 AU space environment.

The two probes allowed to explore the particles and radiation streaming from the sun in unprecedented close distance of 43 Mio km, that is approximately one-third of the sun-earth distance (150 Mio km equals 1 Astronomical Unit AU). To shield against the intense heat the Helios probes were shaped in a characteristic spool of thread form, their surfaces completely mirrored by second surface mirrors (SSM) and solar cells, so that 90 % of the incident radiation heat could be reflected. Supported by an automated louver system the temperature in the instrument compartment could never increase above 30^0 C , while the outside temperature increased up to 370^0C at closest sun approach (perihelion). On the other hand, due to its heliocentric orbit the probes reached a distance of 150 Mio km from the sun (aphelion) with surrounding temperatures of -65^0 C the compartment temperatures had to be kept around $+20^0$ C using heaters. Also the spinning motion of 1 rpm/s of the main body of the spacecraft stabilized its attitude and contributed to the temperature compensation. The problem to keep the orientation of the high-gain antenna stable and always pointing to the earth was solved with a “de-spun” antenna, spinning the light weight wire-mesh antenna into the opposite direction with the same rpm-rate. Pointing to the Earth during the probe’s orbit around the sun was achieved by an automatic magnetic “pick-up” control mechanism.

The scientific payload of the Helios probes consisted of particle- , radiation- and magnetic field sensors and detectors as well as several zodiacal light telescopes (Fig. 3: Helios Experiments - schematic, Fig. 4 HE-1 spacecraft in flight configuration)

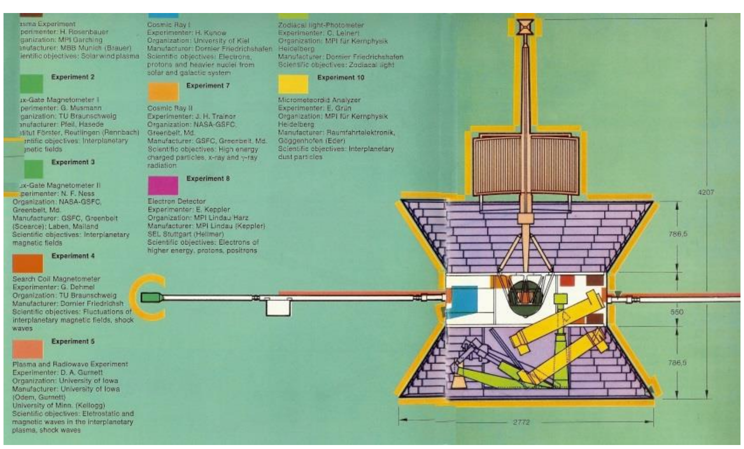


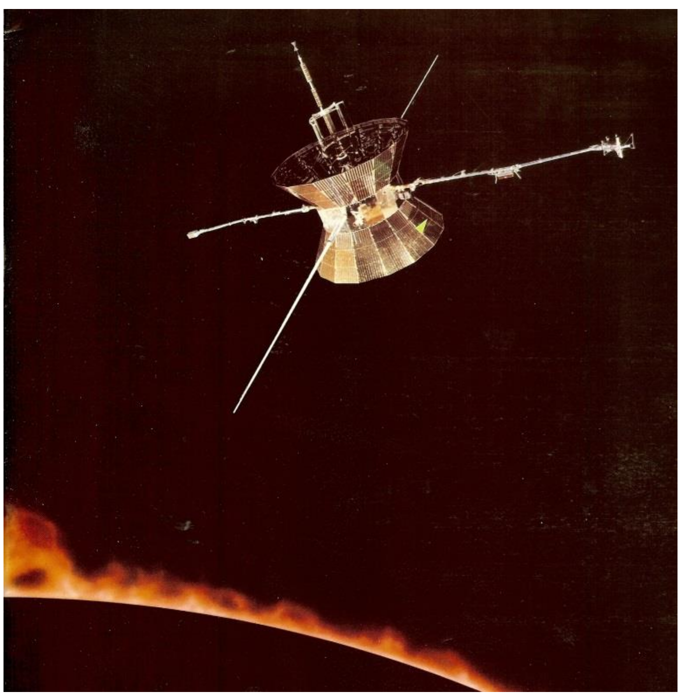
Fig. 3: Schematic representation and location of the Helios experiment instrumentation. The instrumentation was identical on HE-1 and HE-2, however HE-2 approached the sun a little closer than HE-1 and HE-2 was flown “up-side-down” with reference to the ecliptical plane in order to get a symmetrical view north and south of the ecliptic.
(Ref.: Messerschmitt-Bölkow-Blohm MBB Helios brochure, UR-12-75-50).

HELIOS List of Experiments

	Title	Investigators (Princ.Invest. underlined)	Affiliation	Scientific Objectives Measurement of…
1	Plasma Experiment	**H. Rosenbauer** R. Schwenn B. Meyer H. Miggenrieder J.H. Wolfe	MPI f. Physik u. Astrophysik, Institut f. Extraterr. Physik, Garching/München NASA Ames Research Center, Moffet Field, Ca.	low energy protons, alpha particles and electrons (solar wind)
2	Flux Gate	**G. Musmann** F.M Neubauer A. Maier	TU Braunschweig, Institut f. Geophysik u. Meteorologie	interplanetary quasistatic magnetfield a. shock waves
3	Flux Gate Magnetometer (Roma, GSFC)	**N.F. Ness** L.F. Burlaga F. Mariani C. Cantarano	NASA GSFC, Greenbelt, Md. Universita degli Studi, In- stituto di Fisica „G.Marconi" Roma	interplanetary quasistatic magnetfield a. shock waves
4	Search Coil	**G. Dehmel** F.M. Neubauer G.F. Schirenbeck R. Karmann	TU Braunschweig, Institut für Nachrichtentechnik	magnetic field fluctuations, shock wave analysis
5	Plasma and Radio Wave Experiment	**D.A. Gurnett** G.W. Pfeifer P.J. Kellogg S.J. Bauer R.G. Stone R.R Weber	University of Iowa, Dep. of Physics & Astronomy , Iowa City, Iowa University of Minnesota, School of Physics & Astron., Minneapolis, Minnesota, Mn. NASA GSFC, Greenbelt Md.	electrostatic and electromagnetic wave phenomena, shock wave analysis
6	Cosmic Ray Experiment (Kiel)	**H. Kunow** R. Müller G. Green H.G. Hasler	University of Kiel, Istitut f. Reine und Angewande Kernphysik	high energetic nuclei and electrons of solar and galactic origin
7	Cosmic Ray Experiment (GSFC)	**J.H. Trainor** F.B. McDonald B.J. Teegarden E.C. Roclof K.G. McCraken	NASA GSFC, Greenbelt Md. University of New Hampshire CSIRO, Melbourne, Australia	medium and high energy particles and X-rays
8	Electron Detector	**E. Keppler** B. Wilken G. Umlauft W. Williams	MPI f. Aeronomie, Institut Stratosphärenphysik, Lindau/Harz ESSA Boulder, Colorado	medium energy electrons, protons, positrons
9	Zodiacal Light Photometer	**C. Leinert** E. Pitz	MPI f. Astronomie, Heidelberg	interplanetary dust distribution by observation of zodiacal light
10	Micrometeorid	**H. Fechtig** J. Kissel E. Grün P. Gammelin	MPI f. Kernphysik, Heidelberg	properties of dust particles
11	Celestial Mechanics Experiment	**W. Kundt** W.G. Melbourne J.D Anderson	Universität Hamburg. im Institut f. Theoretische Physik JPL, Pasadena, Calif	orbit elements in order to determine parameters of the gravitation theory (see also Ref. 4)

12	Faraday Rotation	**G.S. Levy** Ch. T. Stelzried H. Volland	JPL, Pasadena, Calif Astronomisches Institut der Universität Bonn, Bonn	investigation oft he solar corona
13	Wave Propagation	**P. Edenhofer** V. Stein	DFVLR, Oberpfaffenhofen Institut für Flugfunk und Mikrowellen	plasma distribution in the corona

The data reception at the ground was facilitated by using the three main 65 m dish antennas of the NASA Deep Space Network (DSN) and a smaller German 30 m dish antenna in Weilheim (Bavaria). For radiometric experiments (receiving only) the 100 m dish radio-astronomic telescope at Effelsberg (Germany) was available also. The central satellite monitoring and control station for the Helios project was located at the "German Space Operations Control Center" (GSOC) of the German Aerospace Center (DLR) in Oberfaffenhofen near Munich (Fig. 5: GSOC). The launch and check-out phases were supported by Helios control team using NASA facilities at JPL/Pasadena.



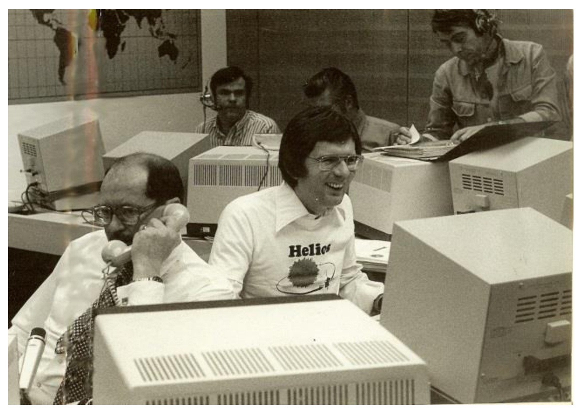


Fig. 5: Helios control center at GSOC at DLR Oberpfaffenhofen/Bavaria, during HE-2 launch on 15th January 1976.

< Fig. 4 Helios-1 “in-flight” configuration

Starting with the project implementation phase in 1969 up to 1st September 1975 the DFVLR project office counted 336 publications and /or papers presented covering various technical/scientific topics related to the development of the Helios system, subsystems and experiments and as of April 1, 1976 this number had increased to 425 publications and presentations for the scientific technological community.

One hundred of these papers presented were prepared for educational purposes or for advancing professional careers (43 are university studies, 41 theses were submitted for an academic degree, 14 doctoral theses and 2 theses were submitted for qualification as university lecturer). This was the status at the beginning of the extended mission with years of scientific data collection and evaluation still to come.
Based on the Helios results German scientists could continue their studies of solar-terrestrial relations with the AMPTE project some years later, a German-American-British joint cooperation consisting of three satellites conducted between August 1984 and August 1986 (AMPTE end of mission).

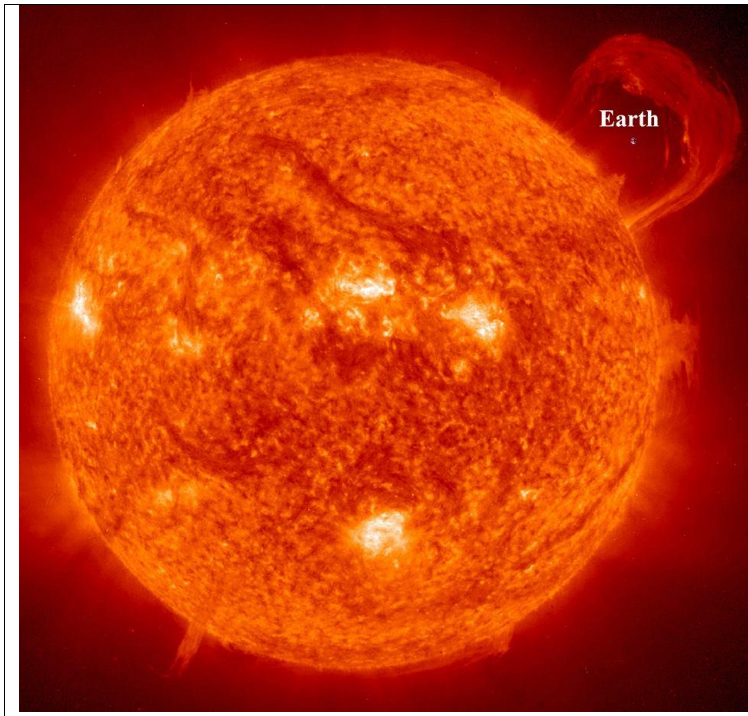
One important result of the Helios project was the establishment of the systematic observation and prediction of the "solar weather" (solar flares and associated magnetic storms) based on the Helios results and is routinely performed since then.

At the Helios 10th anniversary symposium U .S. program scientist Al Opp summarized all the scientific findings produced by the Helios Project: "The direct propagation of solar disturbances and shock waves through interplanetary space have given new insight into the structure of the interplanetary medium, the generation of the solar wind at the Sun, as well as fundamental new knowledge of tenuous, collision-less plasmas. The fact that the Helios spacecraft operated from solar minimum into and through solar maximum, has given the scientific world a detailed, close-in view of the Sun over vastly differing solar conditions. This has enabled scientists to observe cosmic rays coming into the solar system from our galaxy, and when combined with results from deep space probes and Earth orbiting satellites, has given a detailed picture of the structure of the solar system and of the characteristics of low energy galactic cosmic rays ."

The operational challenges were manifold and among the operational "firsts" were the communications management over a distance of max. 300 Mio km respecting trip/round-trip times of the telemetry/command signals (Helios and Earth in opposition). Sometimes the sun was in the line-of sight causing communication black-outs and other disturbances having transmitter output power of only 20 W available. Operating and pointing the "de-spun" spacecraft under severe environmental temperature conditions (e.g., lubrication of de-spin and bearing mechanisms cycling through the hot and cold obit-phases) was challenging, thermal control of the central compartment of temperature ranges between 11.9 and 1 Solar Constants (SC), i.e., ranging from +360^0 C to -65^0 C had its difficulties with increasing solar cell performance degradation. The requirement for controlling the attitude of the spacecraft was to keep the spin axis perpendicular to the ecliptic plane by ± 1^0 in order to avoid stray-light damaging the optical telescopes was keeping the attitude control team on its toes.

This all had to take the 1970's technology into account: Helios possessed an onboard core memory of only 0.5 Mbit (!) i.e., almost exclusively real-time data transmission at bitrates between 8 b/sec (uplink) and up to max. 2048 b/sec (convolutional coded) for the downlink had to be used. In the ground control centers multi-mission processing computers like the IBM 360/75 (at JPL) and the Siemens 306 (real-time processing). An outdated CDC 3800 (science data processing) was used at GSOC for off-line science data processing. Science data distribution was accomplished by sending "strained" magnetic tapes (Experiment Data Records – EDR's) to the international partners located around the world using postal services. The Internet was not known at that time and the transfer of high volume and data rates through dedicated commercial data lines was very expensive.

Nevertheless the Helios project was a complete success and the scientists were satisfied fulfilling their scientific goals close to one hundred percent.



The Prologue in Heaven

(J.W. von Goethe, Faust)

Die Sonne tönt, nach alter Weise,
In Bruderspähren Wettgesang,
Und ihre vorgeschriebne Reise
Vollendet sie mit Donnergang.
Ihr Anblick gibt den Engeln Stärke,
Wenn keiner Sie ergründen mag;
die unbegreiflich hohen Werke
Sind herrlich wie am ersten Tag.

"The day-star, sonorous as of old,
Goes his predestined way along,
And round his path is thunder rolled,
While sister-spheres join rival song.
New strength have angels at the sight,
Though none may scan the infinitude,
And splendid, as in primal light,
The high works of the world are viewed."

References

1. "Helios – Interplanetary Experience (DLR/GSOC)". The GSOC operational experience with the two solar probes is available for download (.pdf) at researchgate:

2. "10 Years Helios, a publication celebrating the 10th launch anniversary of Helios-1" by H. Porsche (ISBN 3-88135-156-6), bilingual issue.

3. "Das Langzeitverhalten von Energieversorgungssystemen am Beispiel Helios und Symphonie" (Dissertation, Joachim Kehr, Technische Universität München 17. März 1987)

4. Forschungsbericht BMFT-FB-W 83-016: "Das Himmelsexperiment (E 11) von Helios" (E. Krotscheck, W. Kundt, August 1983.

June 2014, Joachim J. Kehr, Editor SpaceOps News