BMFT-FB-W 81-015

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# Bundesministerium für Forschung und Technologie

Forschungsbericht W 81-015

Luft- und Raumfahrt

– Weltraumforschung/Weltraumtechnologie –

# Die Instrumente des Plasmaexperiments auf den HELIOS-Sonnensonden

von


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August 1981

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This handbook contains a work report on a project funded by the Federal Ministry for research and technology.

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This is an English translation of the original German document.

The work was carried out by Imperial College London using computer translation with limited further copy editing, with the goal producing a technically useable English document for understanding the operations of the Helios E1 experiment. It is not intended to be a perfect translation; if you find errors however, please send corrections to Tim Horbury (t.horbury@imperial.ac.uk).

Our thanks to the original engineers, Eckart Marsch (provision of the document), U. Kiel (document scanning), Chadi Salem (provision of the PDF), Sophie Albosh (copy editing) and Ingo Muller-Wodarg and Christoph Larndorfer (German expertise).



*Tim Horbury, Chris Chen, Lorenzo Matteini, David Stansby*

*Imperial College London, October 2016*

Vertrieb:

Fach-informations-zentrum Energie Physik Mathematik GmbH Karlsruhe

7514 Eggenstein-Leopoldshafen 2
Telefon 07247 / 824600 / 01
Telex 7 826 487 fize d

Als Manuskript gedruckt.

Preis: DM 39,10 + MwSt.

Printed in the Federal Republic of Germany

Druck: Engelhardt Offsetdruck GmbH, Himmelschlüsselstraße 39, 8000 München 50

ISSN 0170-1339

BMFT-FB-W 81-015

Federal Ministry for research and technology

research report W 81-015 air and space
-Space Exploration / Space Technology-

# The instruments of the Plasma experiments on the HELIOS-Sun probes

by

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BERICHTSBLATT

| 1. Berichtsnummer | 2. Berichtsart | 3. |
|---|---|---|
| BMFT-FB-W 81-015 | Abschlußbericht | Weltraumforschung/ Weltraumtechnologie |

4. Titel des Berichts
Die Instrumente des Plasmaexperiments auf den HELIOS-Sonnensonden

5. Autor(en) (Name, Vorname(n))
Rosenbauer, Helmut; Schwenn, Rainer; Miggenrieder, Hans; Meyer, Bernhardt; Grünwaldt, Heiner; Mühlhäuser, Karl-Heinz; Pellkofer, Heinz; Wolfe, John H.

6. Abschlußdatum
November 1980

7. Veröffentlichungsdatum
August 1981

8. Durchführende Institution (Name, Adresse)
Max-Planck-Institut für Aeronomie
Postfach 20
3411 Katlenburg-Lindau 3

9. Ber.Nr.Auftragnehmer

10. Förderungskennzeichen
01H3001I/WRS0107I

11. Seitenzahl
226

12. Fördernde Institution (Name, Adresse)
Bundesministerium für Forschung und Technologie (BMFT)
Postfach 200706
5300 Bonn 2

13. Literaturangaben
26

14. Tabellen
43

15. Abbildungen
68

16. Zusätzliche Angaben

17. Vorgelegt bei (Titel, Ort, Datum)

18. Kurzfassung (Gliederung s. Hinweise)

Four independent instruments are grouped under the name "Plasma Experiment", whose shared responsibility is the investigation of the interplanetary plasma, the so-called solar wind.Primarily, the speed distribution functions of the different types of particles are measured.From this you can derive all hydrodynamic parameters of the solar wind plasma.Three instruments measure the positive component of the solar wind (protons and heavy ions with energy charge values between 0.155 and 15.32 kV).Two of them allow the determination of particle direction on both the angle of incidence.The fourth instrument analysed electrons in the energy range of 0.5 up to 1660eV with one-dimensional direction resolution.

The history of the mission shows that all instruments that are completely new to the part, fulfill the expectations.

19. Schlagwörter
Sonnensonden HELIOS 1/2, Plasmaexperiment, Protonen, Elektronen, Meßtechnik.

| 20. | 21. | 22. Preis |
|---|---|---|
| | | DM 39,10 + MwSt. |

DOCUMENT CONTROL SHEET

| | | |
|---|---|---|
| 1. Report No. BMFT-FB- W 81-015 | 2. Type of Report Final Report | 3. Space Research/ Space Technology |

4. Report Title

The instruments of the plasma experiment aboard the HELIOS solar probes

| | |
|---|---|
| 5. Author(s) (Family Name, First Name(s)) Rosenbauer, Helmut; Schwenn, Rainer; Miggenrieder, Hans; Meyer, Bernhard; Grünwaldt, Heiner; Mühlhäuser, Karl-Heinz; Pellkofer, Heinz; Wolfe, John H. | 6. Report Date November 1980 <br> 7. Publication Date August 1981 |
| 8. Performing Organization (Name, Address) <br> Max-Planck-Institut für Aeronomie <br> Postfach 20 <br> 3411 Katlenburg-Lindau 3 | 9. Originator's Report No. <br> 10. BMFT-Reference No. 01H3001I/WRS0107I <br> 11. No. of Pages 226 <br> 13. No. of References 26 |
| 12. Sponsoring Agency (Name, Address) <br> Bundesministerium für Forschung und Technologie (BMFT) <br> Postfach 200706 <br> 5300 Bonn 2 | 14. No. of Tables 43 <br> 15. No. of Figures 68 |

16. Supplementary Notes

17. Presented at (Title, Place, Date)

18. Abstract


The "Plasma Experiment" aboard of the solar probe HELIOS consists of four independent instruments which are designed to investigate the interplanetary plasma, the so-called solar wind. Primarily the velocity distribution functions of the different kinds of particles are measured. All important hydrodynamic parameters of the solar wind plasma can then be derived. Three instruments analyze the positive component of the solar wind (protons and heavier ions with energy-per-charge values from 0.155 to 15.32 kV). Two of them permit an angular resolution in both directions of incidence. One instrument measures electrons in the energy range from 0.5 to 1660 eV with a one-dimensional angular resolution.

Since the launch all the instruments, which are partially novel developments, have performed very well.



19. Keywords

HELIOS solar probes, plasma experiment, protons, electrons, measurement techniques.


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|---|---|---|
| 20. | 21. | 22. Price DM 39,10 |

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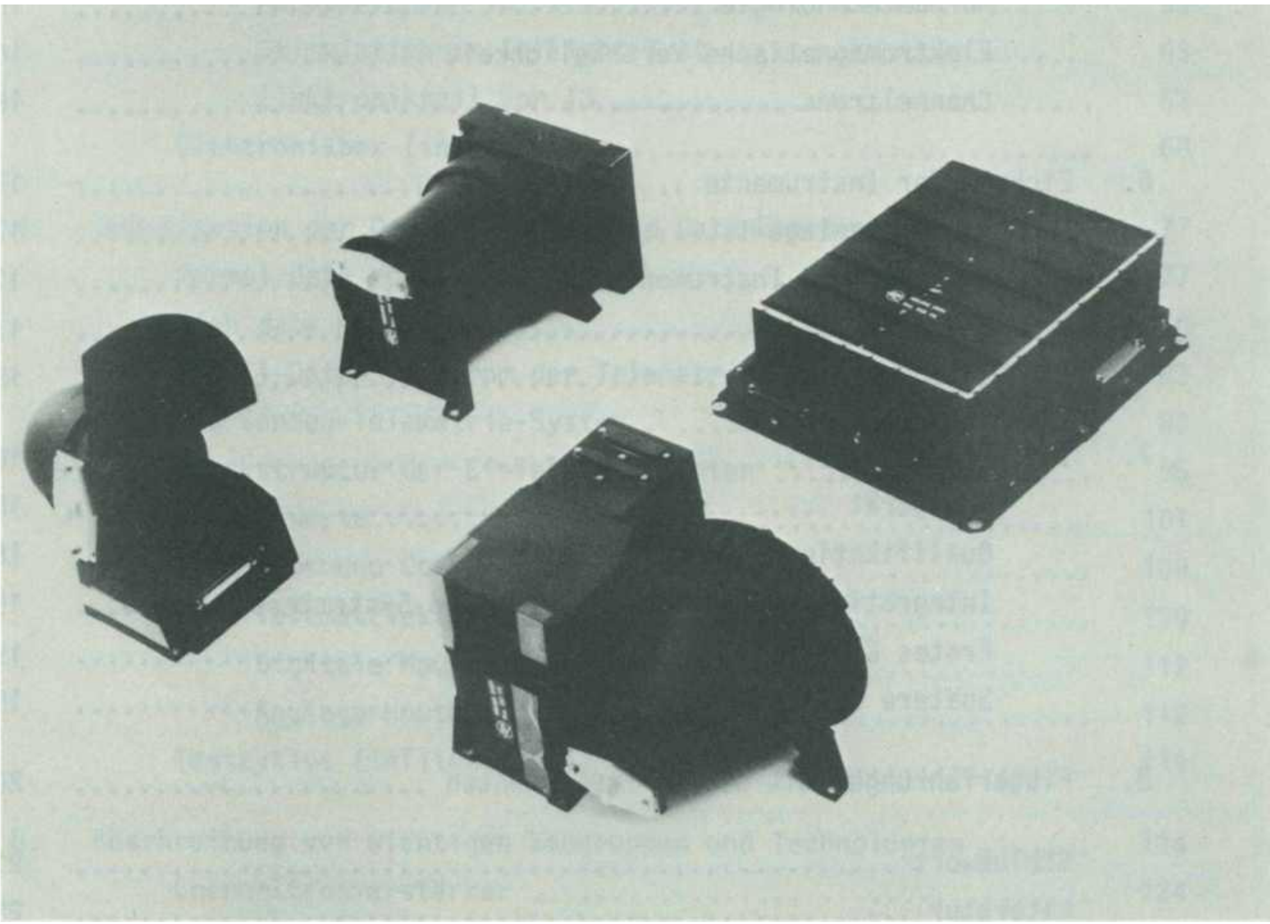


Figure 1: The tools of the Plasma experirments for the HELIOS-Sun probes.

The box E1A (center top) contains the two electrostatic instruments I1a and I1b, for positive ions, box E1B (left) the electron instrument I2, box E1C (center bottom) the dynamic mass spectrometer I3 for positive ions.The box E1D right contains the common power supply and control, as well as the digital electronics for preprocessing of measured data.

The devices shown here are on board Helios 2.

SUMMARY

Four independent instruments are grouped under the name "Plasma Experiment", whose shared responsibility is the investigation of the interplanetary plasma, the so-called solar wind.Primarily, the speed distribution of the different types of particles are measured.From this you can derive all hydrodynamic parameters of the solar wind plasma.Three instruments measure the positive component of the solar wind (protons and heavy ions with energy charge values between 0.155 and 15.32 kV).Two of them allow the determination of particle direction on both the angle of incidence.The fourth instrument analysed electrons in the energy range of 0.5 up to 1660eV with one-dimensional direction resolution.

The two HELIOS first have each a set of these instruments on board.All - up on the electron instrument on HELIOS 2, where since August 1977 switching between the two fields of energy does not longer work properly - working since the beginning of the mission on the 10.12.74 and 15.1.76 completely trouble-free, far beyond the intended mission duration 18 months also.The concept laid down long before the launch has distinguished itself for the experiment - type of instruments, sensitivity, dynamics and measuring ranges, measurement programs, redundancies etc - during mission operation in almost all details proven.

# PREFACE

This description of the instruments of the HELIOS plasma experiment based on the experiment descriptions that had been created as a basis for the industrial production of instruments.Largely the contractually agreed-upon final report delivered by the contract company Messerschmidt-Bölkow-Blohm was incorporated with, in particular its detailed technical part.

This report reflects some of our own experiences in addition throughout the project.These include the tests of Channeltrons carried out at the Institute and also continued after the start as "Endurance test".In addition, we report on preparations and implementation of instrument calibrations, which took place at the plant built at MPE.The topic data evaluation is not long since completed and remains here excluded.However, some general experiences due to the operation of the mission will be discussed, especially in comparison to the set several years earlier instrument concepts.

> *Such assessments from the perspective of today are all interspersed in the report in the form of comments - marked by a different font -.*

The drafting of this report, we sought an accurate and complete collection of all details that could be ever important, passed all those who work with the data of these instruments, to the hand.This seems particularly important to us because the HELIOS mission has brought us an unexpected abundance of unique data and brought even further, many scientists for years to come are dealing with those, including also more and more those who have never seen the instruments.

The report presented the Federal Ministry for research and technology as a technical final report according to BEwF-Z/A-1969 for the funds as part of the promotion donations from chapter 3006, title 893.20 the BMFT for the development and production of the plasma experiment for the solar probe HELIOS with the mark WRS 10/7 had been granted.

1.Overview

The HELIOS mission

The German-American space program "Solar probe HELIOS" is supposed to contribute to the exploration of interplanetary space between 0,29 and 1 AU (1 AU = 150 Mill. km).Two nearly identical built spacecraft were placed highly eccentric elliptical orbits around the Sun, up to 0,3095 or 0,290 AU introduce on the Sun.The launch of HELIOS 1 was on the 10.12.1974, HELIOS 2 followed on the 15.1.1976.A full orbit around the Sun takes 186 days for HELIOS 2, 191 days for HELIOS 1.Figure 2 shows the orbit ellipses from HELIOS 1, HELIOS 2 and the Earth, with marks for the day number of the year 1976.

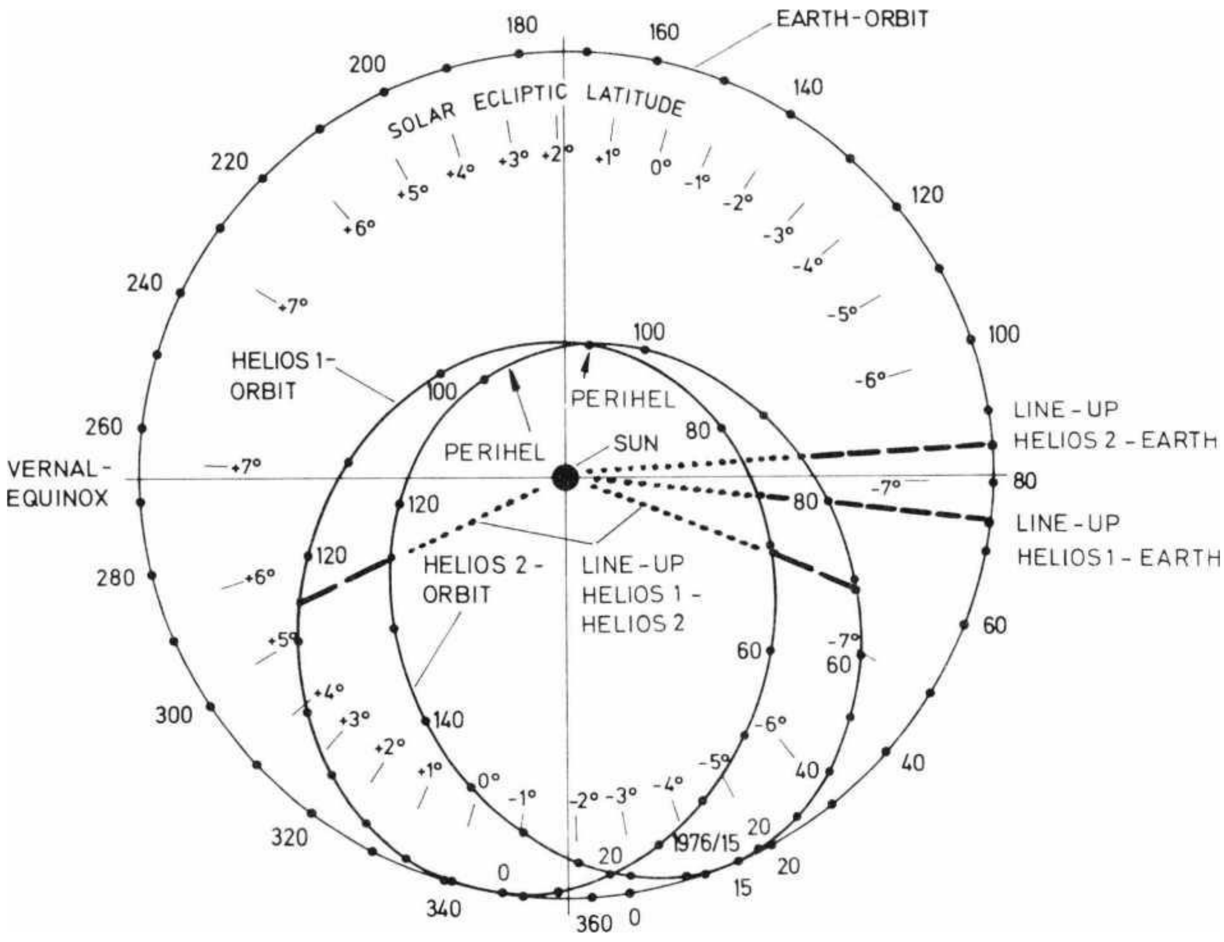



Figure 2: The orbit ellipses from HELIOS 1, HELIOS 2 and the Earth.The day numbers refer to the year 1976.

*Due by the start dates - we had no better wish us the location of the ellipses -.The long axis of the HELIOS 1-lift is located almost on the node line of the solar Equator, i.e.exactly perpendicular to the Sun axis, around 7,25° to the ecliptic is inclined. Therefore, HELIOS 1 in terms of perihelion - flies over where his path speed is largest - in less than 20 days is a range of 12° in solar width. For this the Earth needs four months! So, we witnessed for the first time directly the width dependency of structures in the solar wind. The displacement of the HELIOS 2 starts from December 75 on January 76 we have to owe the torsion of the HELIOS 2 ellipse towards the HELIOS 1 ellipse.Only resulted in 1976/77 a total of 8 "line up" constellations (see fig. 2), where both probes of the Sun seen in a row stood.In some cases, there was also the Earth just nearby.So could here from the Sun away flowing plasma successively examined in several places in the area and radial changes directly detected.Due to the different orbital periods there was line up more no after 1977 unfortunately.*
*The distance between of the probes remain small enough that spatial and temporal structures in interplanetary space are often good to distinguish. In this respect, HELIOS is considered the first real interplanetary double mission.*

The basic design of HELIOS is shown in the diagram in Fig. 3.
Figure 4 shows a view of HELIOS 2 shortly before the start.Due to the characteristic spool shape, temperatures will be anywhere bearable in spite of solar radiation fluctuating by a factor of 11.The figure axis, the HELIOS rotating at 60 revolutions per minute, is oriented perpendicular to the orbital plane and the ecliptic.But has the top at HELIOS 1 North, at HELIOS 2 South.

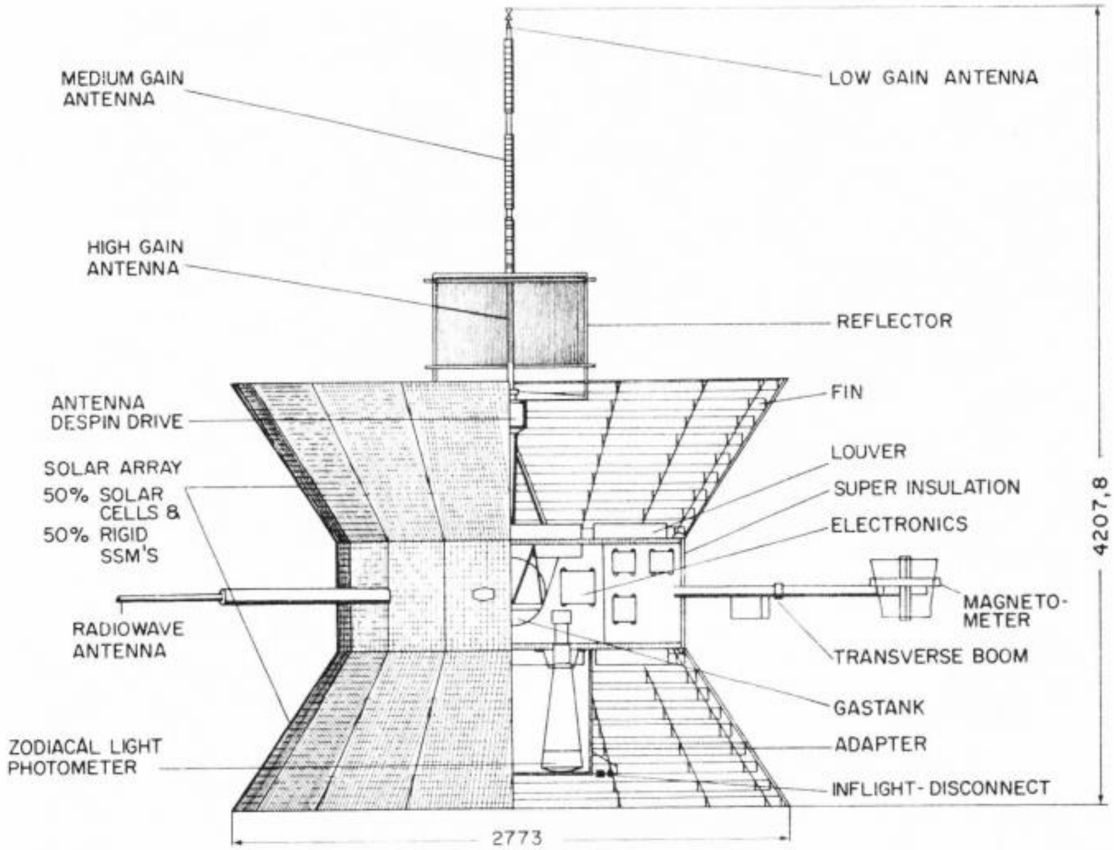



Figure 3: A diagram showing the construction of HELIOS

The main technical features of the two probes are summarized in table 1.Both probes are equipped with a nearly identical set of instruments for the implementation of in-situ measurements.These instruments are a total of 10 groups of instruments - called linguistically untidy "experiments" - which are maintained by different groups of researchers from the Federal Republic and the United States.Table 2 gives an overview of the experiments, their ranges, as well as the approximate order in the spacecraft.The experiment 1, the "plasma experiment", carried out under direction of Dr. Helmut Rosenbauer at the Max Planck Institute for Extraterrestrial physics in Garching, now at the Max Planck Institute for Aeronomy in Lindau, is the subject-matter of the present final report.

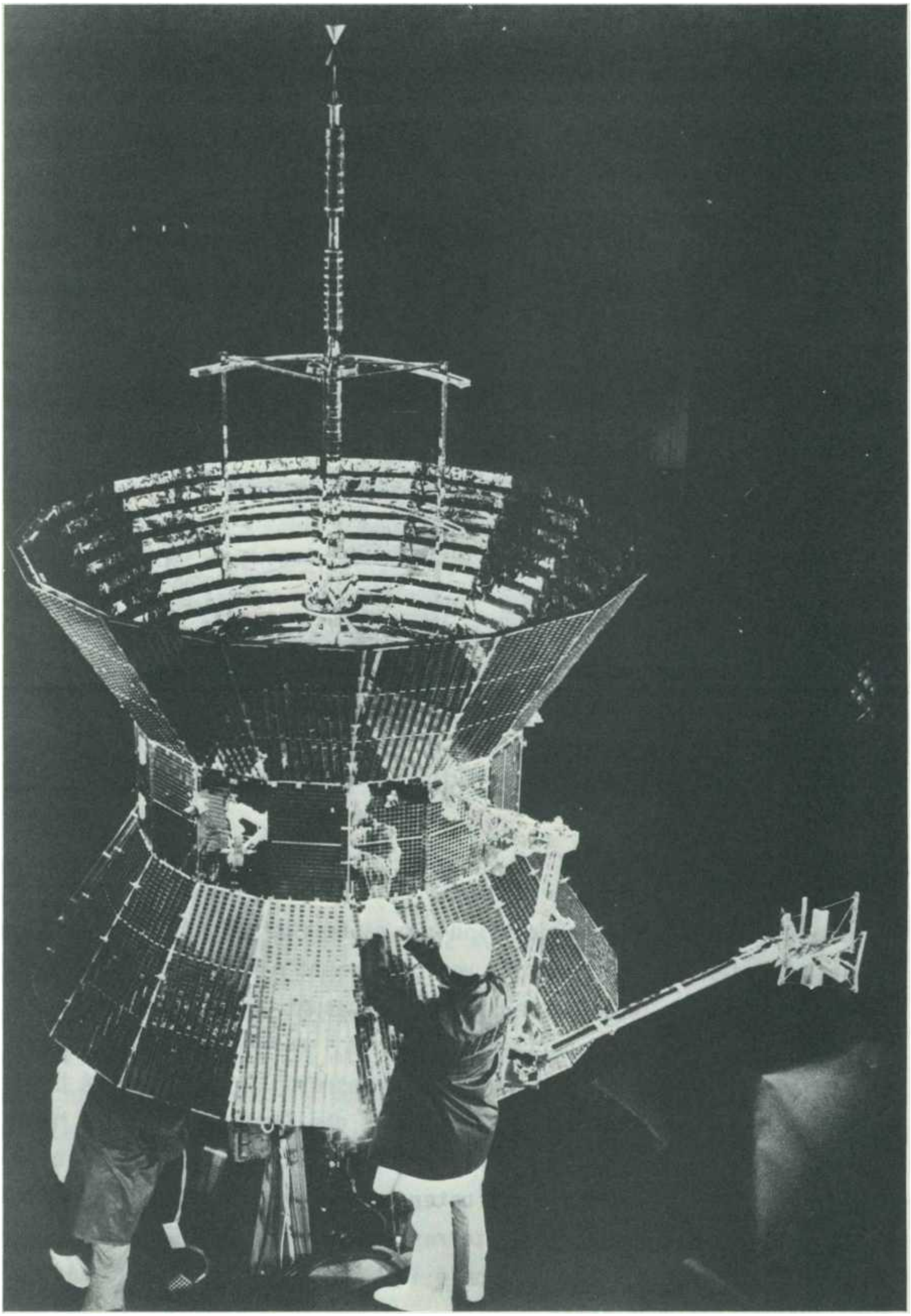


Figure 4: The solar probe HELIOS 2, just before the start

| | |
|---|---|
| Mass | 370.0 kg |
| Mass of experiments | 74.2 kg |
| Largest diameter | 2.773 m |
| Height including antenna | 4.208 m |
| Magnetometer reeling expanded | 9.20 m |
| Power supply | Solar cells |
| Maximum power of Aphelion/perihelion | 229W / 238 W |
| Power consumption of the experiments | 57.2 W |
| Telecommunication | S-band |
| Frequency of the transmitter | 2297MHz (2295 MHz) |
| Frequency of the receiver | 2115MHz (2113 MHz) |
| Bitrates, switchable | 8 up to 4096 BPS |
| On-board memory | 500 kBit |
| Number of telemetry formats | 6 |
| Max.Power of the transmitter | 20W |
| Temperature heat shield | -60°C to +150°C |
| Solar cells | -60°C to +180°C |
| Antenna | -50°C to +220°C |
| Central part | -25°C to +35°C |
| Launcher Titan IIIE/Centaur D-1T/TE-M-364-4 | |
| Perihelion distance | 0.30958 AU (0.29038 AU) |
| Inclination | < 0.02 ° |
| Orbital period | 191 Days (186 days) |
| Spin rate | 60 ± 1 RPM |
| Spin axis, perpendicular to the orbital plane | Tolerance ± 1 ° |
| The first plans for project solar probe | 1966 |
| Mission definition | 1968/69 |
| Beginning the probe development at MBB | April 1970 |
| Start date | 10.12.1974 at 7.11 GMT<br>(15.1.1976 at 5.34 GMT) |
| Total cost of the HELIOS project | 695 Million DM |
| of which German share | 465 Million DM |

Table 1: Data of the HELIOS solar probe.
The numbers in brackets are valid
for HELIOS 2.

| No. | Designation: | Experimenters: **Head** | Organization: | Scientific task: measurement..... |
|---|---|---|---|---|
| 1 | **Plasma Experiment** | **H.Rosenbauer**<br>R.Schwenn<br>J H. Wolfe | MPI for physics and Astrophysics, Institute for Extraterrestrial Physics, Garching / Munich<br>NASA Ames Research Center, Moffett field, CAL. | of low-energy charged particles (solar wind), protons, $\alpha$-particles, electrons |
| 2 | **Förster-probes magnetometer I**<br>(Brunswick) | **G.Musmann**<br>A.Maier<br>F. M. Neubauer | Technical University of Braunschweig, Institute of geophysics and meteorology | the interplanetary quasi stationary magnetic field and of shock fronts |
| 3 | **Förster-probes magnetometer II**<br>(Rom. GSFC) | **N.F. Ness**<br>L.F. Burlaga<br>F. Mariani | NASA-GSFC, Greenbelt, Md.<br>Università degli Studi, instituto di Fisica "(G).Marconi".Rome | the interplanetary magnetic field and magnetic shock fronts |
| 4 | **Induction coil - magnetometer** | **G.Dehmel**<br>F.M. Neubauer | Technical University of Braunschweig, Institute for telecommunications | by rapid changes of the magnetic field and magnetic shock waves |
| 5 | **Plasma and Radio wave Experiment** | **D.A. Gurnett**<br>P.J. Kellogg<br>R R. Weber | University of Iowa, DEP.of Physics & Astronomy, Iowa City, Iowa<br>University of Minnesota, school of Physics & Astronomy, Minneapolis, Minnesota,<br>NASA-GSFC, Greenbelt, Md. | by electrostatic and electromagnetic wave phenomena and shock waves |
| 6 | **Experiment of cosmic rays I**<br>(Kiel) | **H.Kunow**<br>G Green<br>R. Müller<br>G. Wibberenz | University of Kiel, Institute of pure and applied nuclear physics | Protons, $\alpha$-particles and heavy nuclei of solar and Galactic origin. |
| 7 | **Experiment of cosmic radiation II**<br>(GSFC) | **J.H. Trainor**<br>K.G. McCracken<br>E.C. Roelof<br>B.J. Teegarden | NASA-GSFC, Greenbelt, Md.<br>University of New Hampshire SCIRO, Melbourne/Australia | of medium - and high-energy particles, x-rays |
| 8 | **Electron Detector** | **E.Keppler**<br>G.Umlauft<br>B. Wilken<br>Dr. Williams | Max Planck Institute for Aeronomy, Institute for Physics of the stratosphere, Lindau, Harz<br>ESSA, Boulder, Colorado | of medium energy electrons.Protons and positrons |
| 9 | **Zodiacal light photometer** | **C.Leinert**<br>H.Link<br>E. Pitz | Max Planck Institute for astronomy, Heidelberg | the zodiacal light |
| 10 | **Micrometeorites Analyser** | **E.Grün**<br>P.Gammelin<br>J. Kissel | Max Planck Institute for nuclear physics, Heidelberg | of dust particles |

Table 2a: The "active" experiments on HELIOS

| No. | Designation: | Experimenters: **Head** | Organization | Scientific task measurement |
|---|---|---|---|---|
| 11 | **Celestial mechanics Experiment** | **W.Kundt**<br>O.Böhringer<br>H. Ovenhausen<br>J. Peyn<br>W. G. Melbourne<br>I. D. Anderson | University Hamburg, Institute for theoretical physics I<br><br>JPL, Pasadena, Cal. | Test of general relativity (Einstein, Brans-Dicke) with the help of a precise orbit determination of the solar probe (exploitation of the "signal delay effect '") |
| 12 | **Faraday-Rotation-Experiment** | **H.Volland**<br>M. Bird<br><br>G. S. Levy | University of Bonn, Radio-astronomical Institute<br>JPL.Pasadena, CAL | By measuring the following errors:<br>1. Rotation of the polarization plane (Faraday effect),<br>2. Runtime change (run-time effect) of the signals by the plasma.<br>3. Line distribution of the telemetry carrier as a result of high plasma density and temperature,<br>Determination of the Electron density and completion of scientific discovery, HELIOS-programme in terms of the dynamics of Solar Interplanetary events |
| 12Z | **Occultations Experiment** | **P.Edenhofer**<br>E.Lüneburg<br>Fr.H. Stark | DFVLR Oberpfaffenhofen. Institute of aviation radio and microwaves | Determination of the Electron density distribution of the solar corona in the heliocentric distance of approx.5-25 solar radii based on analysis of distance and Doppler data during the three planned occultations through appropriate numerical inversion procedures |
| 13 | **Additional study on the plasma experiment (E 1)** | **G. H. Voigt**<br>B. Könemann<br>H. Schröder | Technical University of Braunschweig. Chair of theoretical physics B | By calculating the disturbance caused by the HELIOS spacecraft (as a result of the Special geometry and surface coating) and implementation of correction invoices allow the physical interpretation of particle measurements (E 1) |

Table 2b: the 'passive' experiments on HELIOS

## Task of the plasma experiment

Since L. Biermann in 1957 concluded from Comet observations, that constantly ionized gas in the interplanetary space must escape from the Sun, many theories have been developed about this phenomenon, and since the first interplanetary spacecraft flights it is also directly experimentally verified.It was called a "Solar wind", and the interest in his research has continued since then.Several reasons: firstly an astrophysical plasma, which probably is emitted in a similar way by a majority of all the stars, is directly accessible; us here on the other hand, the solar wind provides us information about operations on the Sun.He decisively influenced also the physical events in the Earth's magnetosphere and in the vicinity of other planets.In addition can be obtained by studying plasma physical findings, which are difficult or impossible to obtain in the laboratory.

Close to the Earth's orbit, the parameters of the solar wind are now fairly well known.It is known that he composed on average to about 95% of protons, 4% from $\alpha$-particles and small amounts of heavier ions and a lot of electrons just compensate the ion charges. The particle density is located close to the Earth's orbit in the order of 10 $cm^{-3}$. This plasma flow with a mean speed of approx.400 km $s^{-1}$ about radially from the Sun out to the outside.The direction of movement of the individual protons scatters towards this direction slightly due to the "temperature" of the Proton component of about $10^5$ K.

However, the average thermal energy predominates when the electrons (approx. 15 eV) opposite the translational energy ($\approx$ 1 eV), so that their Velocity distribution by a spacecraft out appears nearly isotropic.The numbers specified here are subject to fluctuations, which are taken of interest for themselves, because they either on structures on the Sun or on operations, E.g. point out wave propagation in plasma between the Sun and Earth.

Yet major questions for understanding of the underlying physical processes are open despite the apparently already very good study of the solar wind.This is because to a large extent, that virtually all previous measurements in the solar system beyond the orbit of Venus were made, that so about the development of the phenomenon between the place of origin and approx.0.7 AU nothing is known.

The various theories differ but above all in the course of important plasma parameters in this field.Here, so just measurements of HELIOS from can provide insight into the accuracy of the various models.Due to the large approaching of HELIOS the Sun is also succeeding to correlate the observations in the solar wind much closer than was previously possible, with appearances on the Sun's surface and clarify important details not previously collected in the theories about the expansion of the solar wind.Finally, the plasma parameters measured at the location of the probe are also an important basic information for other HELIOS experiments, because the electric and magnetic fields (the 4 experiments deal with its measurement) are directly influenced by the solar wind, and the higher energy particles (3 experiments) are also influenced by him.

The plasma experiment is designed but not so that it gets its value only through the special orbit by HELIOS; instead attempted to allow for measurements, which have not yet been made so far even close to Earth's orbit through the development of new tools.Here, especially the analysis of plasma electrons are up to lowest energies and the complete separation of the distribution functions of protons and of $\alpha$-particle to name a few.

*The instruments have met each of these expectations so far fully and in detail.In addition there have been some other very important aspects mainly because of the unexpected length of the mission: on one of the years of "formation flying" the two probes provides new insights into the large-scale structure of the interplanetary medium.On the other hand a now closed record by end of 1974 - a year before the end of the solar cycle 20 - currently late in 1980, before where the activity maximum of cycle 21 is already exceeded. This record is unique therefore because by exceedingly skillful mission operation with the help of the onboard memory almost all gaps in the data received at the ground stations, also with a low data rate, could be bridged, which was not originally intended. Therefore, there are good prospects for new insights into changes of the solar wind with the solar cycle.*

## Historic overview

The HELIOS project started end of 1966.At the time, the Governments of the United States and the Federal Republic of Germany a bilateral project "Solar probe" decided as it was called at that time.In July the mission definition study was then begun.The result was definition until April 1969 the mission group report.Finally in July 1969 could with the signing of the memorandum of understanding the cooperative project HELIOS between the American space agency NASA and the Federal Ministry of scientific research are contractually agreed.

In parallel, the plans for the implementation of in-situ plasma measurements ripened up already at the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching. Prof. Reimar Lüst and Prof. Klaus Pinkau, which are certainly among the fathers of the HELIOS project, were directors at the Institute.They commissioned Helmut Rosenbauer early in 1967 with the development of appropriate instruments.As a kind of exercise, he first designed a "dream"-instrument with all only conceivable finesse, he suggested then - again as an exercise - for the ESRO satellite HE0S-A2.Contrary to expectations, this proposal early 1968 was adopted and had to be built.Heiner Grünwaldt and Heinz Pellkofer, took over the care at MPE the instrument was developed to flight readiness and finally built by the company AEG-Telefunken.The novel concept of this instrument, as well as the characteristic size of the sensor part are identical with those of the later instruments I1a and I1b for HELIOS: 3D-resolution with the help of nine channeltrons behind a quarter sphere analyser, almost concentrically arranged hemisphere Analyzer with atomizing electrometer, vacuum concept, the location of the measurement channels, the principle of the selection according to the position of maximum of distribution etc.At that time began the first laboratory tests of channeltrons, who soon encouraged us in the hitherto unheard-of view that life of Channeltrons, through appropriate treatment, especially by consistently avoiding contamination with organic molecules (pump oil, plastic, epoxy, colors etc.), practically can be extended indefinitely.

When the HEOS instrument the Interior of the UHV suitable sensor principle was therefore introduced and held: exclusive use of materials such as glass, metal, ceramic, evacuable housing, operating only in the absolutely oil-free vacuum.As a result of which no degradation of channeltrons could be determined in fact during the HEOS Mission (from 31.1.72 to August 1974).

From the outset, separation and analysis of the heavier ions of the protons had regarded as desirable.Until early 1970 a principle as feasible turned out for various preparatory work and studies, which was later realized in the construction of the electrodynamic mass Analyzer (I3).The measurement of electrons was because of huge surplus of photoelectron in the surroundings of each spacecraft always considered nearly impossible and also appear as less interesting.Only at the direct instigation of Prof. Ludwig Biermann, Helmut Rosenbauer began with serious considerations, which finally culminated in the novel instrument I2.

After several attempts at various vacuum systems, in which first the flow characteristics were examined by spherical analyzers, the construction of the calibration facility began in 1970.She was in a container outside the actual laboratory building as clean room decorated specifically (a wooden shack about 100 m from the main building removed) built.This separation was our blessing in disguise: as on the 22.12.1970 the laboratory building reasons never clarified completely burned down, nothing could be saved literally, out of the container.This fire threw back far us, especially when the HEOS project, a year before the planned start.Luckily, here no flight unit was directly affected, more or less randomly, so that the calibration work could begin in the spring of 1971.There were at that time only on the paper, which however completely burned the HELIOS instruments.By a large part of the documents, there were copies of various project partners to happiness.Yet our already large backlog in the production of project papers was almost hopeless and long time could not be raised.

In May 1970 the company Messerschmitt-Bölkow-Blohm (MBB) in Ottobrunn was selected from the only two received offers from industry companies.
At that time, many interfaces to the probe were still completely unclear orhave been amended several times.

In addition, we had also our ideas about the possibilities of the instruments constantly adapt to what is feasible and vice versa.This extremely constructive design phase until mid 1971 developed a fruitful, very open community in the literal sense that formed a sound basis for further work, from which emerged then finally sophisticated instruments, working excellently and correctly from the start and even after years.In this initial phase, on MBB site except the project manager Jochen Brauer, in particular the gentlemen Stiller and Nogai and Friedrich (electronics), as well as H. Wagner (mechanics) involved, at the MPE H. Rosenbauer, the project manager H. Pellkofer and (since 1971) Rainer Schwenn, who took over the role after the resignation of H. Pellkofer 1972. He conducted also the long-term and selection tests of the channeltrons, supported by the assistants Erna Kusser and later Edith Wantosch.Bernhard Meyer calculated form and flow characteristics of the mass Analyzer (I3).Then in 1972 still Hans Miggenrieder came as the last of the co investigators, who prepared the first of all the special calibration system for the low-energy electrons.The entire UHV vacuum systems were in supervised by Hans Ludwig, who later played with the sensor integration in support of MBB.Konrad Müller oversaw all experiment - and system tests.Together with H. Ludwig, H. Miggenrieder and R. Schwenn, he was instrumental in the launch preparations.

The probe system on the experiment, the constant deadline pressure, long time unclear requirements but also the productive functioning of close cooperation between MBB and MPE were all in all an unwanted side effect: the determination of the volume of work for the contract between MPE and MBB was extremely difficult, simply because the scope is constantly changed.The main treaty was signed only on the 13.12.71.In six additional contracts later 32 were "Change proposals", i.e.collects technical, cost-effective amendments.

First, the electrical integration model (EM) was completed.In January, 72 started the first measurements of the calibration system.Some problems were uncovered here and part before delivery of the EM to the prime contractor (HAN) in May 72 fixed.In April, 72 MBB provided the so-called sensor Kit consisting of the sensor parts without any electronics and completely identical with the EM. Because all details could be, measured on the calibration system exactly regardless of the schedules of the project.These surveys served especially as preparation for the upcoming always under great time pressure calibrations of the flight instruments.To automate the calibration, Matthias Bechly in the framework of a thesis developed a fully automated control and data acquisition unit, the "pacemaker" and later to redundant "Green step machine".

The prototype instruments (P type) were passed in August 1973, the flight unit 1 (F1 type) in November 1973, the flight spare unit (F2 type) in April 1974.It's not the place, all the many names, acts, problems, almost catastrophes, last-minute project quarrels and speciality Affairs to enumerate rescues who kept us in this time in breathing.Facilitating sounds 10 seconds after starting out from the set of an employee is telling: "Thank God, thing we need do no more what...".

Turn on of the experiment by the JPL out ran without problems.K. Müller and R. Schwenn monitored the work of the instruments by the JPL out and led still up in January 1975, mission control to the GSOC of the DFVLR in Oberpfaffenhofen was transferred several tests.Some of the experiences of this first weeks could be used for changes in HELIOS 2, etc.Reduction of microphony of I1b, displacement and reduction of the Azimut channels I2 and move the azimuth channels with a new command at I1a.

Particularly dramatic was the so-called "Multipacting" to the high-gain antenna: electron avalanches trained in narrow slots of the dipole of antenna is apparently in the strong electric field through a kind of resonance effect.This our I2 interference electron electron instrument was almost flooded, and also the wave experiments received bad data.After rigorous testing, it was decided at regular intervals on the medium-gain antenna switch, without the highest bit rates, to help those affected at least temporarily to achieve results.Also, laboratory tests for clarification and possible elimination of the fault for HELIOS 2 were immediately started.This could be achieved by an appropriate modification, in fact.A similar modification must have set up probably by itself aboard Helios 1 the first perihelion approach; because of the disruptive effect ceased completely after the first perihelion for unknown reasons and has never occurred.

In addition to the mission control HELIOS 1 and beginning to review preparations for the HELIOS 2 1975 ran start at full speed.This included the conversion of the P instruments in a set of full-featured flight spare units.All changes carried out for HELIOS 2 proved to be great success; all instruments were flawless.Only in August 1977, the switch-off time of the mercury relay in the electron instrument began to increase, so that since September'77 electrons practically only in the low-energy part of the program can be measured.This is the only change that occurred in all our instruments on both probes since the start.Regular tests show that all functions are completely unchanged, that all power supplies have remained stable and that the channeltrons not degrade.None of the provided cold redundancy must be used so far.

Now is already a wealth of scientific results before (see the bibliography).May be not reported here.
It was however pointed out that the results from 1974 to 1980 at many places in sometimes startling ways justify the design considerations of the years 1967 to 1971.Of course now working on a new generation of instruments, 1985 flying and much more detailed measurements with the ISPM mission.Apart from that, there are very few, almost insignificant points, which from today's perspective, improvements to HELIOS instruments would be desirable.Stated in the technical chapters each.

## 2.Construction of the experiment used measuring methods

Known under the name "Plasma experiment", in following with "E1", summarizes four independent instruments, their shared responsibility is the study of the solar wind plasma.Three of the instruments (I1a, I1b and I3) measure the positive component, a (I2) the electrons of the solar wind.

Primarily, the speed distribution of the different types of particles are measured.The low density of the interplanetary plasma allows to a basically simple process: the particles are sorted according to their energies and incident directions and counted individually.

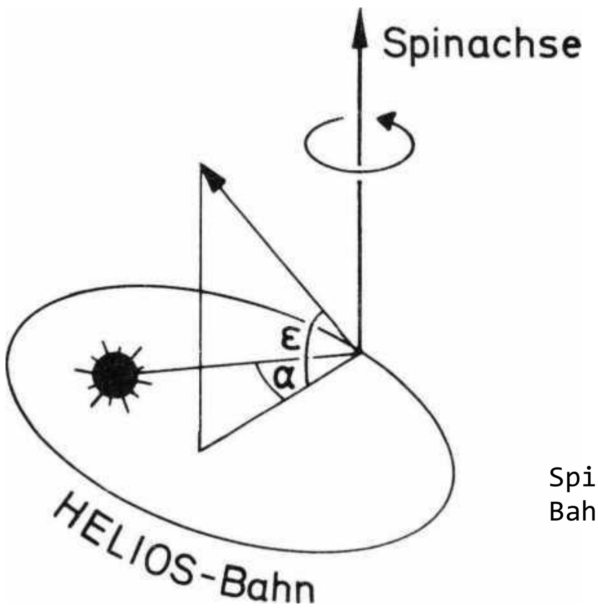
All E1 instruments work on the same basic principle: the charged particles pass through static or dynamic deflection systems; but only particles that come from certain directions, and which is located, the ratio of energy to charge (E/q) in a limited area of suitable can happen and be counted.

As an example, an Analyzer with ball-shaped baffle plates (medium-RADIUS R, distance d), where the voltage up, was called.As a condition for the middle of the passband is:

$$\frac{E}{q} = U_p \cdot \frac{1}{2}\frac{R}{d}$$

By changing the plates voltage the permeability range can be shifted and therefore gradually become an energy spectrum.Such used spherical analyzers in I1a, I1b, and I2.The plate voltage is switched up here in 32 steps from revolution to Revolution (according to the spin of HELIOS).

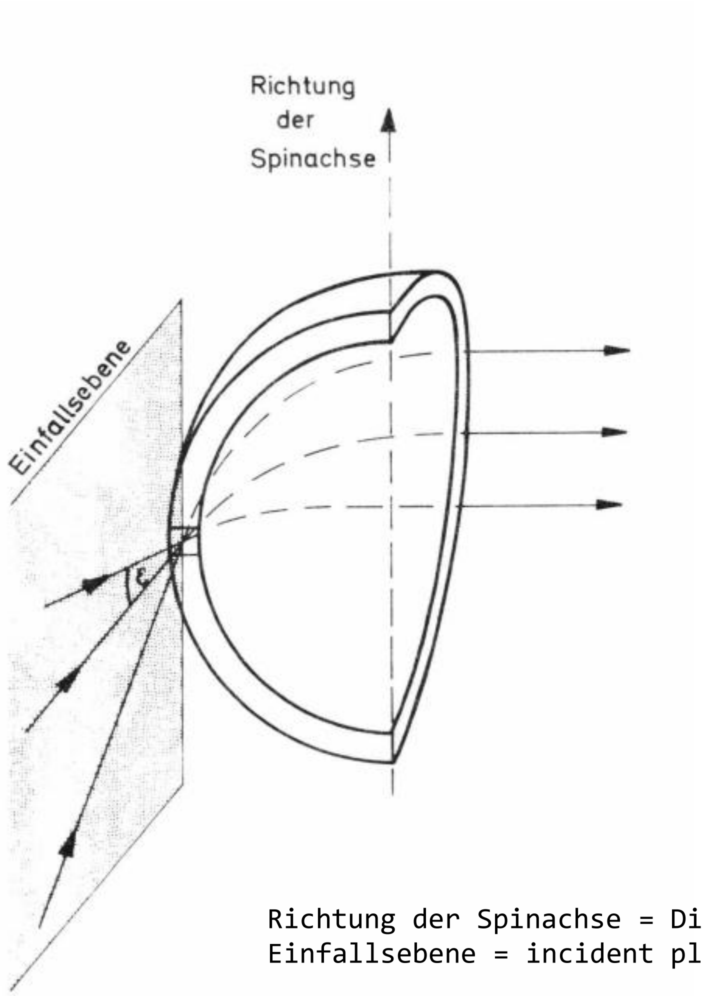
The E1 instruments are assembled in the vicinity of the Equator by HELIOS look with their entrance funnels through gaps in the heat shields radially outward.Due to the orientation of the spin axis of the HELIOS, the middle of the fields is always in the plane of the ecliptic.The rotation is taken to the Azimuthal direction resolution (angle in the plane of the ecliptic, see fig. 5) the measurements of HELIOS directly to help; by spin-synchronous sector pulse, measurement time is divided into each rotation in azimuth appropriate, channels, which cover the range of the expected particle incident direction.




Spinachse = spin axis
Bahn = path

Figure 5: Definition of the angle ($\alpha$) azimuth and elevation ($\epsilon$) of the particle incident direction.

The ion instruments I1a and I3 is also a resolution with regard to the second angle of incidence, the elevation (angle perpendicular to the ecliptic); This allows a "three-dimensional" measurement of the velocity distribution.As shown schematically in Figure 6, particles covered by different elevation angles $\epsilon$ through the inlet to escape after traversing a quarter spherical Analyzer at different points of the border and can be registered by separate detectors. From this scheme can be also derived, that hemispherical




Richtung der Spinachse = Direction of the spin axis
Einfallsebene = incident plane

Figure 6: scheme of a quarter sphere electrostatic analyser.
Particles with different incidence angles $\epsilon$ emerge at various points of the Analyzer and then detected with single detectors.

shaped Analyzer all particles of the implied plane of incidence on a point opposite the inlet be focused.So, a detector at this point provides a measurement result integrated over all the angles of elevation.I1b and the electronic instrument I2 use this principle.

A highly sensitive electrometer, which directly measures the incident ion current is used for detecting particles in I1b.In the other instruments, the particles with the help of open "channeltrons" (continuous electron multiplier) are counted separately.

The most important data of the individual instruments are in table 3 compiled.

**Instrument 1 a für positive Ionen**

| | | | | Kanäle |
|---|---|---|---|---|
| – Energie pro Ladung | 0,155 | bis | 15,32 kV | 32 · 2 |
| – Azimut (bezogen auf Sonne) | –54,5 | bis | 32,7 | 16 · 2 |
| – Elevation | –20 | bis | +20 | 9 |

Analysator: Viertelkugel mit R = 60 mm, d = 1,2 mm
Detektoren: 9 Channeltrons.

**Instrument 1 b für positive Ionen**

| | | | | Kanäle |
|---|---|---|---|---|
| – Energie pro Ladung | 0,145 | bis | 14,32 kV | 32 · 2 |
| – Azimut | –56,25 | bis | +118 | 1 |
| – Elevation | –40 | bis | +40 | 1 |

Analysator: Halbkugel mit R = 54 mm, d = 4,5 mm
Detektor: Elektrometer mit Quantisierungseinheit $1{,}6 \times 10^{-16}$ As.

**Instrument 2 für Elektronen**

| | | | | Kanäle |
|---|---|---|---|---|
| – Energie pro Ladung | 0,5 | bis | 15,5 V (A) | 16 |
| | 10,7 | bis | 1660 V (B) | 16 |
| – Azimut | 360 | | | 8 · 2 |
| – Elevation | –9 | bis | +9 | 1 |

Analysator: Halbkugel mit R = 40 mm, d = 5 mm
Ebene Ablenkplatten mit d = 33,6 mm
Detektor: 1 Channeltron.

**Instrument 3 für positive Ionen**

| | | | | Kanäle |
|---|---|---|---|---|
| – Geschwindigkeit | 199 | bis | 767 km/s | 16 |
| – Azimut | –53,2 | bis | 30,8 | 16 · 2 |
| – Elevation | –20 | bis | +20 | 9 |
| – M/q-Werte (bezogen auf $H^+$) | 1 | bis | 5,33 | 15 |

Analysator: Sinusähnliche Platten mit d = 2 mm, l = 135 mm
Frequenzen von 1,058 bis 4,088 MHz
Detektoren: 9 Channeltrons.

Translation Key:

- Für = for
- Ionen = ion
- Kanäle = Channel
- Energie pro Ladung = Energy per charge
- Bis = to
- Azimut = Azimuth
- Bezongen auf Sonne = based on Sun
- Analysator = Analyser
- Viertelkugel mit = quarter sphere with
- Detektoren = Detectors
- Halbkugel mit = Hemisphere with
- Ekektrometer mit Quantisierungseinheit = Electrometer with quantization unit
- Elektronen = Electrons
- Ebene Ablenkplatten mit = level deflection plates with
- Geschwindigkeit = speed
- M/q-werte = M/q values
- Bezogen auf = based on
- Sinusähnliche Platten mit = Modified sine wave panels with
- Frequenzen von = Frquencies of

Table 3: Main data of E1 instruments

The instruments for positive ions

The main task of the plasma experiment is the measurement of the three-dimensional Velocity distribution of protons in the solar wind.On board Helios, there is no redundancy for these measurements; Therefore the instruments were designed equivalent I1a and I3 in relation to the Proton measurements as largely, in the sense of a "cold" redundancy; Only one of the two instruments is in operation and fills the entire data provided for three dimensional Proton measurements with its data share.

*In the phases of the perihelion, where I3 due to its high power consumption and its approx.30-fold lower sensitivity can only be operated routine switching of I3 after I1a has kept about every hour for each 10 min very.*

The instruments I1a and I1b are housed in a common box (E1A).Their spherical analyzers are almost concentric.The 32 energy channels have 17% distance from each other and are almost exactly the same for both instruments.Every second measuring cycle moves the energy channels by half a channel spacing, the azimuth channels as well.For quiet solar wind then two spectra can be used together which substantially improves the resolution in two dimensions.

*Nevertheless, there are still gaps in the grid of channels.This leads in cases of extremely cold plasma - especially after shocks - to that sometimes the entire Proton flow in a single channel meets and falls right then so to speak "through the grate".A really complete overlapping of the range would be desirable therefore at least for the measurement of cold plasma.It is necessary but also mentioned that in speed space almost "punctate" measurements very facilitate the evaluation of results in not too cold plasma.A complete solution of the problem would be possible only through transmission of results also from the gaps of the current measurement grid, what but a much higher data rate would be necessary.*

The relatively large opening and the wide plate distance of I1b together with the integral effect of the hemisphere allows to measure the flow of ions of the solar wind as ion power.Here, charged ions repeatedly deliver a correspondingly higher contribution than in I1a, where each particle is simply counted regardless of its charge.So, the combination of both measurements provides information about the charge level of heavy ions in the solar wind.At the same time, I1b has a certain redundancy function due to its simplicity.

*This concept has confirmed shining through the unambiguous identification of previously not in the solar wind of suspected ions.*

Also the novel instrument I3, housed in box E1C, should reveal something about the composition of the positive component of the solar wind.It contains a "electrodynamic Analyzer" as the core.His deflection plates have a roughly sinusoidal curve, so that an applied sinusoidal alternating voltage get through only particles with a corresponding speed can be.It is determined by the frequency of the applied alternating voltage and the geometry of the Analyzer.On the other hand, the amount of the plate voltage as in the electrostatic Analyzer provides also for the curvature of the particle paths and for the excretion of all particles with wrong E/q values.The two independent criteria of speed and energy per charge lead to a selection of particles according to their mass-per-charge ratio (M/q).A total of 15 fixed M/q values can be set for each of 16 speed values.The highest value of 767 km / sec corresponds to Proton of energies of 3.08 keV compared to 15.31 keV at I1a.In its azimuth and elevation channels but this instrument resembles exactly the instrument I1a.

*Unfortunately, the sensitivity of I3 is so low that the already rare heavy ions only in exceptional cases to prove really are. The home value consists in the complete separation of α-particles are the Proton, whose distributions often completely overlap in perihelion in the pure range of E/q.*

## The electron instrument

An increasing importance in all theoretical models the electrons of the plasma of the solar wind.But the measurement of such electrons in the energy field of a few electron volts is generally difficult and therefore until today not properly managed: a photo electrons, their density is higher than that of plasma electrons; several magnitude caused by the sunlight on the surface of the probe on the other hand, even the energy areas overlap.

Thus we must distinguish the electrons according to their origin. This is possible; because photoelectron are invading the detector vertically, have - with some simplifying assumptions - always a lower energy than the electric potential $\phi$ of the entire probe, if $\phi$ is positive; Photo electrons with higher energy than $e\cdot\phi$ can not return to the probe and to the detector. Solar electrons reaching the detector, have always a higher energy than $e\cdot\phi$, because you to are accelerated by this amount.Because now the spectra of photo-electrons and plasma electrons will vary in General, you will measure a discontinuity in the measured energy spectrum of electrons at the point of the probe potential.

To do this, one must avoid above all that that photo electrons, only produced within the instrument and hence higher energies $e\cdot\phi$ can have, this moving blur.

You can achieve this by such a geometry which basically makes it impossible for the reaching of the detector all photo electrons generated in the sensor interior.The HELIOS electron instrument I2, housed in box E1B, therefore consists of two consecutive deflection systems: the first serves only the electrons to be analyzed from the cone of light out - and to the actual energy Analyzer, which is always in the shade, to draw into.

It is also provided that the probe potential is positive, and that does not distract in the Visual field of the Inhomogeneities of the electric field sensor the incident electrons.Unfortunately, a complete coating of HELIOS with a conductive layer to achieve a uniform positive potential for various reasons has been impossible to achieve.Only the central part of HELIOS is covered with two wide conductive rings are electrically connected with the probe structure.They provide enough large photo electron emission, and thereby compensate for the strong flow of plasma electrons falling from the top and bottom of the shaded surfaces of HELIOS.These surfaces must be also conductive and "grounded".This potential can be kept most of the time about positive by HELIOS.The interference as a result of electrostatic charging of non-conductive surfaces by plasma and photo electrons however remain and must be taken into account in the evaluation.

*When you first turn of I2, all with great excitement waited whether this novel instrument really works as expected.In fact – from the first range of the predicted buckling about 3eV was to see clearly.However, he is usually slightly smeared by the aforementioned interference and for direct measurement by $\phi$ not suitable. The total area of the senior rings turns during approximately 80% of the time sufficient,to keep $\phi$ positive. Only in solar wind streams with a high Electron density is $\phi$ negative. This is pretty much the estimates.*

*The experimenters had campaigned for the first-time implementation of "electrostatic purity" in an interplanetary probe with all his strength.With the success of this concept at HELIOS - even if it not entirely kept out - has led that "electrostatic purity" has become the standard by space probes, which are to measure low-energy particles and fields.*

The electronics box

All E1 instruments are of a common electronics box (E1D) of supplies.It contains all of the interfaces between the instrument and the probe systems:

o The electrical supply current is led on a 28 V line of the "nonessential bus", in the E1 main converter galvanically from the input pipe decoupled, on the different supply voltages (+ 5V, - 5V, + 28 V, + 33 V) transformed and distributed to the instruments.

o E1D is electrically connected to the probe structure and contains the star point for the grounding of the entire E1 system. All other E1 boxes are electrically isolated mounted structure.

o of telemetry commands are transferred in the E1 command register, evaluated and converted into appropriate control signals for the instruments.Both the arrival of commands as carried out execution according to feedback from the instruments is summarized in the form of individual bits to "digital housekeeping words" and transferred to the engineering data system of the probe.

o the program system controls the switching of plate voltages and the situation and length of the azimuth with the help of clock pulses offered by the probe.

o the data system prepares the data, stores it and passes it to the HELIOS telemetry.The data system

- the counter for the preamplified detector pulse from the instruments,
- the encoder for the count rates,.
- a logic for the selection of the significant measurement channels,
- two magnetic core memory with a capacity of 4096 bits each.

o the measurement data of a cycle are read synchronous spin in one of the store, while the other time-synchronous emits the data previously stored on the telemetry.The memory switches after the slower of these processes, and a new cycle begins.If this memory readout time of less than half or a quarter of the time is, is a cycle twice or read four times.In the reverse case, so at low bit rates, the switching moves so long until the current meter reading is finished.The time distance of two spectra can be between 40.5 sec and 43 min 12 sec.

o the data system is redundant in its main parts.In case of emergency can be toggled via command on the intact part.

*So far, no change has been necessary.*

o the engineering data system to collect important data about the technical condition of the instruments (input currents, high voltages, command State, temperatures).The probe transmits these data in the context of the engineering format (FM4).In the control center via screen can be monitored in real time.

o an automatic test cycle can be used with a command, which is controlled by the electronics box.Instead of the data of two measurement cycles appear then test data to the Control Board voltages, Channeltron reinforcements, zero count advise and the function of digital electronics.

## 3. Technical description of the instruments

### instrument I1a (in box E1A)

A quarter spherical electrostatic Analyzer is the heart of this high-resolution instruments for positive ions.The spherical shells are almost concentrically arranged on the half spherical shells of I1b (see Figure 7).The scoops are close so close together in a common "funnel", who looks through a hole in the wall of the spacecraft outward radial.Along the edge of the outlet of the quarter balls (see Fig. 6) 9 channeltrons are attached, which correspond to an average distance of angle of incidence directions of 5 °..

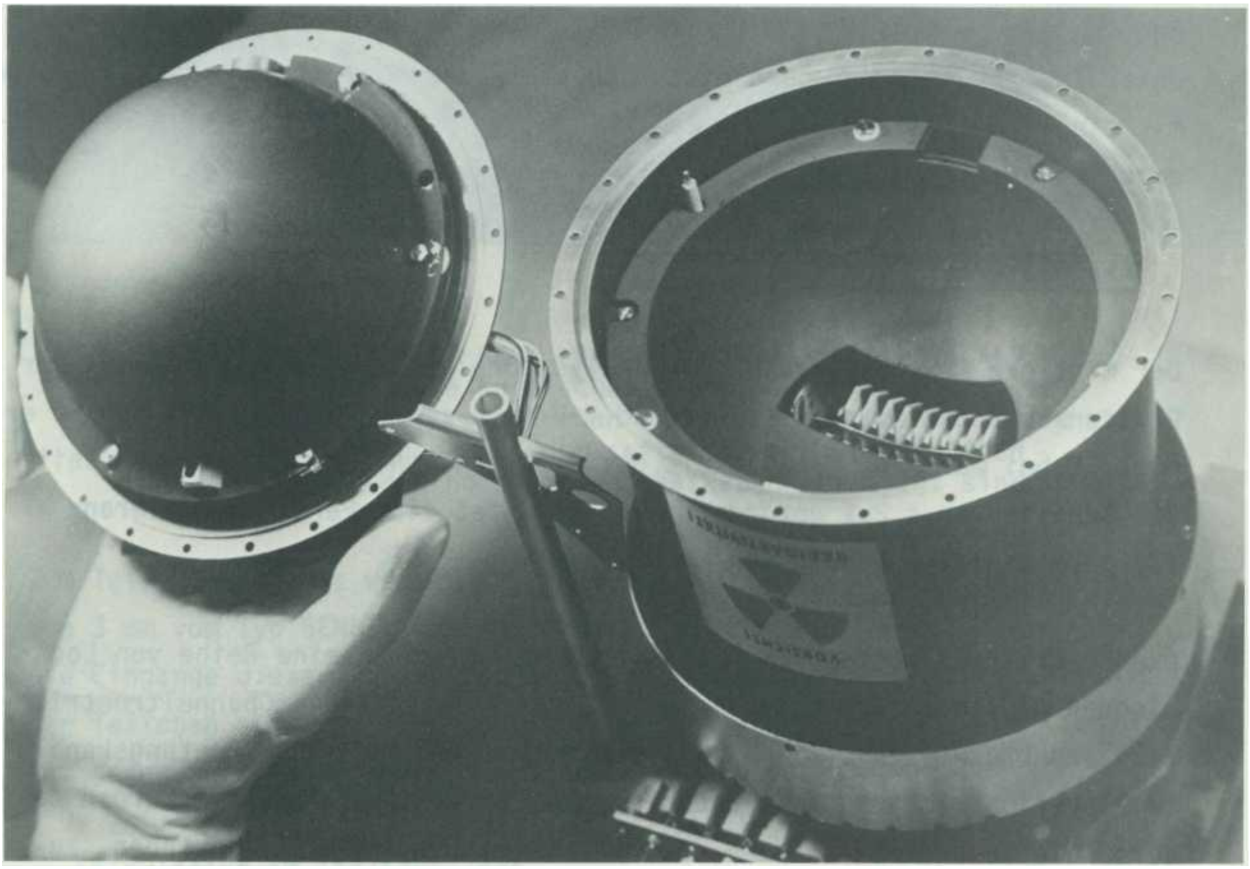


Figure 7: Look in the open instrument I1a/I1b.
Right the Analyzer shells of the quarter sphere instruments I1a with the aperture and the channeltrons at the edge of the outlet.The inlet is front (face-down).Left hemisphere cups of I1b.

The instrument is mounted in the solar probe that the field level of the Analyzer is a Meridian plane.Then matches the direction resolution of a resolution reached by the 9 detectors in the elevation (seeFig. 5).The azimuth resolution can be achieved now electronically subdivision in succession measurements during rotation of the probe.
The used electrostatic Analyzer analyzes the positive ions in the solar wind energy per charge (E/q, dimension: Volt).Since particles of various kinds have usually about the same average speed, the interpretation of a range is not completely clear: so you can for example $^{4}He^{+}$ particles not of equal fast $^{16}O^{4+}$ Distinguish particles, because in two varieties is $E/q = 4$, where $E/q = 1$ for protons. Because you know that the first and greatest maximum must match the protons in the spectrum, one can conclude from the other maxima on the content and the nature of the remaining components.
Using the above direction resolution, you can measure so the full three-dimensional Velocity distribution of the positive particles of the solar wind with a such on analyser.

<u>Analysing Part by I1a</u>

The average radius of curvature of Analyzer plates $R_m$ is 60 mm.The plate distance d is 1.2 mm to give an R/d ratio of 50.Accuracy of the R/d ratio in the "active part" of the shells of ± 2% was required.This means for each individual bowl of $\pm 10\mu$ a manufacturing tolerance.

The outlet of the Analyzer are formed by a series of aperture, which facilitate between the spherical shells and the Channeltron funnels attached (fig. 8).The aperture set elevation towards the channels of direction of and limit the channels.Also, the electrons that arise in the Channeltron funnel, withheld this, because this aperture with a fine mesh grid are covered.

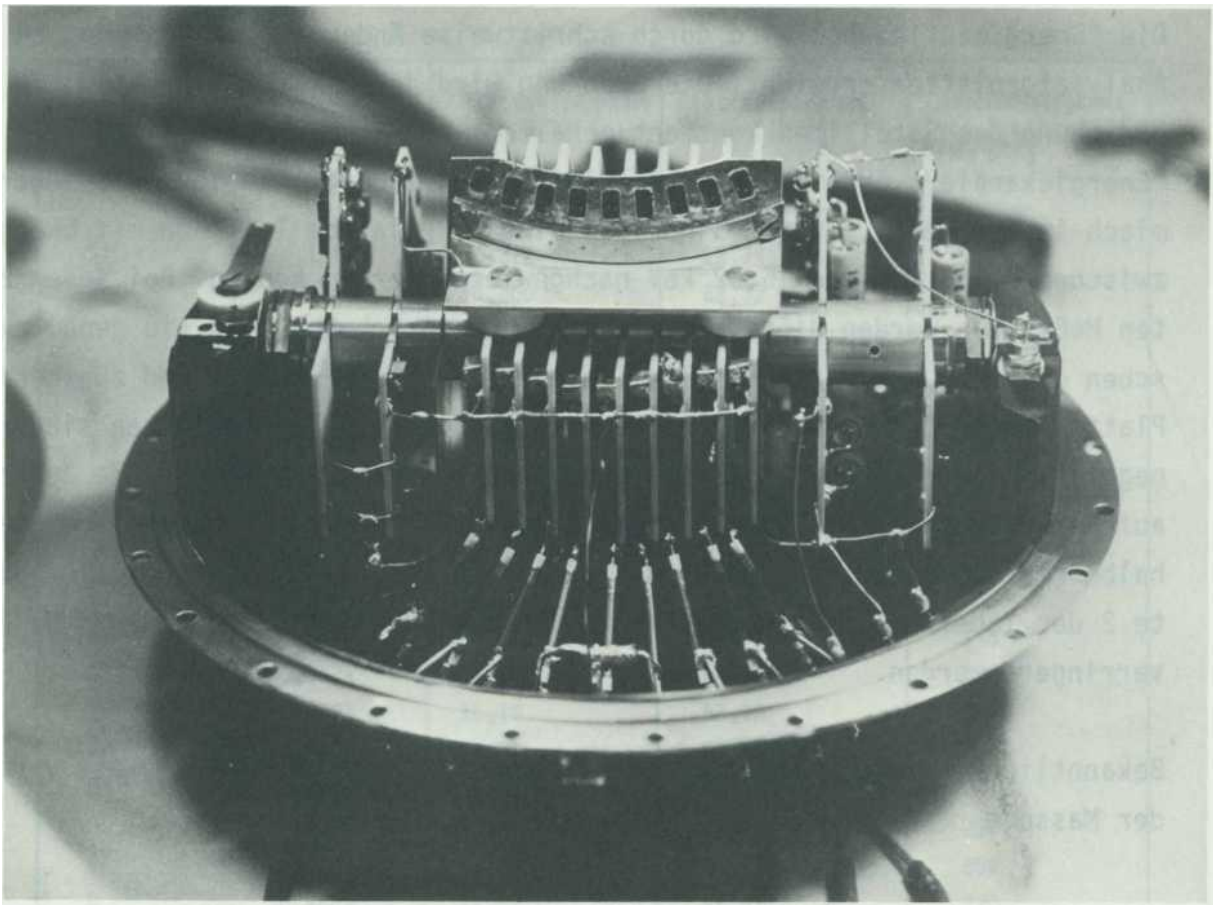


Figure 8: Here also the cylinder part of the housing, as well as the spherical shells by I1a are removed.The channeltrons are carried by a common shaft, on which side the boards with the high voltage cascade are attached.

Channeltrons used for detecting particles funnel diameter by 3 mm type BENDIX CEM 4013 M.

The inputs of this channeltrons are sufficient for acceleration of particles on negative voltage.The aperture with the bars has a potential of 200 V compared to the Channeltron funnels.

Stimulation in Inflight test

To stimulate the channeltrons with the so called "Inflight Test" serves light a UV glow lamp; It is mounted near the Channeltron funnel, so that all channeltrons are lit correspondingly.The intensity of this UV glow lamp is, lit with a high voltage of approximately 550 V and operated at 350 V is set so that Channeltrons emit workable and meaningful count rates.

I1a energy channels

The "energy"resolution is achieved by gradual change of voltage to the plates of the Analyzer.The voltage is kept constant each of the measurements per revolution of the satellite.The instrument has 32 "energy channels", more precisely said "Energy-per-charge channels", which logarith-mixing are considered way, that simply charged particles with energies between 0,158 keV and 15.62 keV can be detected.Every second measuring cycle, these energy channels are moved so that they are exactly between these channels.All energy channels and associated plate voltages are given in table 4.The voltages are negative and are attached to the inner Bowl, while the outer housing potential lies.This means that the ions in the medium to the half plate voltage $U_p$ to be speeded up.So, the values specified in column 2 of table 4 for the channel centers by $U_p/2$ must be reduced.

It is known that the energy of a particle with velocity v and mass m is

$$E = \frac{m}{2} v^2$$

For protons with $m_p = 1.6724 \times 10^{-24} g$ results in a formula for $v_p$ as a function of E

$$v_p = 437.4 \cdot \sqrt{E}$$

where E in keV to use is.The values of $v_p$ to the energy channels from column 2 in table 4 are also specified in column 5, for the data analysis, these values by using the calibration results are modified anything.

The accuracy of the plate voltage is better than ± 1%.

The deviations from these values is in the range of temperature to be expected during the mission not more than + 1% ± 50 mV.The ripple voltage is 2% ss.

| Energiekanal | Energie zu Ladung (keV) | Plattenspannung Sensor 1a (V) | Plattenspannung Sensor 1b (V) | Geschwindigkeit von Protonen (km $s^{-1}$) |
|---|---|---|---|---|
| 1' | 0,1580 | 6,322 | 26,34 | 172 |
| 1 | 0,1700 | 6,800 | 28,33 | 178 |
| 2' | 0,1829 | 7,314 | 30,48 | 185 |
| 2 | 0,1967 | 7,867 | 32,78 | 192 |
| 3' | 0,2116 | 8,462 | 35,26 | 199 |
| 3 | 0,2276 | 9,102 | 37,93 | 206 |
| 4' | 0,2448 | 9,791 | 40,80 | 214 |
| 4 | 0,2633 | 10,53 | 43,88 | 222 |
| 5' | 0,2832 | 11,33 | 47,20 | 230 |
| 5 | 0,3046 | 12,18 | 50,77 | 239 |
| 6' | 0,3277 | 13,11 | 54,61 | 248 |
| 6 | 0,3524 | 14,10 | 58,74 | 257 |
| 7' | 0,3791 | 15,16 | 63,18 | 266 |
| 7 | 0,4078 | 16,31 | 67,96 | 276 |
| 8' | 0,4386 | 17,54 | 73,10 | 287 |
| 8 | 0,4718 | 18,87 | 78,63 | 297 |
| 9' | 0,5074 | 20,30 | 84,57 | 308 |
| 9 | 0,5458 | 21,83 | 90,97 | 320 |
| 10' | 0,5871 | 23,48 | 97,85 | 331 |
| 10 | 0,6315 | 25,26 | 105,3 | 344 |
| 11' | 0,6793 | 27,17 | 113,2 | 357 |
| 11 | 0,7306 | 29,23 | 121,8 | 370 |
| 12' | 0,7859 | 31,44 | 131,0 | 384 |
| 12 | 0,8453 | 33,81 | 140,9 | 398 |
| 13' | 0,9093 | 36,37 | 151,5 | 413 |
| 13 | 0,9780 | 39,12 | 163,0 | 428 |
| 14' | 1,052 | 42,08 | 175,3 | 444 |
| 14 | 1,132 | 45,26 | 188,6 | 460 |
| 15' | 1,217 | 48,69 | 202,9 | 477 |
| 15 | 1,309 | 52,37 | 218,2 | 495 |
| 16' | 1,408 | 56,33 | 234,7 | 513 |
| 16 | 1,515 | 60,59 | 252,5 | 532 |

Table 4: Energy per charge channels and
Plate voltages of instruments I1a and I1b

Energiekanal = Energy channel
Energie zu Ladung = Energy to charge
Plattenspannung = Plate Voltage
Geschwindigkeit von Protonen = Speeed of protons

| Energiekanal | Energie zu Ladung (keV) | Plattenspannung Sensor 1a (V) | Plattenspannung Sensor 1b (V) | Geschwindigkeit von Protonen (km $s^{-1}$) |
|---|---|---|---|---|
| 17' | 1,629 | 65,17 | 271,5 | 552 |
| 17 | 1,753 | 7o,1o | 292,1 | 573 |
| 18' | 1,885 | 75,4o | 314,2 | 594 |
| 18 | 2,o28 | 81,11 | 337,9 | 616 |
| 19' | 2,181 | 87,24 | 363,5 | 639 |
| 19 | 2,346 | 93,84 | 391,o | 663 |
| 2o' | 2,523 | 1oo,9 | 420,6 | 687 |
| 2o | 2,714 | 1o8,6 | 452,4 | 713 |
| 21' | 2,919 | 116,8 | 486,6 | 739 |
| 21 | 3,14o | 125,6 | 523,4 | 767 |
| 22' | 3,378 | 135,1 | 563,o | 795 |
| 22 | 3,633 | 145,3 | 6o5,5 | 825 |
| 23' | 3,9o8 | 156,3 | 651,3 | 855 |
| 23 | 4,2o4 | 168,1 | 7oo,6 | 887 |
| 24' | 4,521 | 18o,9 | 753,6 | 920 |
| 24 | 4,863 | 194,5 | 81o,6 | 954 |
| 25' | 5,231 | 2o9,3 | 871,9 | 989 |
| 25 | 5,627 | 225,1 | 937,8 | 1026 |
| 26' | 6,o52 | 242,1 | 1oo9 | 1064 |
| 26 | 6,51o | 26o,4 | 1o85 | 1104 |
| 27' | 7,oo3 | 28o,1 | 1167 | 1145 |
| 27 | 7,532 | 3o1,3 | 1255 | 1187 |
| 28' | 8,1o2 | 324,1 | 135o | 1231 |
| 28 | 8,715 | 348,6 | 1452 | 1277 |
| 29' | 9,374 | 374,9 | 1562 | 1325 |
| 29 | 1o,o8 | 4o3,3 | 168o | 1373 |
| 3o' | 1o,85 | 433,8 | 18o8 | 1425 |
| 3o | 11,67 | 466,6 | 1944 | 1478 |
| 31' | 12,55 | 5o1,9 | 2o91 | 1533 |
| 31 | 13,5o | 539,9 | 2249 | 1590 |
| 32' | 14,52 | 58o,7 | 242o | 1648 |
| 32 | 15,62 | 624,6 | 26o3 | 1710 |

Table 4: (continued)

Energiekanal = Energy channel
Energie zu Ladung = Energy to charge
Plattenspannung = Plate Voltage
Geschwindigkeit von Protonen = Speeed of protons

I1a direction channels

The rotation (spin) probe to help will be taken to the angular resolution of the Azimuth: it is as simple as temporal Division of the measurement.
The instrument has 16 channels, each 3.5 ° azimuth channels width and 5.6 ° distance.The middle of the azimuth angle range used to measure so that they involved a certain suspension of the viewing direction of the instrument before the Sun line, based on the spin of the probe is situated, is equivalent to.It reflects the fact, that the plasma particles - although almost radially from the Sun flying away - no longer meet because of the significant ground speed of HELIOS from the direction of the Sun on the probe.At HELIOS 2, the hold-back angle via tele command can be toggled in two stages.

This time derivative to the half channel spacing, so 2.8 ° is reduced at any second cycle.This creates a second grid 16 channels of azimuth, which is offset by 2.8 °.This shift of the Azimuth channels is performed simultaneously with the aforementioned shift of energy channels.The exact location of the Azimuth channels is provided in tables 9 and 10 on pages 71 and 72.
The angular resolution in the elevation is achieved through the use of 9 channeltrons in conjunction with quarter spherical analyser.The distance of these channels is approx. 5 °, the width2.8 °.These 9 elevation channels are symmetrical to the equatorial plane of the probes.

Electronic part of I1a (see block diagram fig. 9)

Instrument I1a becomes supplied by the electronics box (E1D) only control signals, that determine the end of the program, as well as with a voltage of 28 V direct from the main current transformer (main-converter), which is also located in the electronics box.The sensor electronics delivers the preamplified Channeltronpulse on the electronics box for the registration, evaluation, and storage.All electronics for assistance and control of the instrument, as well as for data processing is located with the exception of the high voltage cascade in the electronic part of the sensor box.The electronics of the sensor consists of the following units (see Figure 10):

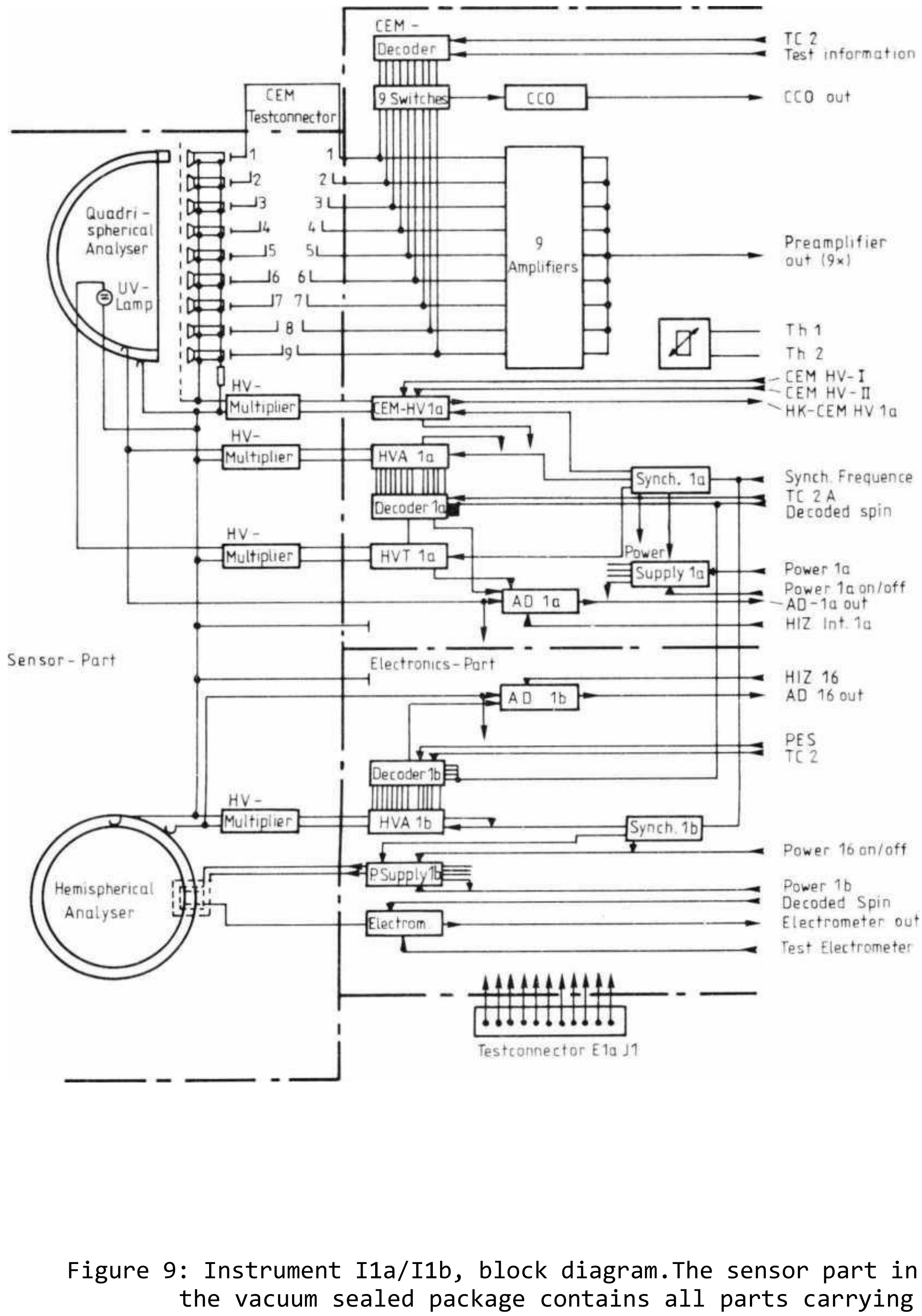



Figure 9: Instrument I1a/I1b, block diagram.The sensor part in the vacuum sealed package contains all parts carrying high voltage, the electronics part analog and digital electronics.

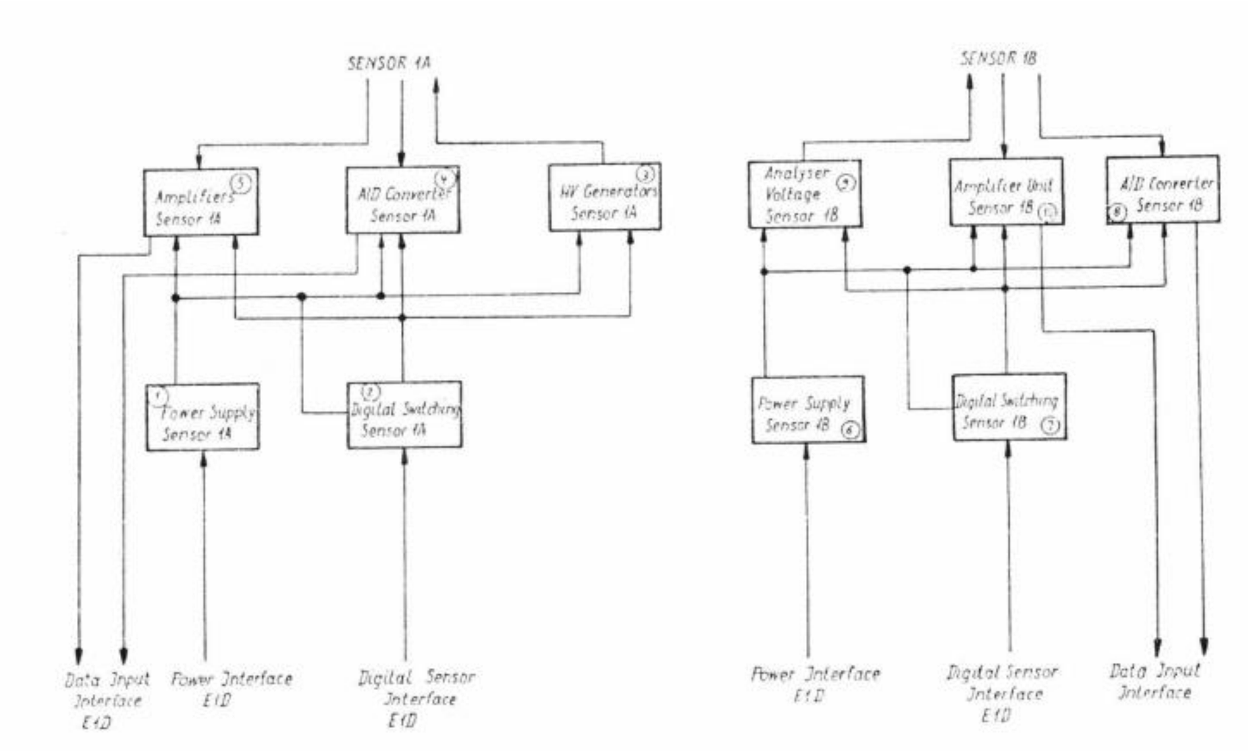



Figure 10: Instrument I1a/I1b Block diagram of the electronic part

- Sensor power supply (power supply)
- Channeltron amplifier unit (amplifiers)
- Analyzer of power generation, power generation for UV – Glow lamp and Channeltron supply voltage - procreation (HV generator)
- Analog - to-digital converters (A/D-converter)
- Digital control unit (digital switching)

The sensor power supply generates all voltages required to operate of the electronics from the 28V-supply of the main power transformer.It is activated and deactivated using the appropriate command.The Channeltron amplifier unit includes 9 Channeltron amplifer which reinforce the output given by the channeltrons and give further processable form. Furthermore, this unit belongs to a so called CCO (current controlled oscillator), which during the Inflight test quantises an ejected charge from a randomly selected Channeltron. This allows the determination of the current amplification of a Channeltron.

The Analyzer power generation is a gradually switchable high-voltage generator with very little input and decay time constant.
The high voltage generator for the UV glow lamp is used only during the Inflight test and supplied the necessary ignition and ARC voltage the lamp.The electronics for the production of Channeltron-is a controlled high-voltage generator that works with a twelve-stage multiplier cascade supply voltage.He is on and off and has three power settings for three different output voltages (3,3 kV, 3.7 kV, 4.1 kV).
All high voltage cascade are housed together with the plates of the Analyzer and the channeltrons in the vacuum-tight part of the sensor and get only their control voltages from the electronics section through soldered unions.
The analog - to-digital converter is used to convert analog voltages to digitally processed readings and is used only for checking the Analyzer voltages during the Infiight test.
The digital control unit prepares the program control signals of the electronics box, (decodes the state of the so-called Energy channel meter) and thus controls the analyser voltage generation.

Instrument I1b (in box E1A)

The instrument I1b will supply energy Spectra by current measurement without any direction resolution in a simple way, so that even in case of failure of the data reduction logic or contamination of channeltrons still the most important plasma parameters speed, temperature and density can be determined.
Here, it used a hemispherical analyser which integrates over approximately 80 ° in elevation.The integration of the azimuth is achieved that is the entire ion flow, over about a half of probe turn the direction of the Sun around, summed up.

Analyzer part of I1b

The hemispherical analyser panels have the following dimensions:

Medium-RADIUS: R = 54 mm ± 1%
Plate distance: d = 4,5 mm ± 2% $R/d = 12$
Inlet opening: 4.5 x 10 mm

The outer plate is connected to the housing potential, the inner plate is at negative potential.
A super-insulated collector located in the focus area of the hemispherical analyser acts as a particle catcher.Between Analyzer plates and particle collector, a grid is attached to decouple of the Analyzer voltages or used to hold back the electrons.It is biased to-36 V against the collector.
The trapped positive charge is fed into a highly sensitive electrometer amplifier, which emits a standard pulse to the digital electronics at the output a digitization level per unit of quantization.The following data are for the electrometer amplifier:

Quantization unit (QE): 1.6 x $10^{-16}$As, i.e.1000 Elementary charges
Dynamic range: 1.6 x $10^{-16}$As up to 3.2 x $10^{-12}$As
Time constant: 60 ms

Accuracy: $\pm 10\%$ for $Q \geq 1.6 \times 10^{-14} As$ $\pm 8\%$ for $Q \geq 1.6 \times 10^{-13} As$

Set zero count rate: $20 \pm 5$ QE/Measurement

Long-term constancy zero count rate: $\pm 10\, QE$

<u>Measuring Channels of I1b</u>

The number and the distribution of energy channels is identical to I1a (tab.4), where here is a translation of the half plate voltage have to consider.The range switch-over from one cycle to another is the same as for I1a.The voltages are correspondingly higher due to the greater distance of plates.For the accuracy orTolerance is the same with the following exceptions:

Temperature stability of DC voltage: $\pm 1\% \pm 250mV$
Drop-out time from the highest to the lowest
Channel :< 200 ms

<u>Electronic part of I1b (see block diagram fig. 9)</u>

Instrument I1b is supplied by the electronics box with control signals, and a voltage of 28 V direct from the main current transformer (main-converter) to determine program flow.The sensor electronics delivers the processed measurements to the electronics box.All electronics to the care and control of the instrument, as well as for data processing is located with the exception of the high voltage cascade in the electronic part of the sensor box.The electronics of the sensor consists of the following units (see Figure 10):

- Sensor power supply (power supply)
- Analyzer voltage generation (analysis of voltage)
- Electrometer amplifier unit)
- Analog - to-digital converters (A/D-converter)
- Digital control unit (digital switching)

The sensor power supply generates all voltages required for the operation of the electronics.It is activated and deactivated using the appropriate command.
The Analyzer power generation is a gradually switchable high-voltage generator with very little input and decay time constant.
The electrometer consists basically of a low-noise high-stability power amplifier and an electronic unit for the quantization of the measured load with the appropriate control circuitry.
The analog - to-digital converter is used to convert analog voltages to digitally processed readings and is only for the validation of Analyzer voltages during the so called "do test" used.
The digital control unit prepares the program control signals of the electronics box, decoded the stand of the so called Energy channel meter and controls so the analyser voltage generation.

*The set zero count rate of approx.20 counts remained stable during the mission remarkably although was been charged with slow drifting due to the strong temperature differences. The short term stability proved problematic: HELIOS-1 were suddenly large fluctuations of the zero count rate, as the motor of the despun high-gain antenna was switched on.Apparently "heard"} the electrometer which Yes very similarly to a highly sensitive capacitor microphone is, the structure-borne sound emanating from the bearings. This disorder was not occur during ground tests, probably because the store were differently loaded under the influence of gravity.*

Instrument I2 (in box E1B)

This instrument is used for the investigation of the electrons of the solar wind.

A hemisphere is used for the analysis of energy also here - like at I1b - Analyzer.A flat disk Analyzer is him however, which hides the electrons in the beam of sunlight and serves as light swamp.The arrangement is designed so that no photoelectrons generated on the entrance Panel or in the Interior of the sensor, can reach the Channeltron at the output of the Analyzer; in addition, only at least dual reflected light between the hemisphere Analyzer cups can reach (see Figure 11).

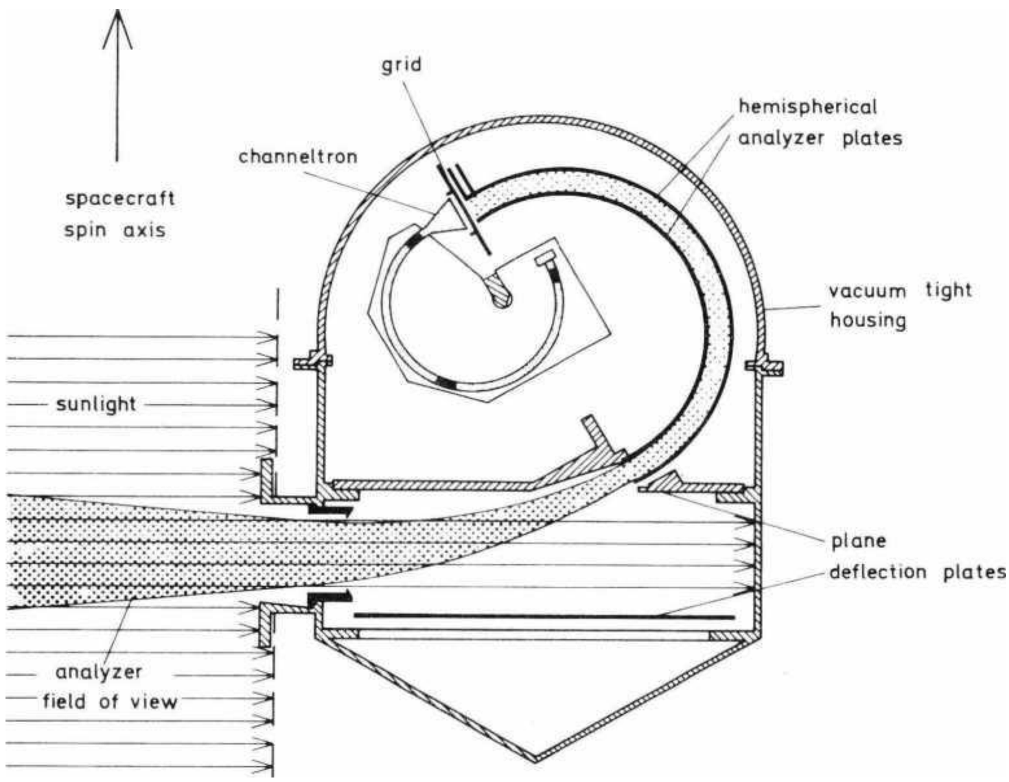



Image 11: Function image of the electron instrument I2

An elevation resolution is omitted here, so that only a single particle detector is required.The azimuth resolution is reached by the spin of the probe.The power range is from 0.5 eV to 1445 eV.

Analyzer part of I2

Following dimensions have the hemisphere shaped Analyzer plates:

Medium RadiusR $R = 40mm \pm 1\%$
Plate distance $d = 5mm \pm 2\%$ $\frac{R}{d} = 8$

The inner Bowl is connected to the housing potential, as well the subsequent plate plates analyser; the outer panels are placed on negative potential.
In order to reduce inhomogeneities in the field, a metallic border runs along the edge of the voltage carrying plate of the plate analyser, reaching roughly half way to the other plate. Close to the entry-opening, this border runs higher to simultaneously act as light aperture.

A Channeltron is for detecting particles used funnel diameter of 8 mm (type CEM 4018 M the company BENDIX).There is a pinhole with 8 mm in diameter, on which, much like at I1a - a mesh is soldered between Analyzer plates and Channeltron. This aperture prevents the funnel of the Channeltron from attracting electrons from a wider area when the funnel is at +200 V potential. You at the same time forms the outlet aperture of the Analyzer and acts as another Light baffle.This aperture is in the measuring program B (for electrons from 9 eV) on a potential of - 6 V put, to hold back photo electrons.

*Flight experience with HELIOS 1 and subsequent laboratory tests proved} this is not necessary.That's why this aperure has been connected with mass in HELIOS 2.*

<u>Stimulation in Infiight test</u>

To stimulate the channeltrons with the Inflight-Test, a UV glow lamp; is mounted near the channeltrons.The intensity of this UV glow lamp which is ignited and operated with high voltage is adjusted by appropriate coating of its surface, that a workable and meaningful the Channeltron count rate is down.

<u>I2 measuring channels</u>

Sensor 2 can run two different measurement programs, telecommands are toggled by (S2A- and S2B program).

<u>In the program A electrons measured in 16 channels with energies between 0.5 eV and 13.3 eV, the required relatively low plate voltages (see table 5) are generated directly in the electronic part of I2 by means of a vacuum-tight implementation in the sensor part.</u>

<u>In program B electrons are measured in also 16 channel with energies between 9.28 eV and 1445 eV.</u>The necessary plate voltages are generated up to 850 V with HV-cascades in the sensor area.Analyzer power supply units different for the two programs are switched by a relay inside the sensor.

The switch from one energy channel to the next higher is done in every turn of HELIOS before azimuth channel facing away from the Sun.The new value of the plate voltage is reached within the allowed tolerances in 3 ms.For the switching time program A to B downtime must be brought because of the switching time of the relay 100ms in purchase (program B is always connect to A; tele command controls only the transfer of one or the other data blocks).This means that the values in the first 4 azimuth channels in the lowest energy channel of program

| Programmteil | Kanalnummer | Kanalmitte (eV) | Kanalabstand (eV) | Spannung am Kugelanalysator (V) | Spannung am Plattenanalysator (V) |
|---|---|---|---|---|---|
| A | 1 | 0 | | 0 | 0 |
| | 2 | 0,5 | 0,5 | 0,125 | 0,294 |
| | 3 | 1 | 0,5 | 0,250 | 0,588 |
| | 4 | 1,5 | 0,5 | 0,375 | 0,882 |
| | 5 | 2 | 0,5 | 0,500 | 1,18 |
| | 6 | 2,7 | 0,7 | 0,675 | 1,59 |
| | 7 | 3,4 | 0,7 | 0,850 | 2,0 |
| | 8 | 4,1 | 0,7 | 1,03 | 2,41 |
| | 9 | 4,8 | 0,7 | 1,20 | 2,82 |
| | 10 | 4,8 | 1,0 | 1,45 | 3,41 |
| | 11 | 6,8 | 1,0 | 1,70 | 4,00 |
| | 12 | 7,8 | 1,0 | 1,95 | 4,59 |
| | 13 | 8,8 | 1,0 | 2,20 | 5,18 |
| | 14 | 10,3 | 1,5 | 2,58 | 6,06 |
| | 15 | 11,8 | 1,5 | 2,95 | 6,94 |
| | 16 | 13,3 | 1,5 | 3,33 | 7,82 |
| B | 1 | 9,28 | | 2,32 | 5,456 |
| | 2 | 13,0 | | 3,25 | 7,639 |
| | 3 | 18,2 | | 4,55 | 10,69 |
| | 4 | 25,48 | | 6,37 | 14,97 |
| | 5 | 35,67 | | 8,92 | 20,96 |
| | 6 | 49,94 | | 12,48 | 29,33 |
| | 7 | 69,92 | Faktor | 17,48 | 41,08 |
| | 8 | 97,89 | 1.4 | 24,47 | 57,50 |
| | 9 | 137,1 | | 34,26 | 80,51 |
| | 10 | 191,9 | | 47,96 | 112,7 |
| | 11 | 268,6 | | 67,15 | 157,8 |
| | 12 | 376,1 | | 94,01 | 220,9 |
| | 13 | 526,5 | | 131,6 | 309,3 |
| | 14 | 737,1 | | 184,3 | 433,0 |
| | 15 | 1032,0 | | 258,0 | 606,3 |
| | 16 | 1445,0 | | 361,2 | 848,8 |

Table 5: energy channels and plate voltages of sensor 2.
To get the real location of the channel centers by adding the half voltage on the ball Analyzer.

Programmteil = Program part
Kanalnummer = Channel Number
Kanelmitte = Channel middle
Kanalabstand = Channel spacing
Spannung am Kugelanalysator = Voltage at the ball analyser
Spannung am Plattenanalysator = Voltage on the plates analyser
Faktor = Factor

B for data analysis, particularly in continuous flow (normal-data mode), may not be used to evaluate.The ratio of the voltage on the plates analyser to the on the ball Analyzer should be nominally about 2.35.The final value was set for the respective sensor calibration and then by attaching trim resistors hardwired. The absolute values of the voltages on the capacitor of the ball are ± 1% exactly, with a maximum ripple voltage of ± 2% ss.

<u>I2 direction channels</u>

The 2 sensor is mounted in the probe so that the two plates of the first Analyzer of parallel to the equatorial plane and the ecliptic are (see Figure 11). The Analyzer on the top plate, ensuing would integrate due to its hemispherical shape about a significant azimuth angle range (unlike sensor 1B, whose integrated hemispherical about the elevation angle).To make a subdivision in single azimuth channels using the probe rotation, the passband of the hemispheres should be limited.This is done by an isolated overlapping aperture arrangement between the plates of the ball that let only an about 15 mm wide strip in the plane of the Analyzer.

There are 8 azimuth channels with 45 degrees distance and 28.1° width (or 11.2° width at HELIOS 2) they are limited with the opening time of the counter. Due to the geometry of sensor 2, the width of the elevation angle - range is designed with about 10 °, symmetrical to the equatorial plane of the probe.So, this instrument measures virtually a cut through the electron distribution.

<u>Electronics part I2 (see block diagram in Fig. 12)</u>

Instrument I2 is powered only by the electronics box with control signals which determine the programme sequence of the sensor, as well as a supply voltage 28 V directly from the main current transformer (main converter).The sensor

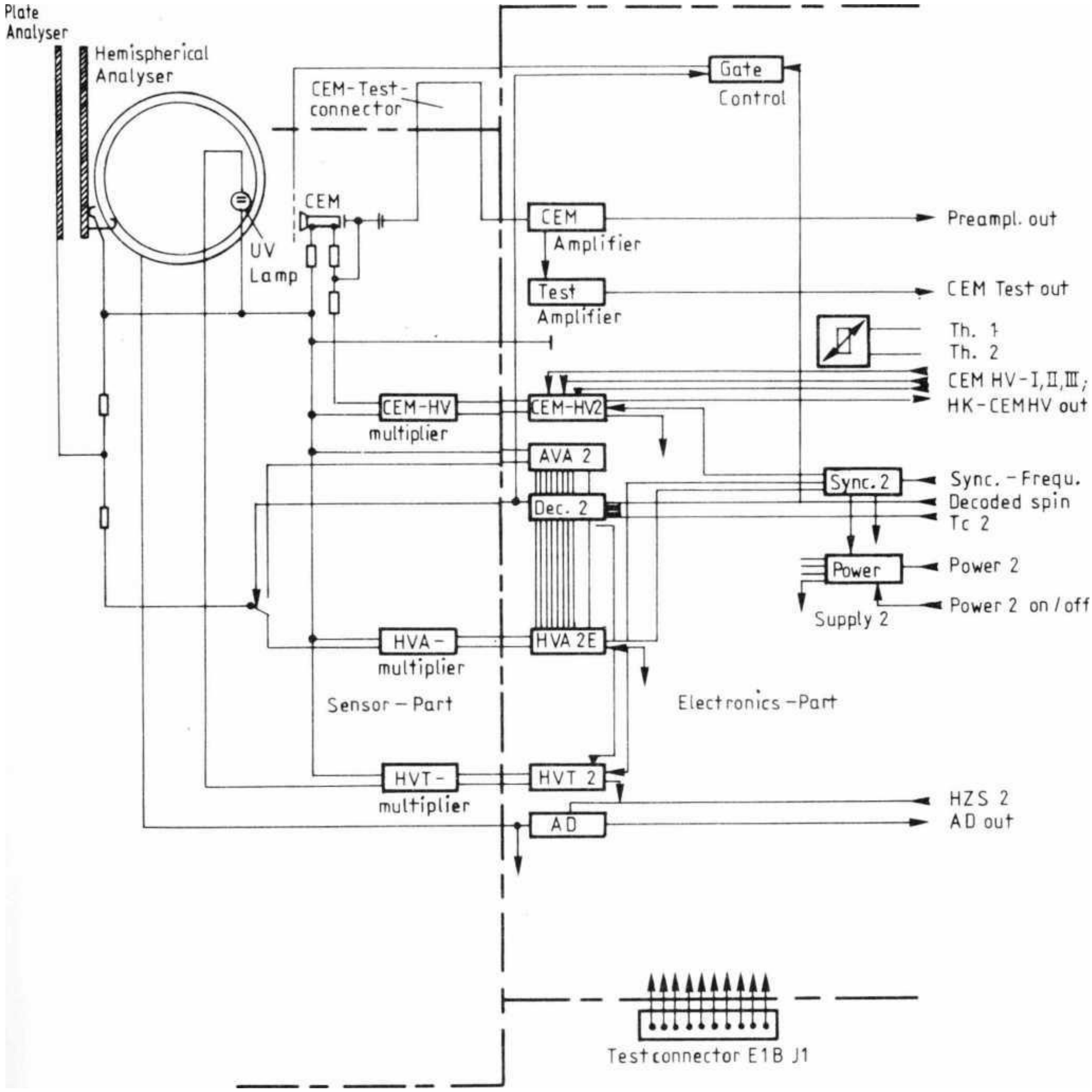



Figure 12: Instrument I2 Block diagram

electronics delivers the preamplified counting pulses to the electronics box on the registration and further processing.All electronics for assistance and control of the sensor and data processing is located with the exception of the high voltage cascade in the electronic part of the sensor box.The electronics of the sensor consists of the following units (see Figure 13):

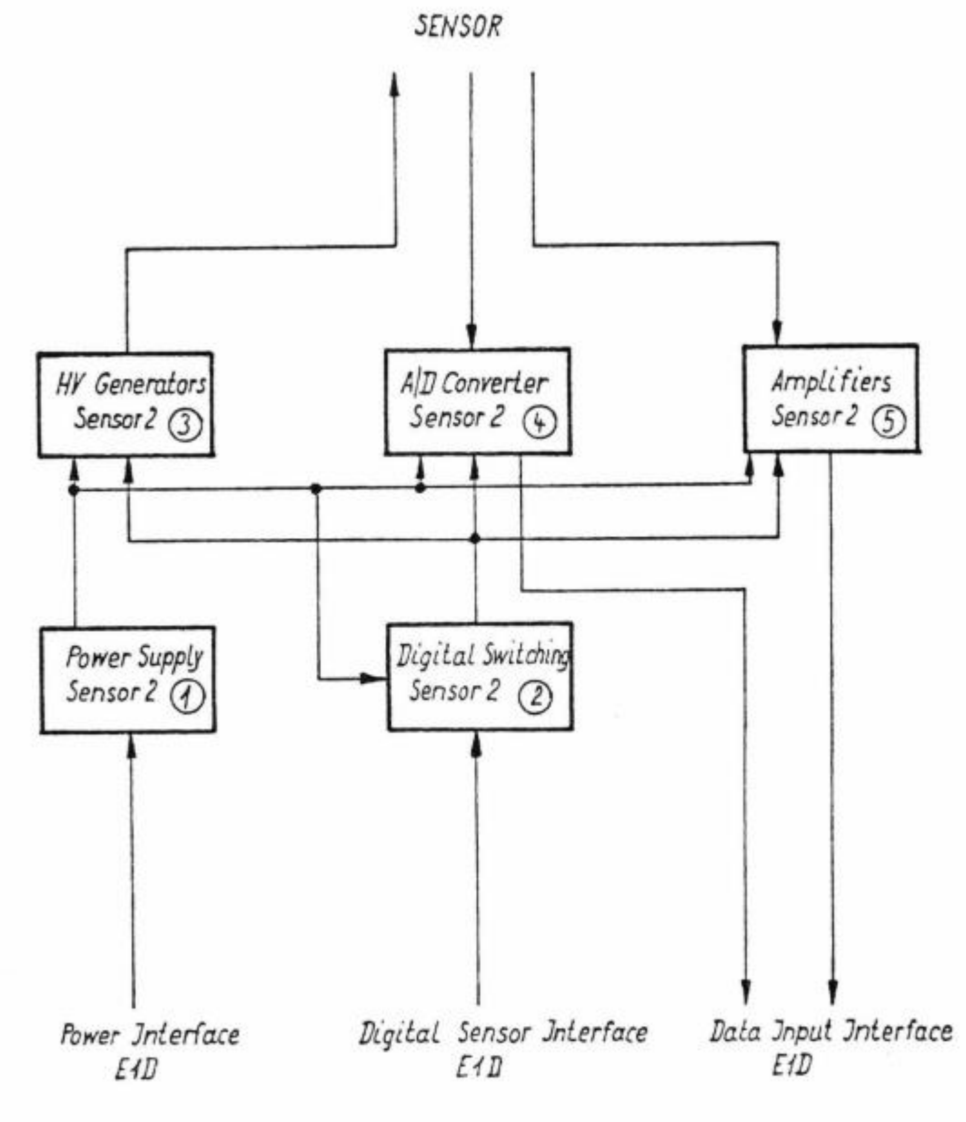



Image 13: Instrument 2 electronics part (block diagram)

- Sensor power supply (power supply)
- Channeltron amplifier unit (amplifiers)
- Analyzer voltage generation, power generation for UV Glow lamp and Channeltron supply voltage generation (HV-generator)
- Analog - to-digital converters (A/D-converter)
- Digital control unit (digital switching)

The Sensor power supply produces all the operation of the electronics required voltages lent.It is activated and deactivated using the appropriate command.The Channeltron amplifier unit consists of a Channeltron-amplifier, which amplifies the impulses emitted by the Channeltron and is in processable form; also from a second such amplifiers with a higher "threshold".This amplifier is used during the Infiight test to verify the adequate reinforcement of channeltrons; As long as the count rates of two amplifiers around are equal and independent of the height of the threshold, the reinforcement of the channeltrons is sufficient.

The Analyzer voltage generation consists of two parts.One part is the production of low voltage of the program part of A and presents itself as gradually switchable reference voltage source; the other part to the generation of the Analyzer voltages of program part B is a gradually switchable high-voltage generator with very little input and decay time constant.The high voltage generator for the UV glow lamp is used only during the Infiight test and supplied the necessary ignition and ARC voltage the lamp.The electronics for the production of Channeltron supply voltage is a controlled high-voltage generator that works with a twelve-stage multiplier cascade.He is on/off and has three power settings for three different output voltages (3,3 kV, 3.7 kV, 4.1 kV).

The analog - to-digital converter is used to convert analog voltages to digitally processed readings and is used only for checking the Analyzer voltage during the Infiight test.

The digital control unit prepares the program control signals from electronics box, decodes the energy channel counter State and controls accordingly both Analyzer power generations.

Instrument I3 (in box E1C)

The energy and direction of distributions of different ions in the solar wind should be measured with this instrument separately.
An angle-resolved, electrodynamic particle path Analyzer is used for the analysis.It consists of two circular segment plates, which are nearly cosine-shaped wavy along the RADIUS (see Figure 14).By applying an electrical alternating voltage manages to separate positively charged particles speed and mass per charge.

Analyzer part I3

The exact shape of the Analyzer plates was calculated on the basis of the following considerations:

The equation of motion for a particle with mass m, charge q and the velocity $\vec{w}$ in an electric field $\vec{E}$ is

$$q \cdot \vec{E} = m \cdot \vec{w}$$

In a narrow channel of the vector of the electric field with good approximation is vertical on the vector of speed, i.e.

$$\vec{E} \cdot \vec{w} = 0$$

This condition is met, if $\vec{w}$ and $\vec{E}$ in component display have the following form

$$\vec{w} = \{u, v\}$$

$$\vec{E} = \{v, -u\} \frac{E}{w}$$

E is an alternating field with the angular frequency $\omega$

$$E = E_0 \cdot cos\omega t$$

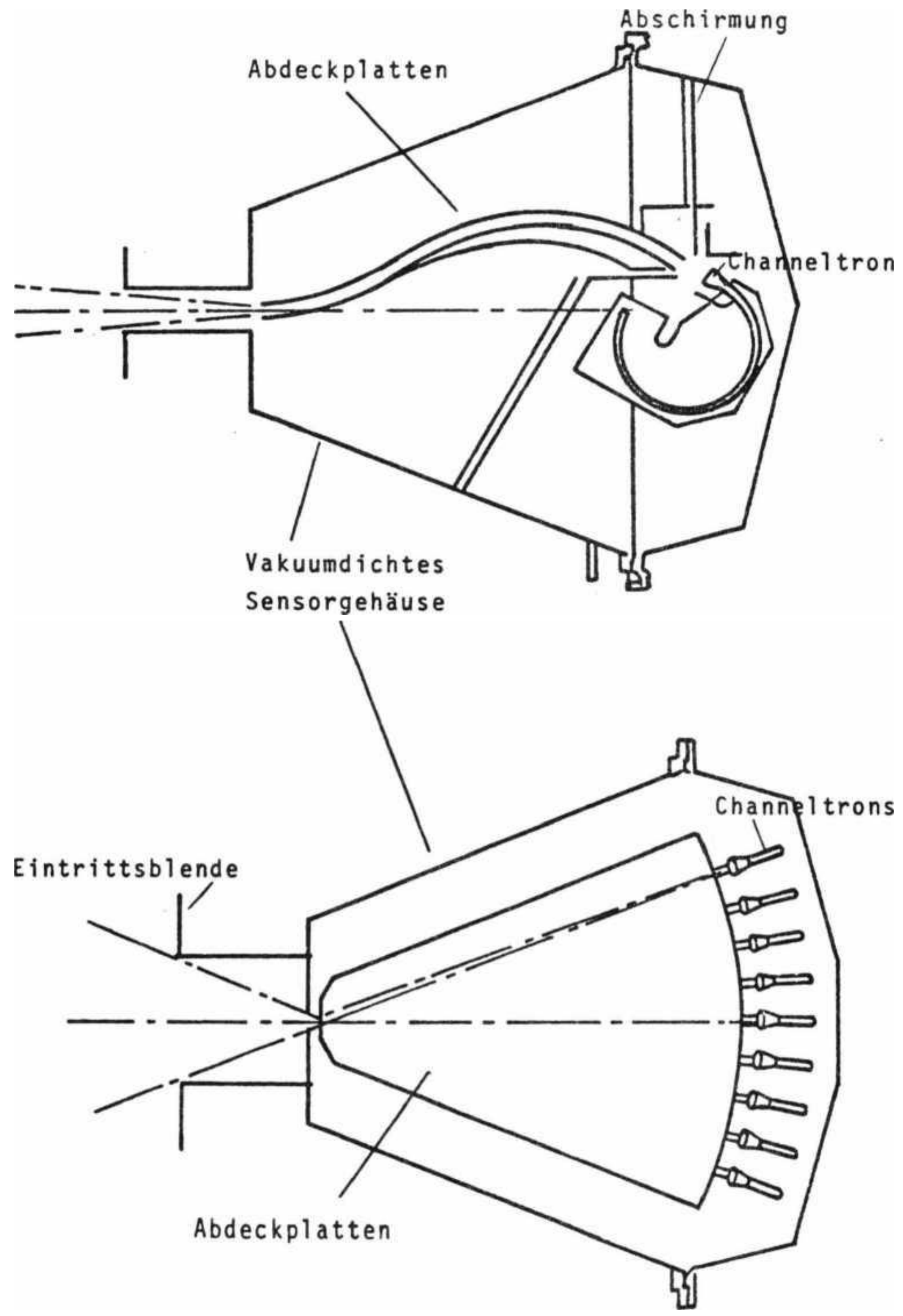



Image 14: Instrument 3 Function image

Abschirmung = Shielding
Abdeckplatten = Cover plates
Vakuumdichtes = Vacuum-tight
Sensorgehäuse = Sensor housing
Eintrittsblende = Entrance aperture

The components of the motion equation is then

$$u = \frac{q}{m} \cdot \frac{v}{w} E_0 cos(\omega t + \phi)$$

$$\boldsymbol{v} = -\frac{\boldsymbol{q}}{\boldsymbol{m}} \cdot \frac{\boldsymbol{u}}{\boldsymbol{w}} \boldsymbol{E_0} \mathbf{cos}(\boldsymbol{\omega t} + \boldsymbol{\phi})$$

with $\phi$ is a possible phase shift of the particle oppposite to the electrical field.

Along with the differential equations for the location coordinates

$$\dot{x} = u \text{ and } \dot{y} = v$$

It has a system of four differential equations 1.All right, this method was solved numerically with the Runge-Kutta.
From the variety of solutions of this system, a solution was selected mainly practical according to the realization in the instrument.This curve was at the same distance of 2 mm with deflection plates "cased".We opted for a period length L of $\frac{3}{2}\pi$ with a total path length S through the Analyzer of 133.4 mm. Parallel curves in this rotation by an angle of 45 ° about an axis through the channel entrance creates a pair of surfaces.At the outlet edge of this plate 9 channeltrons are fitted with the angular distance of the 5 °, allowing a determination of particle direction of incidence regarding the elevation, such as when I1a.Also the subdivision in azimuth channels are just like at I1a.

For a particle with the speed w (based on a full period length $2\pi$) to occur the Analyzer with the length L, it so to speak 'in time' must the electric voltage (frequency $f = \omega/2\pi$), i.e.

$$w = f \cdot L$$

If the amplitude $U_m$ thereby obeys still the condition

$$U_m = \frac{m}{q} \cdot \omega^2 \cdot A \cdot d$$

j

(A is the half amplitude, d the plate distance of the Analyzer, both in cm), can only particles with a fixed mass per charge-value m/q in this speed w just get through.Of course there are many particles that do meet these conditions all but arrive at the wrong time on the Analyzer, i.e.so out of phase with the AC voltage.This restriction leads to the mentioned reduction of sensitivity of I3 to I1a by approximately a factor of 30, despite the slightly larger inlet.

In particular, the following values were chosen:

A = 1.5 cm d = 0.2 cm
S = 13.34 cm for $\frac{3}{2}\pi$ period length.

Measurement Channels I3

The frequency of the plate voltage is switched from turn to turn in 16 steps of 1,058 MHz to 4,088 MHz high.This corresponds to particle velocities from 199 to 769 km $s^{-1}$ (see table 6).Here she is Amplitude between 10,15 and 256,05 V is so varied, so that M/q values of 1 (Proton) up to 5.3 ($^{16}O^{3+}$) can be recorded (see table 7).The You can extract the values of the plate voltages for each combination of speed and mass per charge table 8.In the lower part, some values are specially marked.At high frequencies because the voltages required for large M/q values can not be realized for performance reasons. That’s why the voltage that is outside the marked limits or the M/q value is kept for an appropriate period of time. In the M/q-channel 16, the voltage is set to zero.

Frequencies and voltages be adhered to ± 1%.

The angular resolution in elevation and azimuth is completely analogous to sensor 1a.

| Kanal-Nr. | Geschwindigkeit (km/sec) | Frequenz (MHZ) |
|---|---|---|
| 1 | 198,9 | 1,058 |
| 2 | 217,5 | 1,157 |
| 3 | 238,0 | 1,206 |
| 4 | 260,6 | 1,386 |
| 5 | 286,2 | 1,517 |
| 6 | 312,1 | 1,660 |
| 7 | 341,6 | 1,817 |
| 8 | 373,8 | 1,988 |
| 9 | 409,1 | 2,176 |
| 10 | 447,7 | 2,381 |
| 11 | 489,8 | 2,605 |
| 12 | 536,0 | 2,851 |
| 13 | 586,6 | 3,120 |
| 14 | 641,9 | 3,414 |
| 15 | 702,4 | 3,736 |
| 16 | 768,6 | 4,088 |

Table 6: speed channels and corresponding frequencies of Analyzer voltages in instrument I3.

Geschwindigkeit = speed

| Kanal-Nr. | Ionenart | m/q |
|---|---|---|
| 1 | $^{4}He^{2+}$ | 2,00 |
| 2 | $^{3}He^{2+}$ | 1,50 |
| 3 | $^{1}H^{+}$ | 1,00 |
| 4 | | 1,35 |
| 5 | | 1,65 |
| 6 | $^{12}C^{5+}$ | 2,40 |
| 7 | $^{16}O^{6+}$ | 2,62 |
| 8 | | 3,00 |
| 9 | $^{16}O^{5+}$ | 3,20 |
| 10 | $^{14}N^{4+}$ | 3,50 |
| 11 | $^{16}O^{4+}$ | 4,00 |
| 12 | | 4,40 |
| 13 | $^{14}N^{3+}$ | 4,66 |
| 14 | | 4,90 |
| 15 | $^{16}O^{3+}$ | 5,33 |
| 16 | | 0 |

Table 7: m/q channels instrument I3.

Ionenart = ion

| M/q-Kanal | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atom | | He | He | H | - | - | C | 0 | He | 0 | N | 0 | - | N | - | 0 |
| Masse M | | 4.0026 | 3.0160 | 1.0078 | 1.3505 | 1.6505 | 12.0000 | 15.9949 | 3.0160 | 15.9949 | 14.0031 | 15.9949 | 4.4005 | 14.0031 | 4.9005 | 15.9949 |
| Ladung q | | 2 | 2 | 1 | 1 | 1 | 5 | 6 | 1 | 5 | 4 | 4 | 1 | 3 | 1 | 3 |
| M/q | | 2.0013 | 1.508 | 1.0078 | 1.3505 | 1.6505 | 2.4000 | 2.6658 | 3.0160 | 3.1990 | 3.5008 | 3.9987 | 4.4005 | 4.6677 | 4.9005 | 5.3316 |
| f [MHz] | v [$kms^{-1}$] | | | | | | | | | | | | | | | |
| 1.058 | 198.9 | 20.16 | 15.19 | 10.15 | 13.60 | 16.62 | 24.17 | 26.85 | 30.38 | 32.22 | 35.26 | 40.28 | 44.33 | 47.02 | 49.36 | 53.70 |
| 1.157 | 217.5 | 24.10 | 18.16 | 12.14 | 16.26 | 19.88 | 28.91 | 32.11 | 36.33 | 38.53 | 42.17 | 48.17 | 53.01 | 56.23 | 59.03 | 64.23 |
| 1.266 | 238.0 | 28.86 | 21.74 | 14.53 | 19.47 | 23.80 | 34.61 | 38.44 | 43.50 | 46.14 | 50.49 | 57.67 | 63.47 | 67.32 | 70.68 | 76.90 |
| 1.386 | 260.6 | 34.59 | 26.06 | 17.41 | 23.34 | 28.53 | 41.48 | 46.08 | 52.13 | 55.30 | 60.51 | 69.12 | 76.07 | 80.69 | 84.71 | 92.17 |
| 1.517 | 285.2 | 41.44 | 31.22 | 20.86 | 27.96 | 34.17 | 49.69 | 55.20 | 62.45 | 66.24 | 72.49 | 82.81 | 91.13 | 96.66 | 101.48 | 110.41 |
| 1.660 | 312.1 | 49.62 | 37.38 | 24.98 | 33.48 | 40.92 | 59.51 | 66.10 | 74.78 | 79.32 | 86.80 | 99.15 | 109.12 | 115.74 | 121.52 | 132.21 |
| 1.817 | 341.6 | 59.45 | 44.79 | 29.93 | 40.11 | 49.03 | 71.29 | 79.19 | 89.60 | 95.03 | 104.00 | 118.80 | 130.73 | 138.67 | 145.59 | 158.40 |
| 1.988 | 373.8 | 71.16 | 53.62 | 35.83 | 48.02 | 58.69 | 85.34 | 94.80 | 107.25 | 113.76 | 124.50 | 142.21 | 156.50 | 166.00 | 174.28 | 189.62 |
| 2.176 | 409.1 | 85.26 | 64.24 | 42.92 | 57.53 | 70.31 | 102.25 | 113.58 | 128.50 | 136.30 | 149.16 | 170.38 | 187.50 | 198.88 | 208.81 | 208.81 |
| 2.881 | 447.7 | 102.08 | 76.91 | 51.39 | 68.88 | 84.18 | 122.42 | 135.98 | 153.85 | 163.19 | 178.58 | 203.99 | 224.49 | 238.12 | 250.00 | 250.00 |
| 2.605 | 489.8 | 122.19 | 92.06 | 61.52 | 82.45 | 100.77 | 146.54 | 162.77 | 184.16 | 195.34 | 213.77 | 213.77 | 213.77 | 213.77 | 213.77 | 213.77 |
| 2.851 | 536.0 | 146.36 | 110.27 | 73.68 | 98.75 | 120.70 | 175.52 | 194.97 | 220.59 | 233.97 | 256.05 | 256.05 | 256.05 | 256.05 | 256.05 | 256.05 |
| 3.120 | 586.6 | 175.28 | 132.06 | 88.24 | 118.27 | 144.55 | 210.21 | 233.49 | 233.49 | 233.49 | 233.49 | 233.49 | 233.49 | 233.49 | 233.49 | 233.49 |
| 3.414 | 641.9 | 209.87 | 158.13 | 105.66 | 141.61 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 | 173.08 |
| 3.736 | 702.4 | 251.32 | 189.36 | 126.53 | 169.58 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 | 207.26 |
| 4.088 | 768.6 | 226.72 | 226.72 | 151.49 | 203.04 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 | 248.16 |

Table 8: speed and m/q-channels as the analyser voltages (in $V/_{eff}$) and frequencies (in MHz).At high frequencies, not all m/q channels can be passed through from performance reasons.Here, standing outside the marked areas each m/q value is then persisted.In the m/q-channel 16, the voltage is reset to zero.



r

Ladung = charge

Stimulation in Infiight test

A UV glow lamp, helps to stimulate the channeltrons Infiight test It is mounted near the Channeltron funnel, so that it illuminates all channeltrons accordingly.His intensity is so that meaningful count rates arise.

Electronics part I3 (see block diagram fig. 15)

Instrument I3 is supplied by the electronics box with control signals, and a voltage of 28 V direct from the main current transformer (main converter) to determine program flow.The sensor electronics delivers the preamplified counting pulses on the electronics box for the registration, evaluation, and storage.All electronics to the care and control of the instrument, as well as for data processing is located with the exception of the high voltage cascade in the electronic part of the sensor box.The electronics of the sensor consists of the following units (see Figure 16):

- Sensor power supply (power supply)
- Channeltron amplifier unit (amplifiers)
- Power generation for UV glow lamp and Channeltron - supply generation (HV generator)
- Analog - to-digital converters (A/D-converter)
- Digital control unit (digital switching)
- High frequency generator to the plate voltage generation (RF power generator) with decoding device (digital control unit)

The sensor power supply generates all voltages required for the operation of the electronics.It is activated and deactivated using the appropriate command.The Channeltron amplifier unit consists of 9 Channeltron amplifiers core, which reinforce the emitted pulses given by the channeltrons and leave in the processable form. Furthermore, this unit also includes a so called CCO (current controlled oscillator), that quantises the charge given by the individual channeltrons during the in-flight tests and thus permits a determination of the instantaneous amplification of channeltrons.

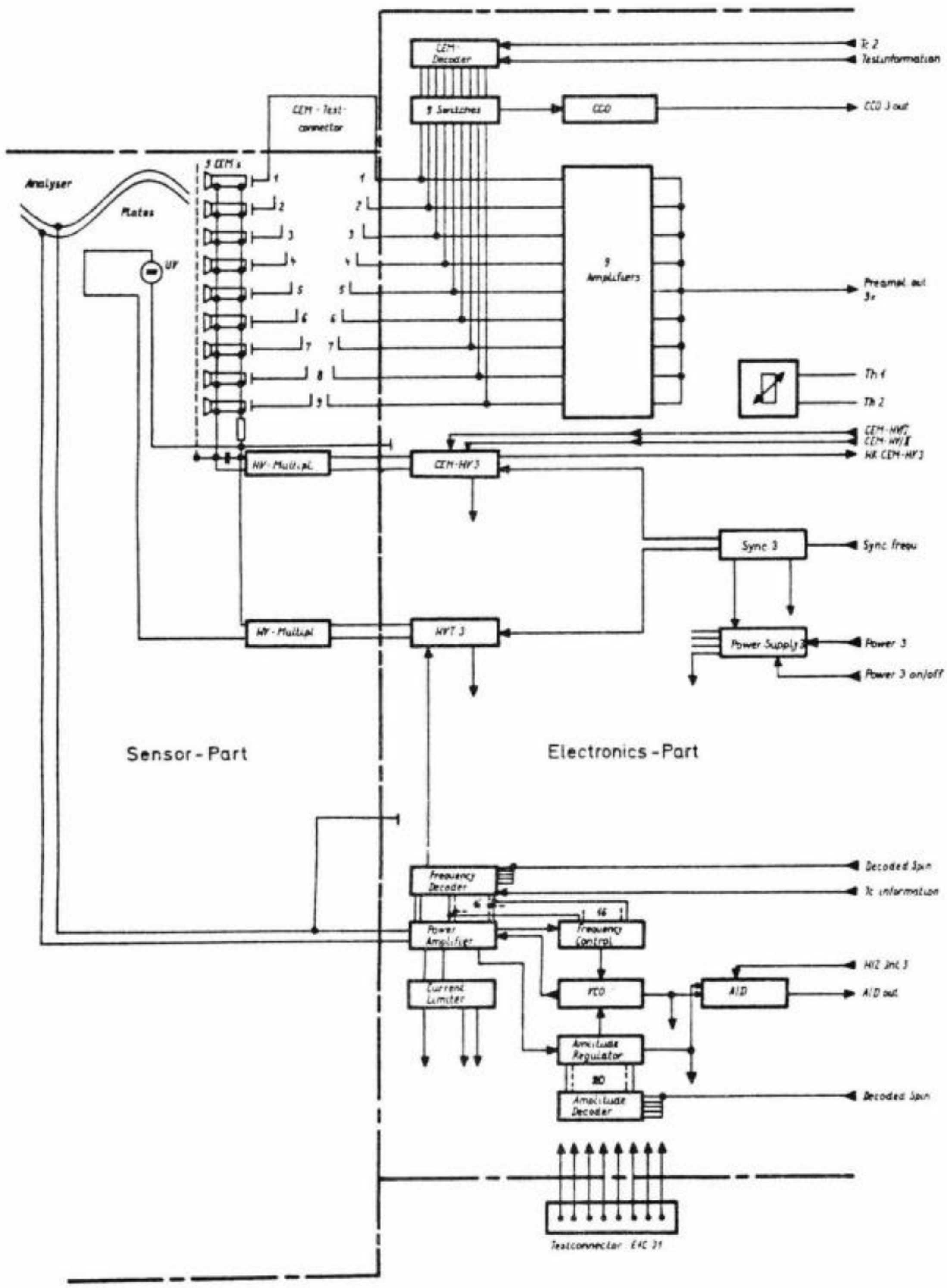



Image 15 Instrument I3 Block diagram

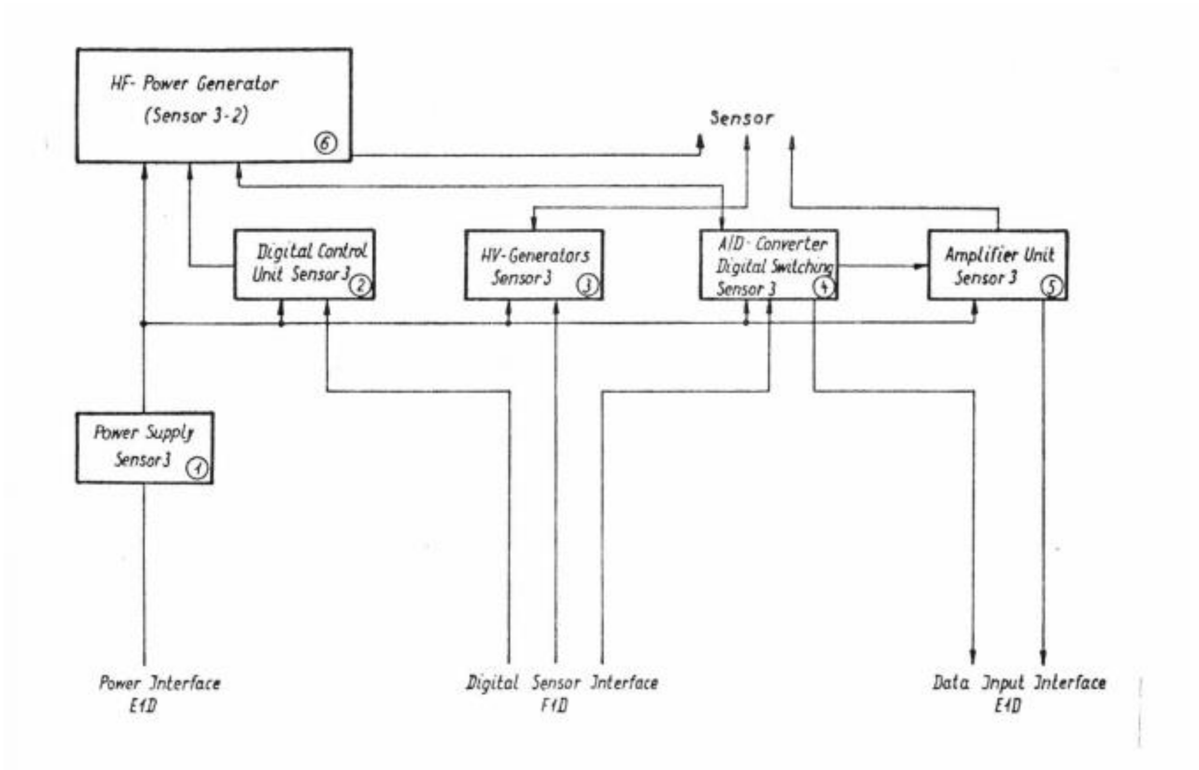



Figure 16: Instrument I3, electronics block diagram

The high voltage generator for the UV glow lamp is used only during the Infiight test and supplied the necessary ignition and ARC voltage the lamp.
The electronics for the production of Channeltron supply voltage is a controlled high-voltage generator that works with a twelve-stage multiplier cascade.He is on and off and has three power settings for three different output voltages (3,3 kV, 3.7 kV; 4.1 kV).

The analog - to-digital converter is used to convert analog voltages to digitally processed readings and is used only for checking the amplitude of the high frequency voltage during flight test.

The digital control unit is greatly simplified compared to sensor 1a for this sensor.She assumes here only control the selection of channeltrons which is switched during flight test on the CCO.
The Analyzer voltages and frequencies is a separate decoding device, which works directly with the frequency generator here (as much more complicated).The high-frequency generator (fig. 17) for producing the plates voltage works as

a resonant circuit, with the capacity of the panels together with stray capacity and a coil forming the circle.The resonance frequency is designed to realize the highest frequency, so the F16.The other lower frequencies are matched this that the capacity of the disk capacity are connected in parallel.At the same time, the control frequency of 16 of course appear voltage-controlled oscillators according to.This control frequency will be adjusted via a control loop of the resonance frequency of the amplifier.The output amplitude of high-frequency voltage is set by a reference generator (DC) and compared with the rectified output voltage in a comparison circuit, and adjusted by means of a control circuit.Selecting the frequency and the desired voltage is performed by the above mentioned decode body that selects the desired channel affiliations from the information supplied by the electronics box.

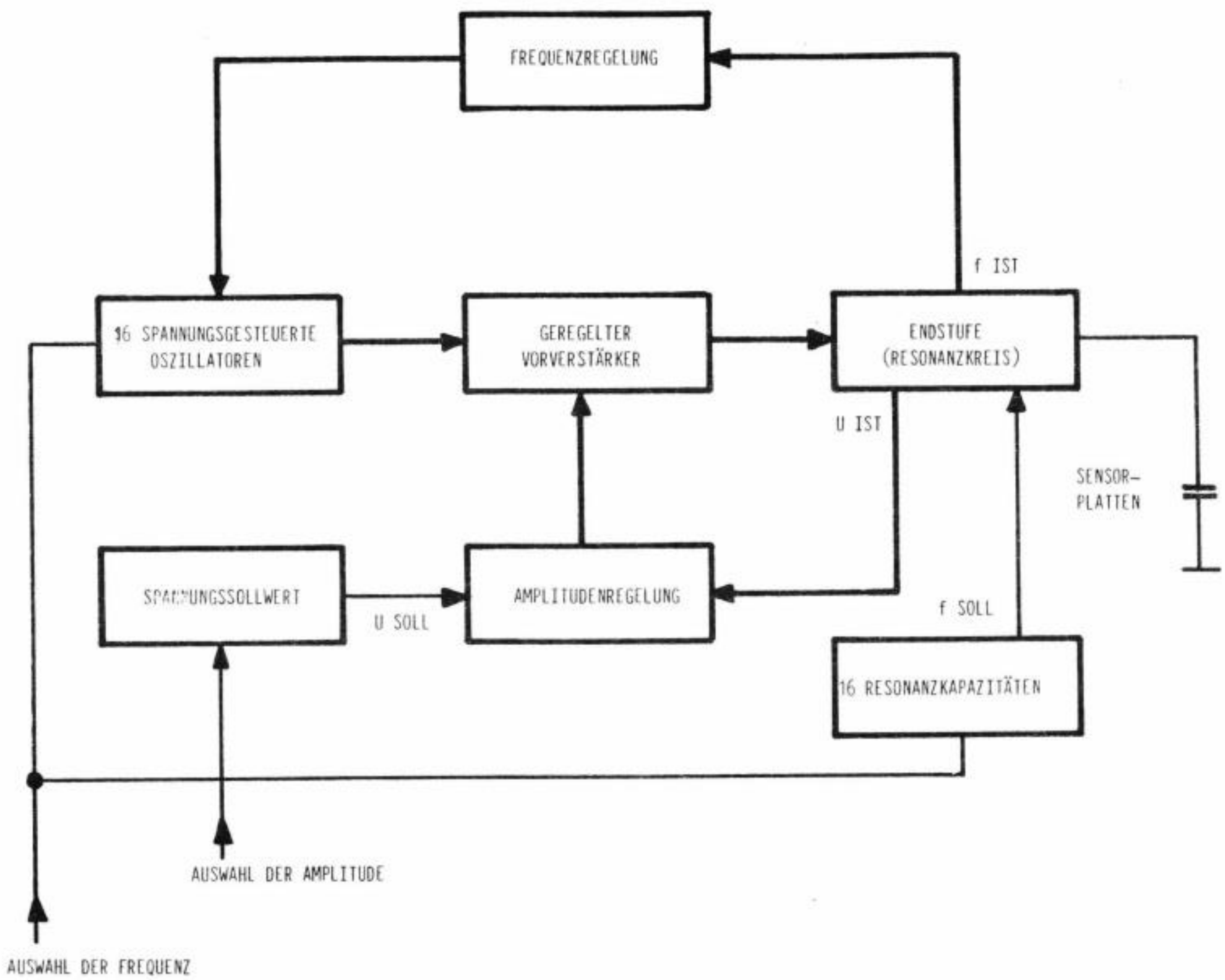



Figure 17: high frequency generator (principle) for instrument I3

Frequenzregelung = frequency control
Spannungsgesteuerte = voltage controlled
Geregelter Vorverstärker =Regulated preamp
Endstufe (Resonanzkreis) = Amplifier (resonant circuit)
Spannungssollwert = Voltage setpoint
Amplitudenregelung = amplitude control
Resonanzkapazitäten = resonance capacitances
Auswahl = selection

<u>Electronics box (in box E1D)</u>

The units of the electronics box have the following main tasks:

- Power supply of the four sensors
- Power supply of units of the electronics box
- Processing of the data from the sensors
- Save the selected data
- Transfer the stored data to the telemetry
- Production of the measurement time grid (spin-synchronous)
- Generation of the signals to control flow and program control of the sensors
- Processing of the tele-commands
- Transfer of housekeeping data, temperatures.

As can be seen from images 18 and 19, run the counting pulses from the sensors via a corresponding switching logic in one of the two redundant digital electronics units.The pulses are counted in the applicable associated counters.The control unit of the counter, i.e.the formation of the corresponding azimuth angle is worried by the control flow.

The Azimuthal measuring ranges of all instruments are specified in tables 9 and 10.HELIOS 2 differs in several respects from HELIOS 1:

- HELIOS 2 is "on its head", i.e.the spin vector is facing South therefore the direction of E1 in HELIOS 2 from East to West over the Sun swings, just vice versa like in HELIOS 1.
- The location of the middle of the ranges is different (different "suspension").
- At HELIOS 2, the suspension can be moved through a tele command 7.03 degrees.
- The width of the Azimut channels of I2 is only 11.25° at HELIOS 2, instead of 28.1° at HELIOS 1.
- The shift of the I2 channels in each 2nd Range of HELIOS 2 is 22.5 °.As a result, two consecutive measurements form a grid of 16-equidistant channel.

The flow of control also ensures the temporally coordinated readout of the counter and the transfer of data to the reducing plant.After the

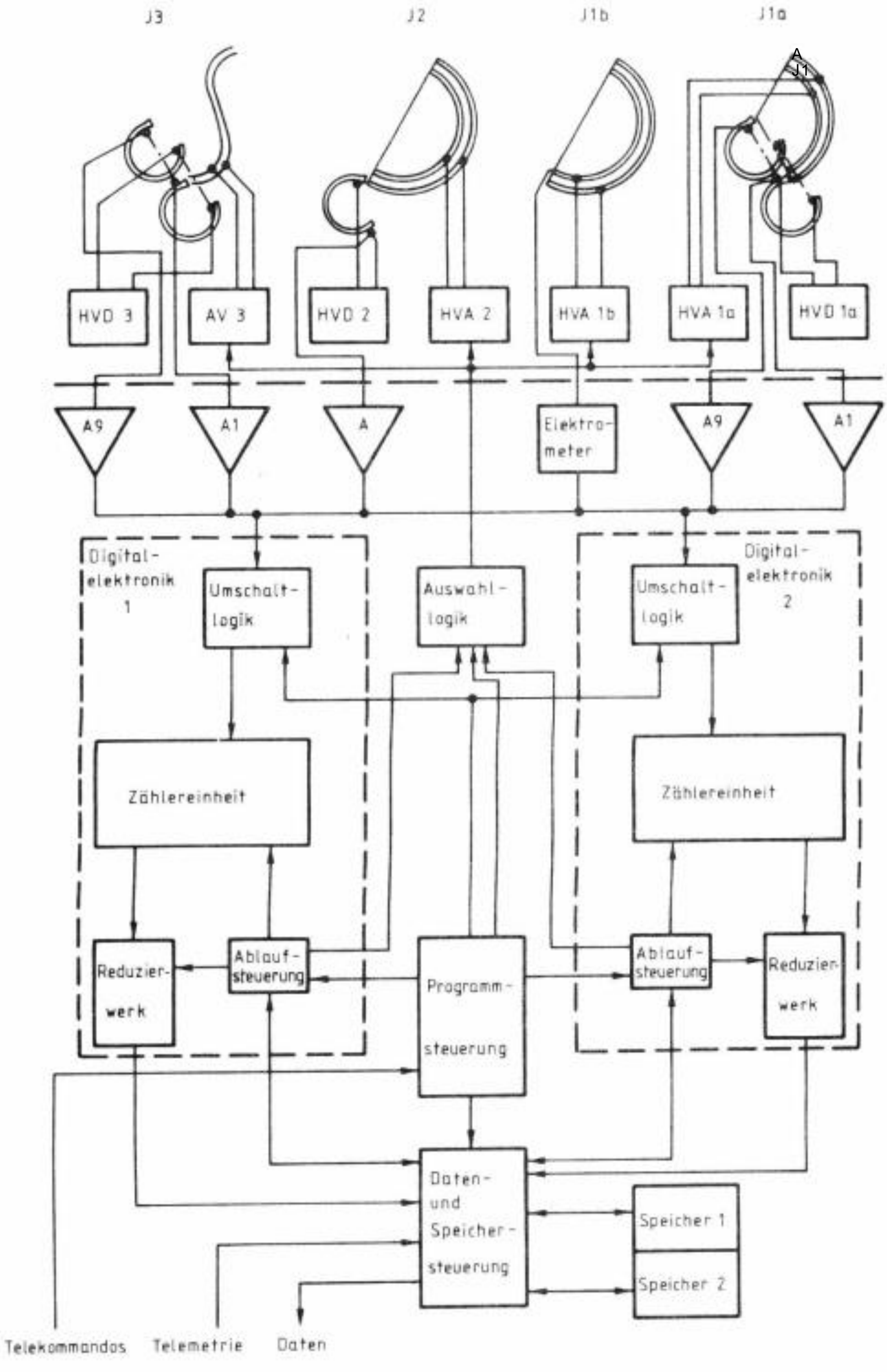



Figure 18: Electronics box, function diagram

Digitalelektronik = Digital Electronics
Umschaltlogik = switching logic
Auswahllogik = selection logic
Zählereinheit = counter unit
Reduzier-werk = Reducing plant
Ablaufsteuerung = flow control
Programmsteuerung = program control
Daten- und Speichersteuerung = Data and storage control
Speicher = memory

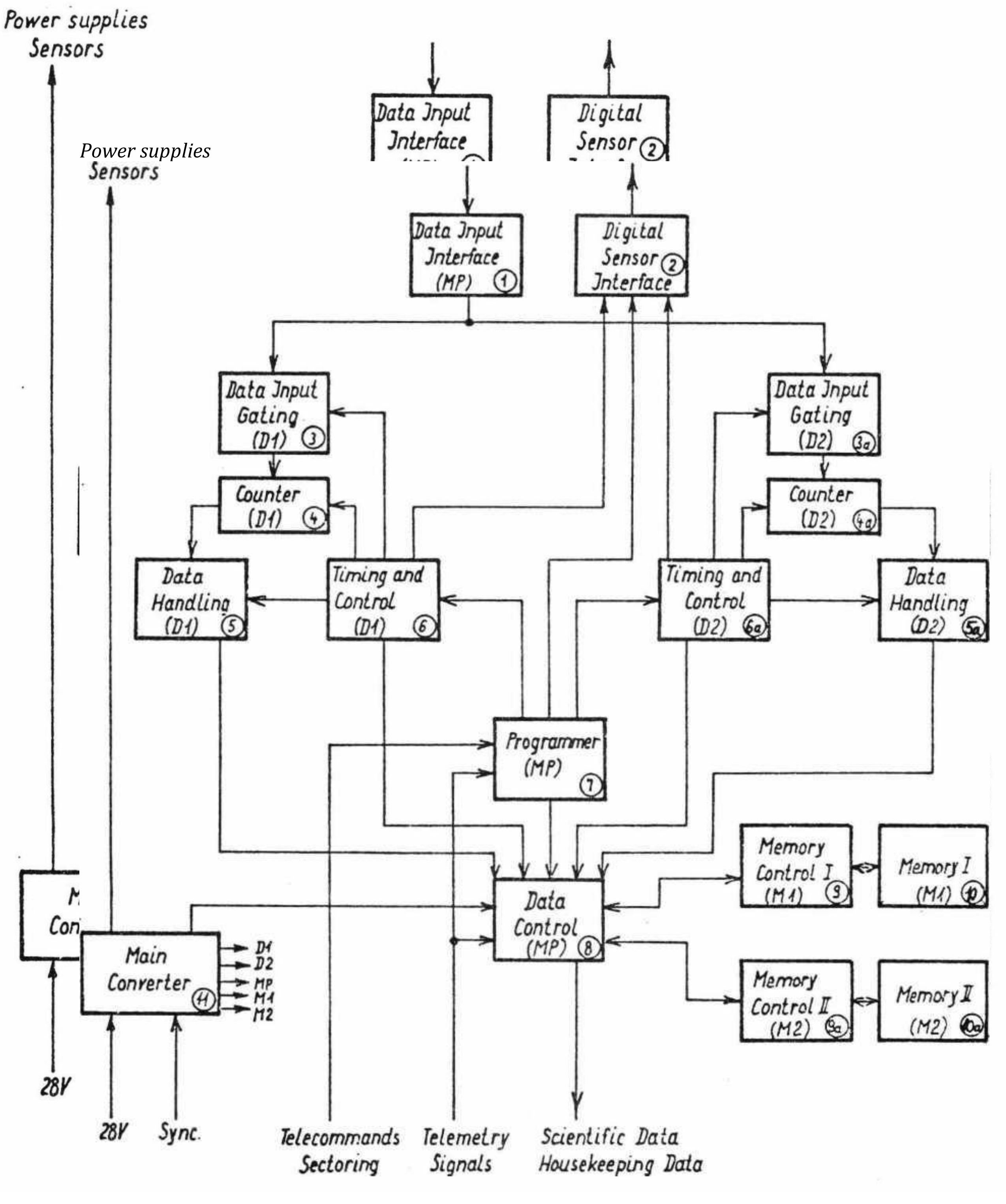



Figure 19: electronic box, block diagram

| SENSOR | MESSWINKEL | OHNE VERSCHIEBUNG | | MIT VERSCHIEBUNG | |
|---|---|---|---|---|---|
| | | ANFANG | ENDE | ANFANG | ENDE |
| Sensor 1a und Sensor 3 | 1. Azimut | $-56{,}36^0$ | $-52{,}84^0$ | $-53{,}55^0$ | $-50{,}03^0$ |
| | 2. Azimut | $-50{,}74^0$ | $-47{,}22^0$ | $-47{,}93^0$ | $-44{,}41^0$ |
| | 3. Azimut | $-45{,}12^0$ | $-41{,}60^0$ | $-42.31^0$ | $-38{,}79^0$ |
| | 4. Azimut | $-39{,}50^0$ | $-35{,}98^0$ | $-36{,}69^0$ | $-33{,}17^0$ |
| | 5. Azimut | $-33{,}88^0$ | $-30{,}36^0$ | $-31{,}07^0$ | $-27{,}55^0$ |
| | 6. Azimut | $-28{,}26^0$ | $-24{,}74^0$ | $-25{,}45^0$ | $-21{,}93^0$ |
| | 7. Azimut | $-22{,}64^0$ | $-19{,}12^0$ | $-19{,}83^0$ | $-16{,}31^0$ |
| | 8. Azimut | $-17{,}02^0$ | $-13{,}50^0$ | $-14{,}21^0$ | $-10{,}69^0$ |
| | 9. Azimut | $-11{,}40^0$ | $-7{,}88^0$ | $-8{,}59^0$ | $-5{,}07^0$ |
| | 10. Azimut | $-5{,}78^0$ | $-2{,}26^0$ | $-2{,}97^0$ | $+0{,}55^0$ |
| | 11. Azimut | $0{,}00^0$ | $+2{,}81^0$ | $+3{,}51^0$ | $+6{,}32^0$ |
| | 12. Azimut | $+5{,}62^0$ | $+9{,}13^0$ | $+8{,}43^0$ | $+11{,}94^0$ |
| | 13. Azimut | $+11{,}24^0$ | $+14{,}75^0$ | $+14{,}05^0$ | $+17{,}56^0$ |
| | 14. Azimut | $+16{,}86^0$ | $+20{,}37^0$ | $+19{,}67^0$ | $+23{,}18^0$ |
| | 15. Azimut | $+22{,}48^0$ | $+25{,}99^0$ | $+25{,}29^0$ | $+28{,}80^0$ |
| | 16. Azimut | $+28{,}10^0$ | $+31{,}61^0$ | $+30{,}91^0$ | $+34{,}42^0$ |
| Integrations-Zähler | Öffnungszeit ist identisch mit AZ 1 bis AZ 16 | $-56{,}36^0$ | $+31{,}61^0$ | $-53{,}55^0$ | $+34{,}42^0$ |
| Sensor 1b | Meßphase | $-56{,}36^0$ | $+137{,}54^0$ | $-53{,}55^0$ | $+140{,}35^0$ |
| | Nullp. korr. | $-87{,}27^0$ | $-84{,}46^0$ | $-84{,}46^0$ | $-81{,}65^0$ |
| Sensor 2 | 1. Azimut | $+154{,}40^0$ | $-177{,}19^0$ | $+157{,}21^0$ | $-174{,}38^0$ |
| | 2. Azimut | $-160{,}33^0$ | $-132{,}23^0$ | $-157{,}52^0$ | $-129{,}42^0$ |
| | 3. Azimut | $-115{,}37^0$ | $-87{,}27^0$ | $-112{,}56^0$ | $-84{,}46^0$ |
| | 4. Azimut | $-70{,}41^0$ | $-42{,}31^0$ | $-67{,}60^0$ | $-39{,}50^0$ |
| | 5. Azimut | $-25{,}45^0$ | $+2{,}65^0$ | $-22{,}64^0$ | $+5{,}62^0$ |
| | 6. Azimut | $+19{,}67^0$ | $+47{,}77^0$ | $+22{,}48^0$ | $+50{,}58^0$ |
| | 7. Azimut | $+64{,}63^0$ | $+92{,}73^0$ | $+67{,}44^0$ | $+95{,}54^0$ |
| | 8. Azimut | $+109{,}59^0$ | $+137{,}69^0$ | $+112{,}40^0$ | $+140{,}50^0$ |

Table 9: Azimuthal angle of sensors for F1, in relation to the HELIOS-Sun line. Negative sign refer to <u>Western</u> directions.The order of the channels is equivalent to the rotation of HELIOS 1 from West to East, i.e.<u>against</u> the clockwise direction when viewed from the North.

Messwinkel = measuring angle
Ohne verschiebung = Without shift
Mit verschiebung = with shift
Anfang = Beginning
Integrations-Zähler = Integrations counter

| SENSOR | MESSWINKEL | KEIN VORHALT | | | |
|---|---|---|---|---|---|
| | | OHNE VERSCHIEBUNG | | MIT VERSCHIEBUNG | |
| | | ANFANG | ENDE | ANFANG | ENDE |
| Sensor 1a und Sensor 3 | 1. Azimut | − 40,78° | − 37,26° | − 43,59° | − 40,07° |
| | 2. Azimut | − 35,16° | − 31,64° | − 37,97° | − 34,45° |
| | 3. Azimut | − 29,53° | − 26,01° | − 32,34° | − 28,82° |
| | 4. Azimut | − 23,91° | − 20,38° | − 26,72° | − 23,20° |
| | 5. Azimut | − 18,29° | − 14,77° | − 21,10° | − 17,58° |
| | 6. Azimut | − 12,67° | − 9,15° | − 15,48° | − 11,96° |
| | 7. Azimut | − 7,05° | − 3,53° | − 9,86° | − 6,34° |
| | 8. Azimut | − 1,43° | + 2,09° | − 4,24° | − 0,72° |
| | 9. Azimut | + 4,19° | + 7,71° | + 1,38° | + 4,90° |
| | 10. Azimut | + 9,81° | + 13,33° | + 7,00° | + 10,52° |
| | 11. Azimut | + 15,43° | + 18,95° | + 12,62° | + 16,14° |
| | 12. Azimut | + 21,05° | + 24,57° | + 18,24° | + 21,76° |
| | 13. Azimut | + 26,67° | + 30,19° | + 23,86° | + 27,38° |
| | 14. Azimut | + 32,29° | + 35,81° | + 29,48° | + 33,00° |
| | 15. Azimut | + 37,91° | + 41,43° | + 35,10° | + 38,62° |
| | 16. Azimut | + 43,53° | + 47,05° | + 40,72° | + 44,24° |
| Integrations-Zähler | Öffnungszeit ist identisch mit AZ 1 bis AZ 16 | − 40,78° | + 47,05° | − 43,59° | + 44,24° |
| Sensor 1b | Meßphase | − 40,78° | + 153,28° | − 43,59° | + 150,47° |
| | Nullp. korr. | − 68,20° | − 65,38° | − 71,00° | − 68,20° |
| Sensor 2 | 1. Azimut | − 172,97° | − 161,72° | + 164,53° | + 175,78° |
| | 2. Azimut | − 127,97° | − 116,72° | − 150,47° | − 139,22° |
| | 3. Azimut | − 82,97° | − 71,72° | − 105,47° | − 94,22° |
| | 4. Azimut | − 37,97° | − 26,72° | − 60,47° | − 49,22° |
| | 5. Azimut | + 7,03° | + 18,28° | − 15,47° | − 4,22° |
| | 6. Azimut | + 52,03° | + 63,28° | + 29,53° | + 40,78° |
| | 7. Azimut | + 97,03° | + 108,28° | + 74,53° | + 85,78° |
| | 8. Azimut | + 142,03° | + 153,28° | + 119,53° | + 130,78° |
| MIT VORHALT: 7,03° zeitlich später | | | | | |

| | 7.Azimut | 97.03 ° | 4 108,28 ° | -f 74,53 ° | 4 85,78 ° |
|---|---|---|---|---|---|

Table 10: Azimuthal angle of sensors for F2 and P, in relation to the HELIOS-Sun line.
Negative sign refers to Eastern directions. The order of the channels is equivalent to the rotation of HELIOS 2 from East to West, i.e. in a clockwise direction when viewed from the North.

4

Messwinkel = measuring angle
Kein vorhalt = No derivative action
Ohne verschiebung = Without shift
Mit verschiebung = with shift
Anfang = Beginning
Integrations-Zähler = Integrations counter
Mit vorhalt = with derivative action
zeitlich später = later in time

reducing the data in the data and storage control run.Here those data to be passed to the memory to be selected.At the same time, this unit concerned - controlled by the control flow - that the respective data in the prescribed space are written.Another part of this Unit ensures - controlled by the satellite telemetry that the memory content is delivered to the telemetry bit - and Word-serial.
Those signals are obtained from the control flow at the same time, which control the sensors, i.e.the energy channels, etc.set.These signals are routed to the sensors with control signals from the control unit of the program selection logic of each switched on digital electronics.Figure 18 is also clearly which parts of the electronics box are redundant, namely:

- Data switching logic
- all counters
- Reduce plant
- Control of flow.

It seems as if the data and storage control unit would constitute a bottleneck regarding the reliability of data processing.That is not the case, is from Figure 19 clearly showing the units of the electronics box slightly clearer.

The control of data contains only the maximum viewfinder for the data of sensor 1a and sensor 3.Also associated with each memory (functionally limited - a memory is written a spin-synchronous with experiment data, the other is read synchronously from the telemetry) its own disk controller.Thus a data control is, i.e.Selection of the data to be stored, performed only in the normal data mode of this unit.In data-mode, this unit virtually represents a short circuit as the data selection in this program directly from control flow, which is redundant.

This means that in Normal-Data-Mode-operation in case of failure of Maximum finder (data control) that are not to use the data under certain circumstances.In this case can immediately on high-data-mode program be switched, because here the maximum viewfinder while running, but is not required, because the data control is performed by the redundant control of flow in this program.The failure of a storage controller or a memory, however, has more serious consequences.While in the above case, no data is lost, only the half time resolution is given in this case in the normal data mode operation, i.e.only every second data block is evaluated.In the high data mode operation, only every second block of data is transmitted when a storage controller or a memory failure, i.e.that only you are transferred half of the energy channels.In this case, the switch over to the normal-data-mode program can help immediately.

*Such emergencies did not occur until late 1979.The redundant digital electronics D2 (see Figure 18) was tested in each case after the start, but since then no longer to be used.*

In the program control unit is also the command of tele reception - register.Here, all the received commands are stored and raised their execution at the appropriate time.

The power supply of the experiment is done via a main voltage converter (main converter), which by the probe supplied to so called"power ground"-related 28 VDC main bus voltage converts and refers to "signal ground".This is done in a converter that is synchronized with the 120 kHz synchronization frequency of the probe.The switching on and off of the experiment is done by switching on or off the voltage of 28 V on the side of the probe.
This main power converter provides for the following units separate voltages, which are permanently present, as soon as the experiment is turned on

- Memory 1 memory control 1 (M1)
- Memory 2 memory control 2 (M2)
- Data control
- Program Control (MP)
- Data interface

The separate voltages for the Digital electronics are switchable via tele command.
Also provides the main transformer yet another + 28 V voltage, switch led to the individual sensors via separate, to be controlled, with tele-commands.Figure 20 shows the voltage distribution within the experiment and the single - switch-off possibilities.
The unit selection logic (digital sensor interface) is supplied with voltage by the individual sensors.This means that only those components in operation are actually used, i.e.If the associated sensors, which the control signals are sent, are turned on.

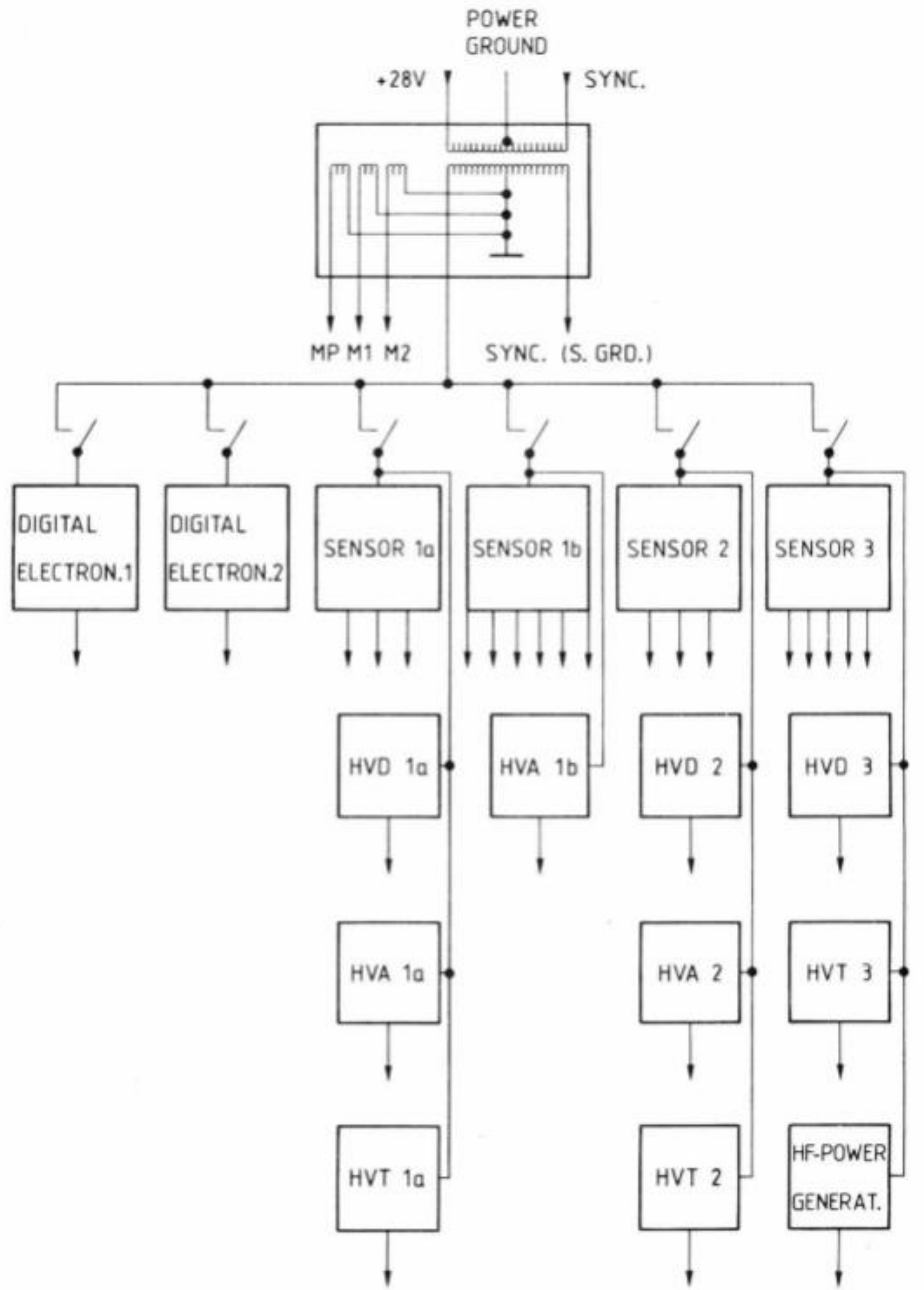



Fig. 20: voltage distribution in the experiment

## 4. Organization of data generation and data transmission

The instrument 1a produced in every HELIOS turn, so per second in 9 elevation and 16 azimuth channels together 144 readings in the form of a 16-bit counter.That alone exceeds already the maximum upper transmission rate of HELIOS.There must occur a pre-evaluation and reducing the data still on board.Initially all data - converted as described later - in 8 bit words. Still, two different measuring programs were provided to reduce data that allow even a certain adaptation to the strongly varying bitrates of the probe.

### Normal data mode (NDM)

The most interesting part of the spectrum of ion - protons and $\alpha$-particle - meets most of the time only a fraction of the entire measuring range, but shifted due to the known fluctuations of solar wind all the time.The "normal data mode" measurement program (NDM) for medium and low bitrate is adapted.Here first look up the maximum of the intensity of Proton experiment internal logic, i.e.the address of the measuring channel in energy (EN), azimuth (AZ) and elevation (EL), in which the highest count rate occurred.In the next measuring cycle only a limited number of measuring channels around this maximum is registered, namely 9 x 5 x 5 (EN x AZ x EL), 225 so values. The nine energy channels are designed that even the helium ions - such as the double E/q ratio of protons - are yet covered.Meanwhile, already a new maximum for the next cycle is determined over the whole measuring range.
In addition, the "integration counter" for I1a and I3 in each energy channel provides a count rate which is created by summing all azimuth and elevation channels - also those are just not transferred on the basis of the selected maximum -.This allows for the estimation of the marginal areas occasionally cut off the three-dimensional measurement and also a direct comparison with the instrument that is also an integral and directly measuring the ion current 1B.Also its 32 results per cycle are always transferred.

When I3 instead of I1a is turned on, applies a similar selection process, with some differences in the NDM: in the first 16 turns of a cycle the full speed range is searched again a maximum of Proton distribution (so for M/q = 1).This is then used as at I1a as Centre for the 225 readings from the first 16 Revolutions of the next cycle. In each case during the revolutions 17 – 32 only works the integration counter.With a fixed "speed channel", where the protons previously had the highest intensity, all M/q-values are sequentially set.This program is based on the observation that the average speed of different ions is always pretty much equal to that of the proton.The integration over the angle makes sense due to the very low density of heavy ions.

*So we knew it until 1974.Meanwhile, just the HELIOS-have measurements shown that α-particles are often much faster than Protons: especially in fast solar wind streams (sometimes in slow), and particularly dramatically close to perihelion.*
*When operating in the NDM, I3 here must almost inevitably miss the α-particles.On the other hand, the Proton Spectra completely purified by α-particles are particularly interesting here.*

Operation of I3 the NDM can enter a special case: if the maximum channel is higher than in channel $V_{10}$, at the end of the 16th Revolution still not 225 results measured.In this case, in turn 17, 18, etc. will also in each 5 x 5 direction channels measure, until filled up the store with the 225 data values. Following the program-sequence valid from rotation 17 onwards, the maximum speed channel is thereby set and after each rotation the M/q channel is advanced. Thereby, one obtains in addition to the integrated M/q spectrum from rotation 17 to 32 the spatial orientation of some M/q channels. To make this effect well to exploit, the somewhat unusual order of M/q channels (see table 7) was elected. From I2 all 16 energy channels transmitted by either part A or part B in 8 azimuth channels , altogether 128 values per cycle.Part A or B are selected by command. Figure 21 shows the arrangement of the data of the individual instruments in the data frame.

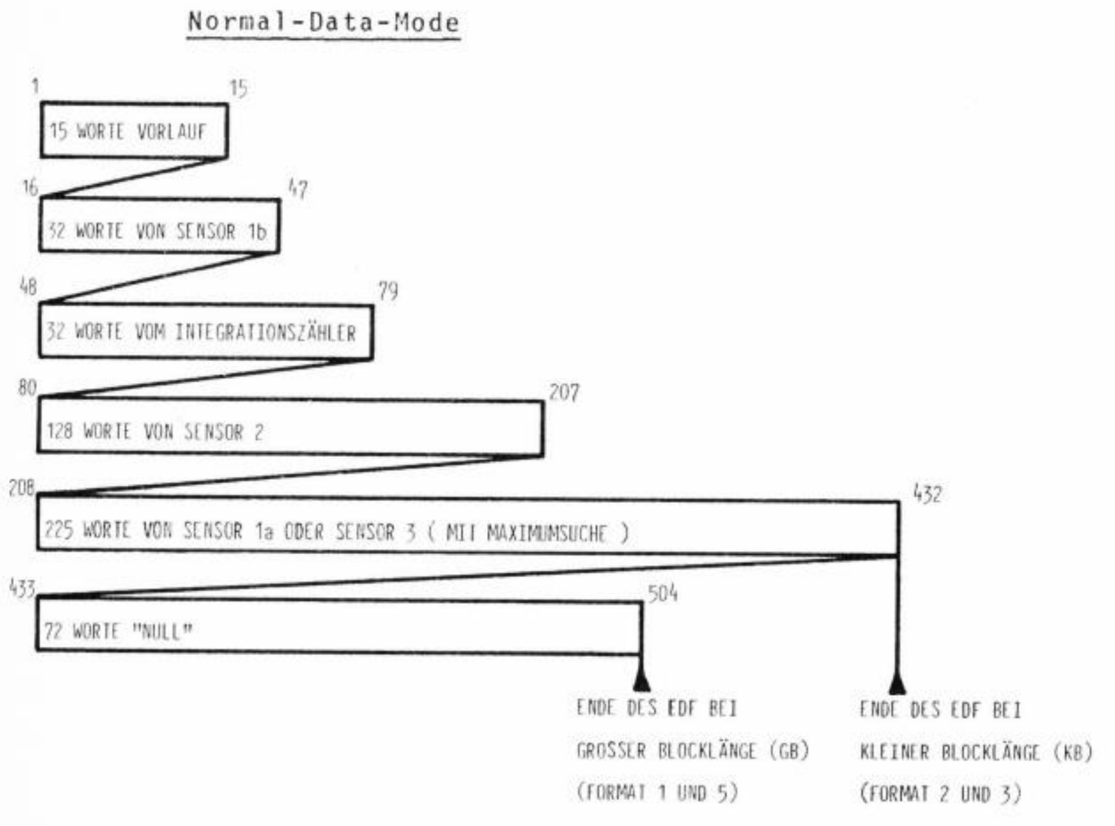



Figure 21: Structure of the experiment data frame (EDF) at normal data mode (NDM).

<u>Translation from top to bottom, left to right:</u>

15 words preceding
32 words from sensor 1b
32 words from integrations counter
128 words from sensor 2
225 words from sensor 1a or sensor 3 (with maximum search)
72 Words ''zero''
End of the EDF at large block length (GB) (Format 1 and 5)
End of the EDF at smaller block length (KB) (Format 2 and 3)

High data mode (HDM)

In the case of high bit rates "High-Data-Mode" (HDM) can be toggled to a command and on the measurement program.Here, the range selection by maximum provision is eliminated.I1a and I3, a fixed grid of 7 x 7 angle channels is transferred for 8 energy channels.These are the channels AZ 5 to AZ 11 or EL 2 to EL 8.When HDM going despite low bit rate and correspondingly shorter block length of 432 instead of 504 words, also EL 8 is still omitted.

*Unfortunately, the solar wind is blowing sometimes from an other direction, as for the selection of AZ 5 until AZ 11 accepted.We had us and also the election of the "hold-back angle" by 11.2° at the slow Wind is oriented in terms of perihelion.At $v \approx 300\, km\, s^{-1}$ and a HELIOS ground speed of 60 km $s^{-1}$ occurs a radial flowing wind under $\alpha \approx -12\,°$ to HELIOS 1.More often we found however fast wind ($v > 600\, km\, s^{-1}$) in the aphelion, where the ground speed is only 25 km $s^{-1}$.There is the "declination" only 2°, nearly 2 azimuth channels in addition to the selected middle of the measuring range (see table 9).In the HDM so unfortunately sometimes important parts of the distribution were cut off.In extreme cases, we were forced even despite the availability of a high-bitrate to operate in the NDM, where this designation is so irrelevant.This justifies belated decision to control the choice of NDM and HDM not automatically by the bit rate but by ground command.*

*Due to this experience we made a change at HELIOS 2: we introduced an additional command, with the entire range of instruments can be moved around 7.03°. In this position, the "declination" due to the high line speed in the perihelion phases in the middle is compensated fairly well (see table 10).*

The 32 energy channels are divided into 4 blocks (HDM1 to HDM 4) each with 8 channels. Each of these groups is filling a whole data frame (EDF) for himself.At the highest data rate of 2048 BPS can all 10,125 s a block of HDM are sent, so after 40.5 seconds all 4 blocks of a measuring cycle energy full-resolution each with 7 x 7 direction channel are available.Again, the result is the highest time resolution can be achieved already with 256 BPS in the NDM.If the bit rate is lower than 2048 BPS (for example1024, 512, etc.BPS), correspondingly long pauses between the HDM-blocks are inserted in the HDM (10.25 s; 20.25 s; 40.5 s etc.).

*If this breaks longer than 20.25s operation in HDM is often meaningless because no longer match the HDM blocks due to faster temporal changes in the solar wind. Therefore, mission control was reliant always to switch from HDM to NDM if the breaks are longer than 10.125 s.*

At I3 during the second part of the cycle the speed channels are again saved and the angle-resolved mass channels are cycled through. However, the speed channel is advanced after each cycle, irrespective of the proton maximum. After 16 cycles you have got for each of the 16-M/q values a three dimensional spectra as well as 16 additional proton spectra.
I2 both parts of the program are transferred to the HDM always completely, as well by I1b and by the I1a/I3 integration counter.

The arrangement of the data of a HDM block in the data frame shown in Figure 22.

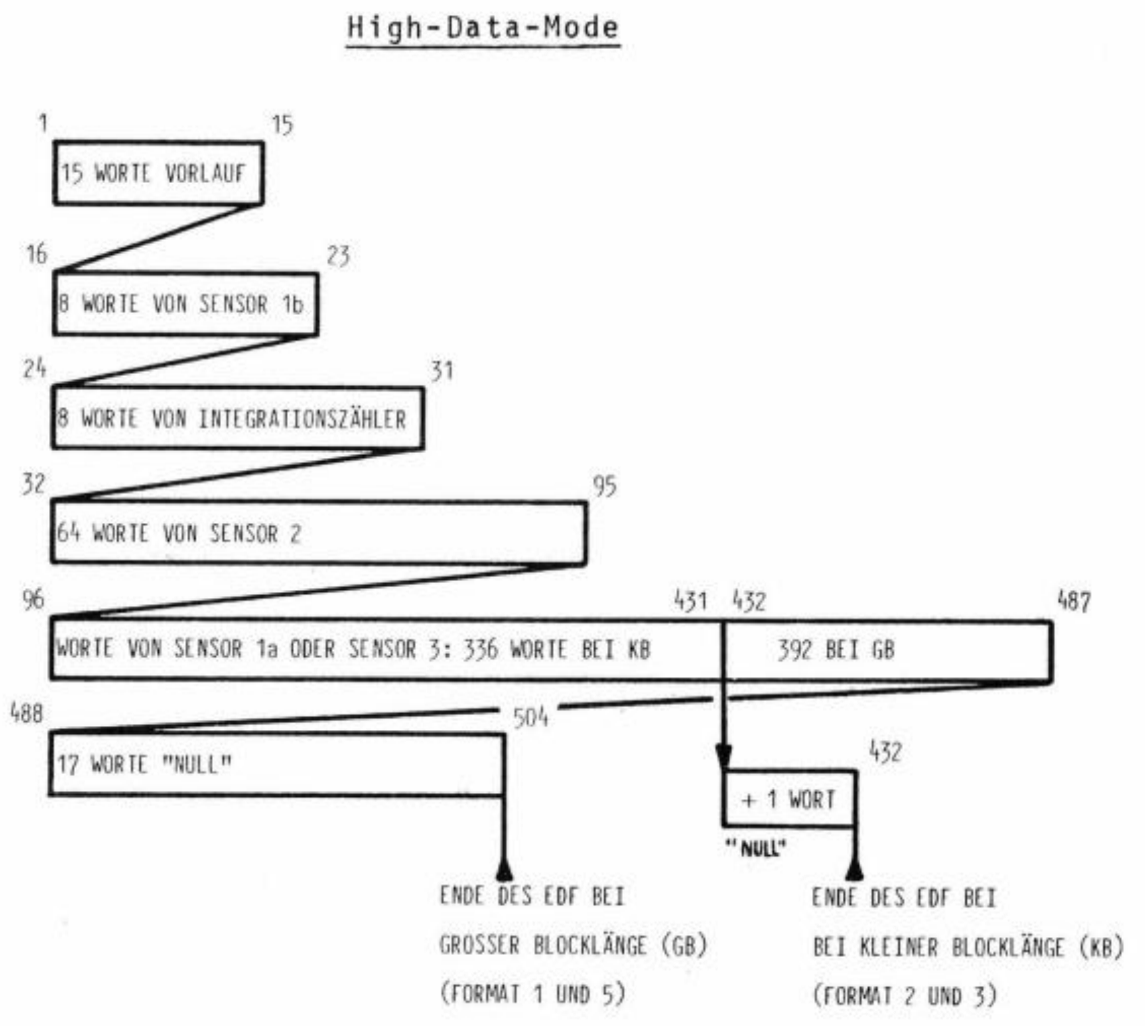



Figure 22: Structure of the experiment data frame (EDF) at high-data mode (HDM).

Translation from top to bottom, left to right:
15 words preceding
8 words from sensor 1b
8 words from integrations counter
64 words from sensor 2
Words from sensor 1a or sensor 3: 336 words in KB
392 in GB
17 Words ''zero''
+ 1 Word ''zero''
End of the EDF in large block length (GB) (Format 1 and 5)
End of the EDF in small block length (KB) (Format 2 and 3)

The E1 data into the stream of telemetry data from HELIOS

First, it is explained how the E1 data are inserted in the telemetry data from.Due to the highly variable telemetry conditions according to the distance of HELIOS – Earth, between 0 and 2 AU varies, there are many variations.By Tele-command operation can be adapted each external conditions by E1.

The probe telemetry system

Due to the strongly changing during the HELIOS mission telemetry conditions (to be bridged distance 2 AU i.e.300 million km, 3 different on-board antennas, 3 different power levels, 3 different antenna systems on Earth) the transmission bit rate of the probe between 8 BPS up to 4096 BPS.At certain times, even no telemetry connection is possible ("blackout" before and behind the Sun); data in the large 500 k-board - memory inscribed and later transmitted to Earth.
The table 11 shows all potential telemetry conditions and their consequences for E1.
Some explanations to do this:

- A "word" (word) of HELIOS telemetry consists of 8 bits.
- A 'framework' (s/c-frame) contains 155 words (1142 bit), which are divided on the experiments and include also housekeeping-data.
- The six "formats" (format, FM1, FM2... FM6), regulate the distribution of words of a framework for individual experiments.
  (FM4 contains only Housekeeping data, and FM6 E1 is not involved in.Both are therefore not listed in table 11.)
- A "main frame" (main frame) contains 72 frames, regardless of format and bit rate.
- An "experiment data frame" (experiment data frame, EDF) includes a self-contained block of data of an experiment, i.e.a complete measurement cycle in the NDM, ora quarter of a cycle in the HDM.

| FORMAT | FM 1 | FM 2 | FM 3 | FM 5 |
|---|---|---|---|---|
| | HIGH RATE | NORMAL RATE | REDUCED RATE | VERY HIGH RATE |
| BITRATEN (bps) | 512<br>1024<br>2048 | 32<br>64<br>128<br>256<br>512 | 8<br>16<br>32<br>64 | 4096 |
| BLOCKLÄNGE:<br>8 BIT-WORTE<br>BITS | <br>504<br>4032 | <br>432<br>3456 | <br>432<br>3456 | <br>504<br>4032 |
| WORTE/RAHMEN | 28 | 48 | 24 | 14 |
| SUBKOMMUTIERUNGSRATE | 18 | 9 | 18 | 36 |
| AUSLESEZEIT FÜR 1 SPEICHER | 10,125 s at 2048 bps | 40,5 s at 256 bps | | 10,125 s |
| DATENANTEIL DES EXPERIMENTS % | 20, 6 % | 35,3 % | 17,6 % | 9,7 % |

Table 11: Overview of the data formats and the shares of E1.

Bitraten = BIT rate
Blocklänge = Block Length
Worte/ Rahmen = Words/Frame
Subkommutierungsrate = Sub Communication Rate
Auslesezeit für 1 speicher = Selection time for 1 store
Datenanteil des Experiments = Data portion of the experiment

- The "sub commutation rate" (subcommrate) refers to how many frames an EDF is divided.
- The "elite"TimeFor 1 EDF is given by

$$\frac{Sub\ commutation\ rate\ \times\ frame\ length\ (bits\ per\ frame)}{Bit\ rate}$$

The block length provided to E1 is dependent on the format.In FM1 and FM5 is 504 words (big block length, GB), FM2 and FM3 432 words (small block length, KB).
In table 12, the selection times for 1 EDF are put together for the different formats and bit rates.You can see here, that for exampleby 32 BPS the read-out time in FM2 with 364 s only half as long is like in FM3 at the same bitrate.The same applies for 512 BPS between the FM1 and FM2.FM2 for E1 is also better.

*Of course, the high proportion of E1 on the total data rate of 35.3% is in FM2 at the expense of other experiments.That is why this compromise was negotiated between the experimenters: for the Time, where at all between the FM2 and FM1 orFM3 can be selected, FM2 used to 50%.Usually shuts alternately depending on a whole passage (over a ground station) in one or the other format.*

<u>Block structure of the E1 telemetry data</u>

First 21 and 22 refers to the images, which show the block construction of the data framework of E1.
Tables 13 and 14 show the structure of the experiment data frames again separately for normal data mode and high data mode.Both data frames differ only by the data units of each instrument.Each EDF begins with 15 words (W) "Advance"-data that indicate the operating status of the experiment for the following data in the digital encoding.

The number of real experiment data is not fully adapted for technical reasons of length of EDF.This can be seen from the following list:

| Format | Bit rate (bit / s) | Elite time for 1 EDF (s) | Measuring time (s) ± 1.7% | Distance two blocks of data (s) | Program |
|---|---|---|---|---|---|
| Format | Bitrate (bit/s) | Auslesezeit für 1 EDF (s) | Meßdauer (s) ± 1,7 % | Abstand zweier Datenblöcke (s) | Programm |
| | 8 | 2592 | 32 | 2592 | NDM |
| | 16 | 1296 | 32 | 1296 | NDM |
| 3 | 32 | 648 | 32 | 698 | NDM |
| | 64 | 324 | 32 | 324 | NDM |
| | (64 | 324 | (9+311)x3+9 | 324x4 | HDM) |
| | 64 | 162 | 32 | 162 | NDM |
| | (64 | 162 | (9+151)x3+9 | 162x4 | HDM) |
| | 128 | 81 | 32 | 81 | NDM |
| 2 | (256 | 81 | (9+ 71)x3+9 | 81x4 | HDM) |
| | 256 | 40,5 | 32 | 40,5 | NDM |
| | (256 | 40,5 | (9+ 31)x3+9 | 40,5x4 | HDM) |
| | 512 | 20,25 | 32 | 40,5 | NDM |
| | 512 | 20,25 | (9+ 11)x3+9 | 20,25x4 | HDM |
| | 512 | 40,5 | 32 | 40,5 | NDM |
| | (512 | 40,5 | (9+ 31)x3+9 | 40,5x4 | HDM) |
| 1 | 1024 | 20,25 | 32 | 40,5 | NDM |
| | 1024 | 20,25 | (9+ 11)x3+9 | 20,25x4 | HDM |
| | 2048 | 10,125 | 32 | 40,5 | NDM |
| | 2048 | 10,125 | (9+ 1)x3+9 | 10,125x4 | HDM |
| | 2048 | 20,25 | 32 | 40,5 | NDM |
| 5 | 2048 | 20,25 | 8 | 20,25x4 | HDM |
| | 4096 | 10,125 | 32 | 40,5 | NDM |
| | 4096 | 10,125 | 8 | 10,125x4 | HDM |

Table 12: time resolution and program opportunities depending on format and bit rate.
Note: In the HDM, a measurement consists of 4 EDFs.Therefore, HDM is not used if the distance between the EDFs is greater than 20,25 s (bracketed values).

Normal-Data-Mode

| WORT-Nr. | INFORMATION | ANZAHL DER WORTE |
|---|---|---|
| 1 ⋮ 15 | VORLAUF | 15 |
| 16 ⋮ 47 | DATEN SENSOR 1b | 32 |
| 48 ⋮ 79 | DATEN INTEGRATIONSZÄHLER | 32 |
| 80 ⋮ 207 | DATEN SENSOR 2 | 128 |
| 208 ⋮ 432 | DATEN SENSOR 1a ODER SENSOR 3 | 225 |
| | EDF - ENDE BEI KB | |
| 433 ⋮ 504 | "NULL" | 72 |
| | EDF - ENDE BEI GB | |
| | | |

Table 13: Layout of the experiment data frame (EDF) at normal data mode.

Wort-Nr. = Word no.
Anzahl der worte = Number of words
Vorlauf = leader
Daten = data
Integrationszähler = integration counters
Oder = or
Ende bei = end with
Null = Zero

High-Data-Mode

| WORT-Nr. | INFORMATION | ANZAHL DER WORTE |
|---|---|---|
| 1 ... 15 | VORLAUF | 15 |
| 16 ... 23 | DATEN SENSOR 1b | 8 |
| 24 ... 31 | DATEN INTEGRATIONSZÄHLER | 8 |
| 32 ... 95 | DATEN SENSOR 2 | 64 |
| 96 ... 431 | DATEN SENSOR 1 ODER SENSOR 3 BEI KB + 1 WORT | 336 |
| | EDF - ENDE BEI KB | |
| ... 487 | DATEN SENSOR 1 ODER SENSOR 3 BEI GB | 56 (392) |
| 488 ... 504 | "NULL" | 17 |
| | EDF - ENDE BEI GB | |

Table 14: Layout of the experiment data frame (EDF) in high data mode.

Wort-Nr. = Word no.
Anzahl der worte = Number of words
Vorlauf = leader
Daten = data
Integrationszähler = integration counters
Oder = or
Bei = at/with/in
Ende bei = end with
Null = Zero

| | available EDF-length | generated data per EDF NDM | HDM |
|---|---|---|---|
| Format 2 and 3 (KB) | 432W | 432W | 431W |
| Format 1 and 5 (GB) | 504W | 432W | 487W |

Those words of EDF which are not filled with data, are also encoded by "Zeros" - filled.
As you can see from the above list, the HDM program on the formats 1 and 5 (GB) is aligned with the high bit rates.This program is applicable also at the lower bitrates of the formats 2 and 3 (KB).Then 56 less words transmitted in the data block from I1a or I3, compared to the normal data block of 487 words.This is done by omitting the channel EL 8 in all 7 azimuth channels at all 8 energy channels of the respective HDM block.

The tables 15 to 25 can exactly detect the formation of each individual reading of all instruments in the different modes of E1.

Normal-Data-Mode

| WORT-Nr. | KANAL | BEDEUTUNG |
|---|---|---|
| 16 | EN 1 | ZÄHLERGEBNIS |
| 17 | EN 2 | ZÄHLERGEBNIS |
| 47 | EN 32 | ZÄHLERGEBNIS |

High-Data-Mode

| WORT-Nr. | KANAL | | | | BEDEUTUNG |
|---|---|---|---|---|---|
| | HDM 1 | HDM 2 | HDM 3 | HDM 4 | |
| 16 | EN 1 | EN 9 | EN 17 | EN 25 | ZÄHLERGEBNIS |
| 17 | EN 2 | EN 10 | EN 18 | EN 26 | ZÄHLERGEBNIS |
| 23 | EN 8 | EN 16 | EN 24 | EN 32 | ZÄHLERGEBNIS |

Table 15: Structure of the data from sensor I1b

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

Normal-Data-Mode

INTEGRATIONSZÄHLER SENSOR 1a

| WORT-Nr. | KANAL | BEDEUTUNG |
|---|---|---|
| 48 | EN 1 | ZÄHLERGEBNIS |
| 49 | EN 2 | ZÄHLERGEBNIS |
| ⋮ | ⋮ | ⋮ |
| 79 | EN 32 | ZÄHLERGEBNIS |

High-Data-Mode

| WORT-Nr. | KANAL | | | | BEDEUTUNG |
|---|---|---|---|---|---|
| | HDM 1 | HDM 2 | HDM 3 | HDM 4 | |
| 24 | EN 1 | EN 9 | EN 17 | EN 25 | ZÄHLERGEBNIS |
| 25 | EN 2 | EN 10 | EN 18 | EN 26 | ZÄHLERGEBNIS |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 31 | EN 8 | EN 16 | EN 24 | EN 32 | ZÄHLERGEBNIS |

Table 16: Structure of the data of the integration counter of I1a

Translation key:
Integrationszähler = Integration counter
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

Normal-Data-Mode

INTEGRATIONSZÄHLER SENSOR 3

| WORT-Nr. | KANAL | BEDEUTUNG |
| --- | --- | --- |
| 48 | F1 M3 | ZÄHLERGEBNIS |
| 49 | F2 M3 | |
| ⋮ | ⋮ | ⋮ |
| 63 | F16 M3 | |
| 64 | F(z) M1 | |
| 65 | F(z) M2 | |
| ⋮ | ⋮ | ⋮ |
| 79 | F(z) M16 | ZÄHLERGEBNIS |

High-Data-Mode

| WORT-Nr. | KANAL | | | | BEDEUTUNG |
| --- | --- | --- | --- | --- | --- |
| | HDM 1 | HDM 2 | HDM 3 | HDM 4 | |
| 24 | F1 M3 | F9 M3 | F(1–16) M1 | F(1–16) M9 | ZÄHLERGEBNIS |
| 25 | F2 M3 | F10 M3 | F(1–16) M2 | F(1–16) M10 | |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 31 | F8 M3 | F16 M3 | F(1–16) M8 | F(1–16) M16 | ZÄHLERGEBNIS |

Legend: $F(z) = frequency\ channel\ (speed\ channel)\ the\ maximums$

$F(1-16) = Frequency\ canal\ (speed\ channel) the\ HDM\ counter\ sensor\ 3\ (speed\ channel\ counter)$

Table 17: Structure of the data of the integration counter I3.

Translation key:
Integrationszähler = Integration counter
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

Normal-Data-Mode

SENSOR 2

| WORT-Nr. | KANAL | | | | BEDEUTUNG |
|---|---|---|---|---|---|
| | PROGRAMM A | | PROGRAMM B | | |
| 80 | Az 1 | EN 1 | Az 1 | EN 17 | ZÄHLERGEBNIS |
| 81 | Az 2 | | Az 2 | | |
| 82 | Az 3 | | Az 3 | | |
| 83 | Az 4 | | Az 4 | | |
| 84 | Az 5 | | Az 5 | | |
| 85 | Az 6 | | Az 6 | | |
| 86 | Az 7 | | Az 7 | | |
| 87 | Az 8 | | Az 8 | | |
| 88 | Az 1 | EN 2 | Az 1 | EN 18 | |
| 95 | Az 8 | | Az 8 | | |
| 96 | Az 1 | EN 3 | Az 1 | EN 19 | |
| 103 | Az 8 | | Az 8 | | |
| 104 | Az 1 | EN 4 | Az 1 | EN 20 | |
| 207 | Az 8 | EN 16 | Az 8 | EN 32 | ZÄHLERGEBNIS |

Table 18: Structure of the data of I2, normal data mode

Translation key:
Integrationszähler = Integration counter
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

High-Data-Mode SENSOR 2

| WORT-Nr. | KANAL | | | | | BEDEUTUNG |
|---|---|---|---|---|---|---|
| | HDM 1 | | HDM 2 | HDM 3 | HDM 4 | |
| 32 | Az 1 | | | | | ZÄHLERGEBNIS |
| 33 | Az 2 | | | | | |
| 34 | Az 3 | | | | | |
| 35 | Az 4 | | | | | |
| 36 | Az 5 | EN 1 | EN 9 | EN 17 | EN 25 | |
| 37 | Az 6 | | | | | |
| 38 | Az 7 | | | | | |
| 39 | Az 8 | | | | | |
| 40 | Az 1 | | | | | |
| | | EN 2 | EN 10 | EN 18 | EN 26 | |
| 47 | Az 8 | | | | | |
| 48 | Az 1 | EN 3 | EN 11 | EN 19 | EN 27 | |
| 95 | Az 8 | EN 8 | EN 16 | EN 24 | EN 32 | ZÄHLERGEBNIS |

Table 19: Structure of the data of I2, high data mode.

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

Normal-Data-Mode SENSOR 1a

| WORT-Nr. | KANAL | | | BEDEUTUNG |
|---|---|---|---|---|
| 208 | EL (x−2) | | | ZÄHLERGEBNIS |
| 209 | EL (x−1) | | | |
| 210 | EL (x) | Az (y−2) | | |
| 211 | EL (x+1) | | | |
| 212 | EL (x+2) | | | |
| 213 | EL (x−2) | | | |
| 214 | EL (x−1) | | | |
| 215 | EL (x) | Az (y−1) | EN (z−2) | |
| 216 | EL (x+1) | | | |
| 217 | EL (x+2) | | | |
| 218 | EL (x−2) | | | |
| | | Az (y) | | |
| 222 | EL (x+2) | | | |
| 223 | EL (x−2) | | | |
| | | Az (y+1) | | |
| 227 | EL (x+2) | | | |
| 228 | EL (x−2) | | | |
| | | Az (y+2) | | |
| 232 | EL (x+2) | | | |
| 233 | EL (x−2) | Az (y−2) | | |
| | | | EN (z−1) | |
| 257 | EL (x+2) | Az (y+2) | | |
| 258 | EL (x−2) | Az (y−2) | EN (z) | |
| 432 | EL (x+2) | Az (y+2) | EN (z+6) | ZÄHLERGEBNIS |

Legend: EL (x) = MAXIMUM ELEVATION channel
AZ (y) = MAXIMUM azimuth channel
EN (z) = MAXIMUM energy channel

Table 20: Structure of the data of I1a, normal data mode.

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

## High-Data-Mode und große Blocklänge

SENSOR 1a

| WORT-Nr. | KANAL | | | | | | BEDEUTUNG |
|---|---|---|---|---|---|---|---|
| | HDM 1 | | | HDM 2 | HDM 3 | HDM 4 | |
| 96 | EL 2 | | | | | | ZÄHLERGEBNIS |
| 97 | EL 3 | | | | | | |
| 98 | EL 4 | | | | | | |
| 99 | EL 5 | Az 5 | | | | | |
| 100 | EL 6 | | | | | | |
| 101 | EL 7 | | | | | | |
| 102 | EL 8 | | EN 1 | EN 9 | EN 17 | EN 25 | |
| 103 | EL 2 | | | | | | |
| ⋮ | ⋮ | Az 6 | | | | | |
| 109 | EL 8 | | | | | | |
| 110 | EL 2 | Az 7 | | | | | |
| ⋮ | ⋮ | ⋮ | | | | | |
| 144 | EL 8 | Az 11 | | | | | |
| 145 | EL 2 | Az 5 | | | | | |
| ⋮ | ⋮ | ⋮ | EN 2 | EN 10 | EN 18 | EN 26 | |
| 193 | EL 8 | Az 11 | | | | | |
| 194 | EL 2 | Az 5 | EN 3 | EN 11 | EN 19 | EN 27 | |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 487 | EL 8 | Az 11 | EN 8 | EN 16 | EN 24 | EN 32 | ZÄHLERGEBNIS |

Table 21: Structure of the data of I1a, high data mode and large block length.

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results
Und = and
Große = large
Blocklänge = Block length

## High-Data-Mode und kleine Blocklänge

SENSOR 1a

| WORT-Nr. | KANAL: HDM 1 | | | HDM 2 | HDM 3 | HDM 4 | BEDEUTUNG |
|---|---|---|---|---|---|---|---|
| 96 | EL 2 | | | | | | ZÄHLERGEBNIS |
| 97 | EL 3 | | | | | | |
| 98 | EL 4 | | | | | | |
| 99 | EL 5 | Az 5 | | | | | |
| 100 | EL 6 | | | | | | |
| 101 | EL 7 | | | | | | |
| 102 | EL 2 | Az 6 | EN 1 | EN 9 | EN 17 | EN 25 | |
| 107 | EL 7 | | | | | | |
| 108 | EL 2 | Az 7 | | | | | |
| 137 | EL 7 | Az 11 | | | | | |
| 138 | EL 2 | Az 5 | EN 2 | EN 10 | EN 18 | EN 26 | |
| 179 | EL 7 | Az 11 | | | | | |
| 180 | EL 2 | Az 5 | EN 3 | EN 11 | EN 19 | EN 27 | |
| 431 | EL 7 | Az 11 | EN 8 | EN 16 | EN 24 | EN 32 | ZÄHLERGEBNIS |

Table 22: Structure of the data of I1a, high data mode and small block length.

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results
Und = and
Kleine = small
Blocklänge = Block length

Normal-Data-Mode SENSOR 3

| WORT-Nr. | KANAL | | | BEDEUTUNG |
|---|---|---|---|---|
| 208 | EL (x-2) | Az (y-2) | F (z-2), MB | ZÄHLERGEBNIS |
| 209 | EL (x-1) | | | |
| 210 | EL (x) | | | |
| 211 | EL (x+1) | | | |
| 212 | EL (x+2) | | | |
| 213 | EL (x-2) | Az (y-1) | | |
| 214 | EL (x-1) | | | |
| 215 | EL (x) | | | |
| 216 | EL (x+1) | | | |
| 217 | EL (x+2) | | | |
| 218 | EL (x-2) | Az (y) | | |
| 222 | EL (x+2) | | | |
| 223 | EL (X-2) | Az (y+1) | | |
| 227 | EL (x+2) | | | |
| 228 | EL (x-2) | Az (y+2) | | |
| 232 | EL (x+2) | | | |
| 233 | EL (x-2) | Az (y-2) | F (z-1), MB | |
| 257 | EL (x+2) | Az (y+2) | | |
| 258 | EL (x-2) | Az (y-2) | F (z), MB | |
| 432 | EL (x+2) | Az (y+2) | F (z+6), MB | ZÄHLERGEBNIS |

Legend: EK (x) MAXIMUM ELEVATION channel
AZ (y) = Maximum azimuth channel
F (z) = MAXIMUM FREQUENCY—(speed) Channel
M = mass channel number

Table 23: Structure of the data of I3, normal mode data

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results

High-Data-Mode und große Blocklänge SENSOR 3

| WORT-Nr. | KANAL | | | | | | BEDEUTUNG |
|---|---|---|---|---|---|---|---|
| | HDM 1 | | | HDM 2 | HDM 3 | HDM 4 | |
| 96 | EL 2 | | | | | | ZÄHLERGEBNIS |
| 97 | EL 3 | | | | | | |
| 98 | EL 4 | | | | | | |
| 99 | EL 5 | Az 5 | | | | | |
| 100 | EL 6 | | | | | | |
| 101 | EL 7 | | | | | | |
| 102 | EL 8 | | F1,M3 | F9,M3 | F(1-16),M1 | F(1-16),M9 | |
| 103 | EL 2 | | | | | | |
| | | Az 6 | | | | | |
| 109 | EL 8 | | | | | | |
| 110 | EL 2 | Az 7 | | | | | |
| 144 | EL 8 | Az 11 | | | | | |
| 145 | EL 2 | Az 5 | | | | | |
| | | | F2,M3 | F10,M3 | F(1-16),M2 | F(1-16),M10 | |
| 193 | EL 8 | Az 11 | | | | | |
| 194 | EL 2 | Az 5 | F3,M3 | F11,M3 | F(1-16),M3 | F(1-16),M11 | |
| 487 | EL 8 | Az 11 | F8,M3 | F16,M3 | F(1-16),M8 | F(1-16),M16 | ZÄHLERGEBNIS |

LEGEND: F(1-16) = Frequency channel ACCORDING TO HDM-COUNTER SENSOR 3 (SPEED CHANNEL COUNTER)

Table 24: Structure of the data of I3, high data mode and large block length

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results
Und = and
Große = large
Blocklänge = Block length

## High-Data-Mode und kleine Blocklänge

SENSOR 3

| WORT-Nr. | KANAL | | | | | | BEDEUTUNG |
|---|---|---|---|---|---|---|---|
| | HDM 1 | | | HDM 2 | HDM 3 | HDM 4 | |
| 96 | EL 2 | | | | | | ZÄHLERGEBNIS |
| 97 | EL 3 | | | | | | |
| 98 | EL 4 | Az 5 | | | | | |
| 99 | EL 5 | | | | | | |
| 100 | EL 6 | | | | | | |
| 101 | EL 7 | | | | | | |
| 102 | EL 2 | | F1,M3 | F 9,M3 | F(1-16),M1 | F(1-16),M9 | |
| | | Az 6 | | | | | |
| 107 | EL 7 | | | | | | |
| 108 | EL 2 | Az 7 | | | | | |
| 137 | EL 7 | Az 11 | | | | | |
| 138 | EL 2 | Az 5 | | | | | |
| | | | F2,M3 | F10,M3 | F(1-16),M2 | F(1-16),M10 | |
| 179 | EL 7 | Az 11 | | | | | |
| 180 | EL 2 | Az 5 | F3,M3 | F11,M3 | F(1-16),M3 | F(1-16),M11 | |
| 431 | EL 7 | Az 11 | F8,M3 | F16,M3 | F(1-16),M8 | F(1-16),M16 | ZÄHLERGEBNIS |

SWEEPING: F(1-16) = Frequncy Channel according to HDM-COUNTER SENSOR 3
(SPEED CHANNEL COUNTER)

Table 25: Structure of the data of I3, high data mode and small block length

Translation key:
Wort-Nr. = Word no.
Kanal = Channel
Bedeutung = Importance
Zählergebnis = Counting results
Und = and
Kleine = small
Blocklänge = Block length

Forward words

Each EDF begins with a set of 15 8-bit words, which contain a variety of information about the operating condition of the whole experiment in addition to some code words.The code words are called

L L L L 0 0 0 0.

This pattern is easy to recognize, and is in fact used in any form of data analysis to identify the beginnings of EDF. If one were to interpet a code word as count rate and decode this bit pattern would prove as illegal.

The meaning of all words of flow emerges from the tables 26 and 27.In the test cycle, the last 5 words have a different meaning; in particular, the swapping of code words makes easily identifiable test cycles.

Some notes on the tables 26 and 27

- For safety, the maximum address is transmitted twice.

*Not much help.Data failure almost always whole telemetry frame are affected by E1 so at least 14 words (see table 11).Today we would like a duplicate of the lead words in the middle of each EDF.*

- The S/C-time refers to the first measurement channel of the spectrum.So can each measurement to $2^{-3}$ s i.e. 1/8s are precisely arranged.

*It was very in the identification of some shock events helpful.But the "size" of the clock with $2^{12}$ s: is insufficient She starts all 68 min 16 sec from scratch to count.It is useless for the classification of data that were written during station gaps in the on-board memory.An extension of time words to 8 bit would have been beneficial.*

- Word 5 / bit 1 shows, (MV) or not (KV) are whether the energy and azimuth channels moved.

- The flow of words reveal nothing about the status of the channeltrons.

*The data analysis somewhat more difficult, especially in the common switching at Perihelion between I1A and I3, that require a change of Channeltron volatges. From 4.1 kV to 3,3 kV get only about a "reset"-command that would first put the CEM-HV zero.So, it is possible that counting rates are zero for a short time in the middle of a cycle up to turn back on unless the reason is easily recognizable.As also the Housekeeping data from which the CEM-HV were to recognize, be queried only at larger intervals.Another difficulty arises from the fact that the instruments in the middle of the measurement cycle will be switched.Desirable, therefore delaying the switch until the end of the current cycle and also a new set of would control words at the end of each measurement.*

| WISSENSCHAFTLICHER ZYKLUS | | TESTZYKLUS | |
|---|---|---|---|
| WORT-Nr. | BEDEUTUNG | WORT-Nr. | BEDEUTUNG |
| 1 | CODEWORT | 1 | CODEWORT |
| 2 | S/C TIME WORT 1 | 2 | S/C TIME WORT 1 |
| 3 | S/C TIME WORT 2 | 3 | S/C TIME WORT 2 |
| 4 | CODEWORT | 4 | CODEWORT |
| 5 | MAXIMUM REGISTER 1 | 5 | MAXIMUM REGISTER 1 |
| 6 | MAXIMUM REGISTER 2 | 6 | MAXIMUM REGISTER 2 |
| 7 | CODEWORT | 7 | CODEWORT |
| 8 | PROGRAMM-WORT 1 | 8 | PROGRAMM-WORT 1 |
| 9 | PROGRAMM-WORT 2 | 9 | PROGRAMM-WORT 2 |
| 10 | CODEWORT | 10 | CODEWORT |
| 11 | MAXIMUM REGISTER 1 | 11 | CODEWORT |
| 12 | MAXIMUM REGISTER 2 | 12 | CODEWORT |
| 13 | CODEWORT | 13 | ZUFALLSGENERATOR WORT 1 |
| 14 | CODEWORT | 14 | ZUFALLSGENERATOR WORT 2 |
| 15 | CODEWORT | 15 | CODEWORT |

Table 26: Building of the forward words

Wissenschaftlicher Zyklus = Research Cycle
Testzyklus = Test cycle
Bedeutung = Importance
Zufallsgenerator = Random

**Wort Nr. 1**

Codewort

| | |
|---|---|
| Bit 1 | L |
| Bit 2 | L |
| Bit 3 | L |
| Bit 4 | L |
| Bit 5 | Ø |
| Bit 6 | Ø |
| Bit 7 | Ø |
| Bit 8 | Ø |

**Wort Nr. 2**

S/C-Time Wort 1

| | | |
|---|---|---|
| Bit 1 | $2^{12}$ | sec |
| Bit 2 | $2^{11}$ | sec |
| Bit 3 | $2^{10}$ | sec |
| Bit 4 | $2^{9}$ | sec |
| Bit 5 | $2^{8}$ | sec |
| Bit 6 | $2^{7}$ | sec |
| Bit 7 | $2^{6}$ | sec |
| Bit 8 | $2^{5}$ | sec |

**Wort Nr. 3**

S/C-Time Wort 2

| | | |
|---|---|---|
| Bit 1 | $2^{4}$ | sec |
| Bit 2 | $2^{3}$ | sec |
| Bit 3 | $2^{2}$ | sec |
| Bit 4 | $2^{1}$ | sec |
| Bit 5 | $2^{0}$ | sec |
| Bit 6 | $2^{1}$ | sec |
| Bit 7 | $2^{2}$ | sec |
| Bit 8 | $2^{-3}$ | sec |

Table 27: Meaning of the lead words (Word 1 with 3)

Wort Nr. 4

Word no.4

Codewort wie Wort Nr. 1

Code word such as Word no.1

Wort Nr. 5

Word no.5

Maximum-Register Wort 1

Maximum register Word 1

| | | | |
|---|---|---|---|
| Bit 1 | Ø, KV; L = MV | Verschiebung | |
| Bit 2 | Ø | konstante Null | |
| Bit 3 | Ø = NDM, L = HDM | Data Mode | |
| Bit 4 | ENR B1 | Maximumadresse Energie (ØØØØØ = EN1) | Energiekanal $B2^4$ |
| Bit 5 | ENR B2 | | Energiekanal $B2^3$ |
| Bit 6 | ENR B3 | | Energiekanal $B2^2$ |
| Bit 7 | ENR B4 | | Energiekanal $B2^1$ |
| Bit 8 | ENR B5 | | Energiekanal $B2^0$ |

KV = bit 10, KV; L = MV
Bit 20
Bit 30 = NDM, HDM = L
Shift constant null data mode
Bit 4ENRB1
Bit 5ENRB2
Bit 6ENRB3
Bit 7ENRB4
Bit 8ENRB5
Maximum address energy (= 00000 ENI)
Energy channel B2
Energy channel B2
Energy channel B2 energy channel B2 energy channel B2 °

Wort Nr. 6

Word no.6

Maximum-Register Wort 2

Maximum register Word 2

| | | | |
|---|---|---|---|
| Bit 1 | ELR B1 | Maximumadresse Elevation (ØØØL = EL1) | Elevationskanal $B2^3$ |
| Bit 2 | ELR B2 | | Elevationskanal $B2^2$ |
| Bit 3 | ELR B3 | | Elevationskanal $B2^1$ |
| Bit 4 | ELR B4 | | |
| Bit 5 | AZR B1 | Maximumadresse Azimuth (ØØØØ = AZ1) | Azimuthkanal $B2^3$ |
| Bit 6 | AZR B2 | | Azimuthkanal $B2^2$ |
| Bit 7 | AZR B3 | | Azimuthkanal $B2^1$ |
| Bit 8 | AZR B4 | | Azimuthkanal $B2^0$ |

Bit 1ELRB1
Bit 2ELRB2
Bit 3ELRB3
Bit 4ELRB4
Bit 5AZRB1
Bit 6AZRB2
Bit 7AZRB3
Bit 8AZRB4
Maximum address elevation (0001 = ELI)
Maximum address azimuth (0000 = AZ1)
Elevation channel B2
Elevation channel B2
elevation B2
Azimuthkanal B23
Azimuthkanal B2
Azimuthkanal B2
Azimuthkanal B2

Table 27 (continuation): Meaning of leading words (word 4 with 6)

Codewort wie Wort Nr.1 = code word as word No.1
Verschiebung = Shift
konstante null = constant zero
Kanal = channel
Maximumadresse = Maximum address

Wort Nr. 7

Codewort
wie Wort Nr. 1

Wort Nr. 8

Programm-Wort 1

| | | |
|---|---|---|
| Bit 1 | Ø = Sp 2, L = Sp 1 | Auslesespeichernummer |
| Bit 2 | Ø | konstante Null |
| Bit 3 | ENZ B1 | HDM-Blocknummer HDM $2^1$ |
| Bit 4 | ENZ B2 | (ØØ = HDM1) HDM $2^0$ |
| Bit 5 | HDMZS3 B1 | HDM-Massenka- $2^3$ |
| Bit 6 | HDMZS3 B2 | nalzähler $2^2$ |
| Bit 7 | HDMZS3 B3 | Sensor 3 $2^1$ |
| Bit 8 | HDMZS3 | (ØØØØ = MK 1) $2^0$ |

Wort Nr. 9

Programm-Wort 2

| | | |
|---|---|---|
| Bit 1 | L = S1A on, Ø = off | Sensor 1a ein/aus |
| Bit 2 | L = S1B on, Ø = off | Sensor 1b ein/aus |
| Bit 3 | L = S2 on, Ø = off | Sensor 2 ein/aus |
| Bit 4 | L = S3 on, Ø = off | Sensor 3 ein/aus |
| Bit 5 | L = D1 on, Ø = off | Digitalelektr. 1 ein/aus |
| Bit 6 | L = D2 on, Ø = off | Digitalelektr. 2 ein/aus |
| Bit 7 | L = AVL off, Ø = on | Vorhaltewinkelverschiebung ein/aus |
| Bit 8 | L = S2A, Ø = S2B | Programmart Sensor 2 |

Table 27 (continuation): Meaning of leading words (word 7 with 9)

Codewort wie Wort Nr.1 = code word as word No.1
Auslesespeichernummer = Readout memory number
konstante null = constant zero
Massenkanalzähler = Mass channel counter
Ein/aus = on/off
vorhaltewinkel verschiebung = lead angle offset
Programmart = Program Type

<u>Word no.10</u>

Code word such as Word no.1

<u>Word no.11 scientific cycle</u>

Maximum register Word 1 as Word no.5

<u>Word no.11 test cycle</u>

Code word such as Word no.1

<u>Word no.12 scientific cycle</u>

Maximum register Word 2 as Word no.6

<u>Word no.12 test cycle</u>

Code word such as Word no.1

<u>Word no.13 scientific cycle</u>

Code word such as Word no.1

Table 27 (continuation): Meaning of leading words (word 10 with 13)

Wort Nr. 13 bei Testzyklus

Zufallsgenerator Wort 1

| | | | |
|---|---|---|---|
| Bit 1 | Ø | konstante Null | |
| Bit 2 | ELZG B1 | Zufallsgenerator | $2^2$ |
| Bit 3 | ELZG B2 | Elevationskanal | $2^1$ |
| Bit 4 | ELZG B3 | (ØØØ = El 1) | $2^0$ |
| Bit 5 | AZZG B1 | | $2^3$ |
| Bit 6 | AZZG B2 | Zufallsgenerator | $2^2$ |
| Bit 7 | AZZG B3 | Azimuthkanal | $2^1$ |
| Bit 8 | AZZG B4 | (ØØØØ = Az1) | $2^0$ |

Wort Nr. 14 bei wissenschaftlichem Zyklus

Codewort
wie Wort Nr. 1

Wort Nr. 14 bei Testzyklus

Zufallsgenerator Wort 2

| | | | |
|---|---|---|---|
| Bit 1 | L = Tc2, Ø = Tc1 | Testzyklusnummer | |
| Bit 2 | Ø | Konstante Null | |
| Bit 3 | Ø | Konstante Null | |
| Bit 4 | ENZG B1 | | $2^4$ |
| Bit 5 | ENZG B2 | | $2^3$ |
| Bit 6 | ENZG B3 | Zufallsgenerator | $2^2$ |
| Bit 7 | ENZG B4 | Energiekanal | $2^1$ |
| Bit 8 | ENZG B5 | (ØØØØ = EN1) | $2^0$ |

Wort Nr. 15

Codewort
Wie Wort Nr. 1

Table 27 (continued): Meaning of the words of the lead
(Word 13 with 15)

Testzyklus = test cycle
Zufallsgenerator = Random
konstante null = constant zero
bei wissenschaftlichem Zyklus = in scientific cycle

Commands and checking the execution

The operation of the instruments by telemetry commands from the Mission control central is remote control.The execution of commands, as well as other important functions are monitored continuously with the help of "housekeeping" data on the screen from mission control.An optional command automatic test cycle ("Inflighttest") allows in addition a detailed review of the status of the instruments.

Telemetry commands

There are 19 commands on separate lines from the satellite as the so called "low-power-commands" available.
In addition to the input and switching off of the entire experiment, all switching of individual instruments, the digital electronics, the channeltron high voltages and the measuring programs using these commands performed.
The commands are listed in table 28.The command numbers and names (E.g.374-1S0F) are the names used in the operation of the mission.
Some commands are executed immediately after arrival, others only after the end of the current cycle (X marked by).
With command 004-E10N, the 28 V power supply for E1 is switched on by the probe system.This throws the main converter and transferred the whole experiment in a working condition, through the automatic execution of all commands that are marked in table 30 "Coercion".So all the instruments as well as the Digital electronics and also the Channeltron high voltages are switched off.The two stores are already active and can be read out.But while no digital electronics, storage and program control does not work.Therefore the same memory is read out in this state again and again.

*This sometimes resulted in misunderstandings.After switching command 004-E10N, the store contain mostly recognizable worthless information – they had been de-energised beforehand.If however the normal operation of E1 command 374-1SOF is canceled, from then on again the last meaningful measurement cycle. This*

Table 28: E1 command list

Zwang = Forced
Ausführung = Execution
Rücksetzen durch kommando-nr. = Reset by command no.
sonden-kommandos = probes-details

| NR. | KOMMANDO-NR. | FUNKTION | ZWANG | AUSFÜHRUNG | VERIFIKATION (DHK) | RÜCKSETZEN DURCH KOMMANDO-NR. |
|---|---|---|---|---|---|---|
| 1 | 003-1S1A | I1a on, I3 off | | direkt | W2 B5, B6 | 4; 7 |
| 2 | 024-1S1B | I1b on | | direkt | W2 B4 | 7 |
| 3 | 353-1SE2 | I2 on | | direkt | W2 B3 | 7 |
| 4 | 045-1SE3 | I3 on, I1a off | | direkt | W2 B6, B5 | 1; 7 |
| 5 | 066-1DE1 | Dig. 1 on, Dig. 2 off | | direkt | W2 B7, B8 | 6; 7 |
| 6 | 311-1DE2 | Dig. 2 on, Dig. 1 off | | direkt | W2 B8, B7 | 5; 7 |
| 7 | 374-1SOF | All off | Zwang | direkt | | |
| 8 | 332-1TCY | Tc on (autom. reset) | | X | W1 B3 | 7; autom. |
| 9 | 107-1V11 | CEM HV 1a/3 I | | direkt | | (9);7 |
| 10 | 270-1V12 | CEM HV 1a/3 II | | direkt | W1 B5, B6 XX | 10; 7 |
| 11 | 151-1V1R | CEM HV 1a/3 off | Zwang | direkt | | 9; 10 |
| 12 | 172-1V21 | CEM HV 2 I | | direkt | | (13);10 |
| 13 | 205-1V22 | CEM HV 2 II | | direkt | W1 B7, B8 XX | 12; 7 |
| 14 | 226-1V2R | CEM HV 2 off | Zwang | direkt | | 12;13 |
| 15 | 122-1HDM | High-Data-Mode | | X | W1 B1 | 16; 7 |
| 16 | 213-1NDM | Normal-Data-Mode | Zwang | X | | 15 |
| 17 | 234-1PGA | I2A Programm | | X | W1 B2 | 18; 7 |
| 18 | 247-1PGB | I2B Programm | Zwang | X | | 17 |
| 19 | 130-1AVL | Perihel/Azim. (HELIOS-2) | | direkt | W1 B4 | 7 |
| | | SONDEN-KOMMANDOS | | | | |
| | 004-E1ON | E1 on | | direkt | | |
| | 277-E1OF | E1 off | | direkt | | |

X = NACH ABLAUF DES LAUFENDEN MESSZYKLUS
XX = CODIERUNG SIEHE TABELLE

X = At the end of the current measuring cycle
XX = coding see table

*let alone considered to not realize that everything has been turned off, because all the code words, status bits, and count rates are apparently fine.*

Only the command 066-1DE1 or 311-1DE2 makes sure that also the memory reading works. That’s why only then, if no instruments are running, zeros are generated and therefore the rest of the memory is erased. Now the code words, time words and status bits of the initial run will be set correctly and you can see what is really on or off.

130-1AVL command does not work with HELIOS 1. At HELIOS 2, it serves for switching the hold-back angle to the perihelion position.Again, it may be withdrawn only by 374-1SOF.

The instrument can not be switched off individually but only together with 374-1SOF.

*This proved awkward.In the late phase of the mission, temporarily single instruments must be switched off for performance reasons.That also the non-relevant instruments, as well as the Digital electronics must be with switched off and switched on again until then, certainly increases the risk.*

Three commands to get the circuit of Channeltron high voltages.
With command 107-1V11 (or172-1V21) the CEM-HV is set to 3.3 kV.Only then you can with 270-1V12 (or205-1V22) switch up to 3.7 kV.
4,1 kV can be achieved by again sending 107-1V11 through (or172-1V21).Direct switching down to 3.3 or 3.7 kV is not possible.To do so must with 151-1V1R (or226-1V2R) to zero and then shift up again.
The CEM HV commands are ineffective, if not also the corresponding sensors are switched on.When switching from I1a to I3 or vice versa automatically also the respective CEM-HV is with on or off.

The commands 234-1PGA and 247-1PGB control the measuring program I2.This affects only in the NDM because anyway both parts of the program be transferred to the HDM.

### Digital housekeeping channels (DHK)

Digital housekeeping channels are used for the monitoring of command execution in the instruments.There are 4 words with each 8 bits available, parallel offered the probe system, adopted by the telemetry bit-serial, and sub-commutes in the format 4 (engineering-format) with 4 lines.There they are called B016-B019.B016 and B017 represent the State of the command register (i.e.They show have sent commands to the experiment).The words B018 and B019 reveal whether the experiment has run the commands.The importance of all the bits is broken down in table 29.Each bit has an acronym as "Name", which eases the detection.These names also appear on the screens of the Mission Control Center, where the function of all units is routinely monitored.

### Housekeeping analog channels

There are nine channels of analog measurement of input streams (with sensors and electronics, words B020 to B023, C020, C021) and by the CEM - high voltages (words C022-C024).The individual measured data are shown in table 30.Also, this data is passed the satellite from the electronic box on separate lines, where they are also queried at specific time intervals and queued in the "engineering data" of the FM4.
In addition, temperatures are measured with Thermistors at all 4 devices.The analog values of the Thermistors are passed on additional lines on the telemetry of the satellite and processed there.
The digital and analog Housekeeping data, as well as the temperatures be transferred depending on the mode - approximately every second cycle.

| S/C Wd No. | Bit no. | Acronym | Meaning |
|---|---|---|---|
| B016 | 1 | NORMDM | Normal data Mode (0) (L) |
| | 2 | 12PROA | 12Program A (L) |
| | 3 | CREGTC | Testcycle on (L) |
| | 4 | 11BLIM | Meaning no. |
| | 5 | I13CEM | CEM HV I1A/3 I |
| | 6 | | CEM HV I1A/3 II |
| | 7 | I2HCEM | CEM HV 12 I |
| | 8 | | CEM HV 12 II |
| | | | 0 LOL |
| | | | 0 > 0 L L |
| | | | 0 3.7 3.7 4.1 [kV] |
| B017 | 1 | CREGM2 | Memory 2 on (L) |
| | 2 | ZERO | Must be zero 0 |
| | 3 | CREGI2 | 12 on (L) |
| | 4 | CREGIB | 11b on (L) |
| | 5 | CREGIA | I1a on (L) |
| | 6 | CREGI3 | 13 on (L) |
| | 7 | CREGD1 | D1 on (L) |
| | 8 | CREGD2 | D2 on (L) |
| B018 | 1 | ENCHAN | number of energy channel $2^4$ |
| | 2 | | $2^3$ |
| | 3 | | $2^2$ |
| | 4 | | $2^1$ |
| | 5 | | $2^0$ |
| | 6 | STATTC | Testcycle on (L) |
| | 7 | STATC2 | Testcycle Part 2 (L) |
| | 8 | PRENDS | Program end signal (L) |
| B019 | 1 | STATIA | 11 a on (L) |
| | 2 | DUST | I1b on (L) |
| | 3 | STATI2 | 12 on (L) |
| | 4 | STATI3 | 13 on (L) |
| | 5 | STATD1 | D1 on (L) |
| | 6 | STATD2 | D2 on (L) |
| | 7 | CONPOW | Power for CMD-register on (L) |
| | 8 | STATM1 | Memory 1 on (L) |

Table 29: Digital housekeeping data (DHK)

Figure 23 shows an example of the practical use of the Housekeeping data at the mission control.Here is monitored on the screen, whether currents, voltages or temperatures move within allowable limits.That exceed by "soft limits" - marked by a S+ or S- behind the numerical value - is usually not critical.The two S + in image 23 about are merely due to too tight ranges.Exceedances reported by H + or H - by "hard limits", means the alarm, which requires immediate clarification by the party concerned for the mission control.Also, verified the arrival of commands with this screen format, and monitors their execution.

*In practice we have can pull little benefit from the analog - housekeeping data.This is of course because, in part that never critical phases or even failures occurred.But the values not representative are enough.Because the current recordings E.g.vary during the measuring cycle quite sharply, due to the varying plate voltages, so that random snapshots have little significance.*

Test cycle (Inf1ight test)

The test cycle is to provide information about the technical condition of the entire experiment.This test cycle consists of two consecutive parts and is executed instead of measuring cycles.The experiment remains in previously existing on-State.
The test cycle is started with the command of 332-1TCY.The command is reset automatically after the end of the second part.

The Declaration of expiration of a test cycle is appropriately based on a practical example.Figures 24 and 25 show a paper copy of a test cycle generated in real time in the Mission control center in the NDM. You will find all necessary explanations to do so in the comments.The HDM, a test cycle is accordingly modified.

| KANAL-Nr. | ACRONYM | LEITUNG | BEDEUTUNG |
|---|---|---|---|
| 1 | CURRIA | ASE SA + | Eingangsstrom Sensor 1a |
| 2 | CURRIB | ASE SB + | Eingangsstrom Sensor 1b |
| 3 | CURRI2 | ASE S2 + | Eingangsstrom Sensor 2 |
| 4 | CURRI3 | ASE S3 + | Eingangsstrom Sensor 3 |
| 5 | CURRD1 | ASE E1 + | Eingangsstrom Digitalelektronik 1 |
| 6 | CURRD2 | ASE E2 + | Eingangsstrom Digitalelektronik 2 |
| 7 | CEMI1A | ASE V1 + | Channeltronhochspannung Sensor 1a |
| 8 | CEMHI2 | ASE V2 + | Channeltronhochspannung Sensor 2 |
| 9 | CEMHI3 | ASE V3 + | Channeltronhochspannung Sensor 3 |

Table 30: Analog housekeeping channels
The least significant bit means 20 mV.These voltages are directly proportional to measuring currents and voltages.

Leitung = Line
Bedeutung = Importance
Eingangsstrom = input current
Digitalelektronik = Digital electronics
Channeltronhochspannung = Channeltron high voltage

```
H-91 DSS-63   77 105 07:53:00   FORMAT 13: PAYLOAD1-E1
  B/R:2048     FM 1       DM 3-0                 FN: 103

CURRIA MA +.1360E+01            STATUS     E1PWR   ON
CURRIB MA +.1240E+01
CURRI2 MA +.9800E+00          CREGM2  ON   STATM1  ON
CURRI3 MA +.4000E-01          ZERO     0   CONPOW  ON
CURRD1 MA +.3120E+01          CREGI2  ON   STATI2  ON
CURRD2 MA +.0000E+00          CREGIB  ON   STATIB  ON
CEMI1A KV +.4080E+01 S+       CREGIA  ON   STATIA  ON
CEMHI2 KV +.3640E+01          CREGI3 OFF   STATI3 OFF
CEMHI3 KV +.2800E+00 S+       CREGD1  ON   STATD1  ON
ENCHAN    25                  CREGD2 OFF   STATD2 OFF

 TEMPERATURES                 NORMDM HIG   STATTC OFF
E1ELEC  C +.1295E+02          I2PROA   B   STATC2 OFF
E1SEN1  C +.1540E+02          CREGTC OFF   PRENDS OFF
E1SEN2  C +.2700E+02          AZSHFT PER
E1SEN3  C +.1540E+02          I13CEM 4.1
                              I2HCEM 3.7
```

Figure 23: Representation of the digital and analog Housekeeping data from E1 in the screen format of the mission control.

```
DFVLR-GSOC 3031 OBERPFAFFENHOFEN  GERMAN SPACE OPERATION CENTER        5. 7.80 GMT 17H 53M  25 163MS        PAGE-NO.   18
MISSION      HELIOS-A
                                                                       DM 3-0          FMT 34: EXPT-NOR
                                                                                FW : 216        FRAFE= 0/ 2
STATUS:                                                                D2-OFF   I1A-ON   I2-ON   I1B-ON    WS   I3-OFF
INITIAL DATA:   11110000 10011110 01000111 11110000 10001000 01001010 11110000 00001000
CW: 5                                                                                              F = F 0 / 2
I1B                                        1344   1536   1792   2048   2304   2560   3200   3584   4096   4864
                                          15360  16432  20480  24576  28672  32768  36864  43008  51200
I1A INTEGR.
I2
```

Fig. 24: Infiight test in the NDM, first part
(explanations on p. 117).

Image 24Infiight-Test in the NDM, first part

(1) The status of E1 for this TC is decoded ("initial data") from the 15 words of flow (see table 27).

(2) This count rates are proportional to the plate voltages of I1b.

(3) the same for I1a.If I3 instead of I1a, applies the encoding as specified in table 32.

(4) the same for I2.

(5) In the NDM not the correct voltage due to long changeover time from the low energy range A to high energy sector B in the first 4 AZ-channels.

(6) Similarly for EN25 in AZ1 and AZ2.These channels are to be omitted so when evaluating data.In the HDM this problem does not occur, because before EN17 orEN25 break are (at least) 2 s; because for each block of HDM of 8 EN channels 10 rotations available.

(7) ZGMax returns the address of a channel invented by a random number generator in the I1a/I3 grid in an increased rate is now fed.So will the maximum searcher who must find this artificial maximum, tested, and also the corresponding shift of the measurement grid in the entire grid.The address of this artificially generated maximum is in the words of 13 and 14 of the initial run (see table 27).The encoding of the address is different for I1a and I3 (tables 31 and 32).

(8) These are the 5 x 5 x 5 channels of I1a/I3, which are used here with a fixed frequency, so that the function of the counter can be tested. Would ZGMax happen to fall in this grid, would be at this point to see just the artificial maximum a counting rate of 3072.

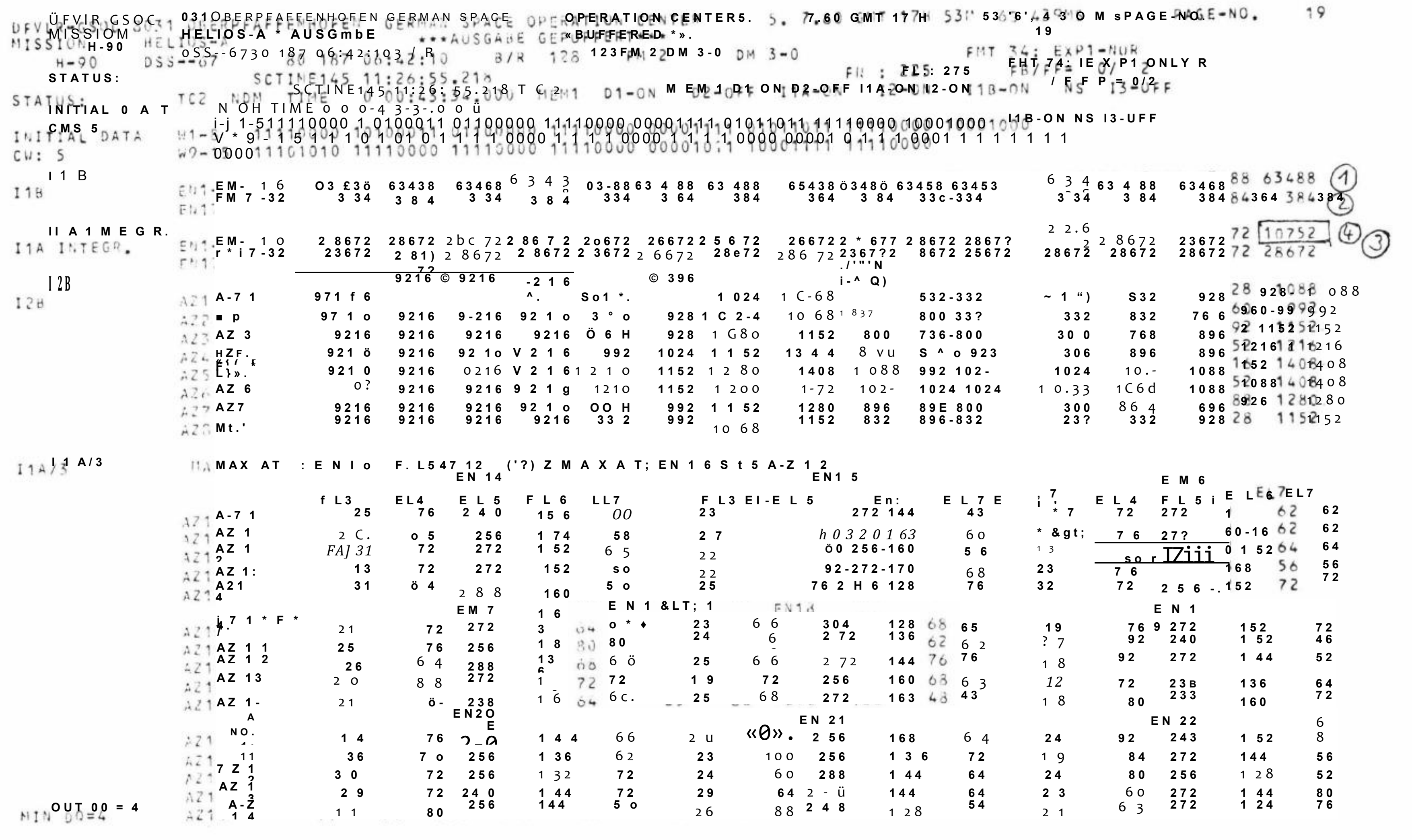



Fig. 25: Infiight test in the NDM, second part
(explanations p. 119/120).

<u>Fig. 25 Infiight test in the NDM, second part</u>

(1) The counter of I1b is tested here from EN1 to EN16 using a test frequency.

(2) From EN 17 to EN32 is the electrometer with a test load applied, so that the consistency of the quantization unit (1000 charges) in flight can be checked (see Figure 23).

(3) Here the I1a integration counter with a fixed frequency will be tested.

(4) EN15 - that is in the place of the artificial maximum - the count rate of the CCO will be shown there, corresponding to the output current of the tested CEMs (from CEM6 to ZGMax) by I1a/I3.

(5) The I2-counter with a fixed frequency will be tested in the first four turns (EN17 - 20).

(6) After it is hung CEM again from I2 to the counter and the UV - Glow lamp switched on.The plate voltage is switched off.

*The flight showed that apparently still some Residual voltages (from a few mV) are on the plates, so solar wind electrons can penetrate.Is the only way to explain that a strong dependency on the test count rate of the AZ channel is observed, quite similar to the way they occur in the lowest EN channel.This complicates some evaluation of the test cycle. This residual voltage increases slightly at each rotation. This repeats every 8 rotations in correspondence with the voltage generation at the plates which are subdivided into 4 groups of 8. That is why the counting rate of channels EN21-24 are pretty much the same as those of EN29-32.*

(7) From here on, the threshold of the CEM-amplifier from the normal value of $5x10^5$ is raised for the remainder of the test to $1X10^7$ charges. If the test count rates are about the same for both thresholds, proves that the CEM still has sufficient gain.

If count rates are lower at elevated threshold, does mean that a part of the pulse contains less than $10^7$ charges.Then care must be taken, and it is advisable to raise the CEM voltage.In the present case, we find: 39936 is the sum of all counts of EN21 until EN24, the comparable total of EN29 until EN32 is 31872, so 25% lower.This result should be slightly distorted by temporal variations in the intensity of the UV-Lamps and not exactly known influence of plasma electrons.Long-term trends are certainly accurate enough to realize.

(8) The maximum seeker has detected so really the artificial maximum.

(9) Also in I1a/I3 now burns the UV-Lamp, and the plate voltages are suspended.The count rates are different in the individual EL channels, because the illumination of channeltrons through the UV lamp is not uniform.

(10) A fixed frequency is entered at the ZGMax address.The average count rate of the concerned channeltrons (here 268) along with the number of CCO 10752 results according to the formula of p. 134 the average amplification $\bar{G} = 1.248 \times 10^6 \times 10752/268 = 5.0 \times 10^7$.

**ENERGIE** EN ZG

(Vorlaufwort 14, bit 4 - 8)

| BIT | | | | | BEDEUTUNG |
|---|---|---|---|---|---|
| B1 | B2 | B3 | B4 | B5 | |
| Ø | Ø | Ø | Ø | Ø | EN-Kanal 1 |
| Ø | Ø | Ø | Ø | L | EN-Kanal 2 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| L | L | L | L | L | EN-Kanal 32 |

**AZIMUT** Az ZG

(Vorlaufwort 13, bit 5 - 8)

| BIT | | | | BEDEUTUNG |
|---|---|---|---|---|
| B1 | B2 | B3 | B4 | |
| Ø | Ø | Ø | Ø | Az-Kanal 1 |
| Ø | Ø | Ø | L | Az-Kanal 2 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| L | L | L | L | Az-Kanal 32 |

**ELEVATION** EL ZG

(Advance Word 13-bit 2-4)

| BIT | | | IMPORTANCE |
|---|---|---|---|
| B1 | B2 | B3 | |
| 0 | 0 | 0 | EL Kanal 5 |
| 0 | 0 | L | EL-channel 2 |
| 0 | L | 0 | EL channel 3 |
| 0 | L | L | EL-Channel 4 |
| L | 0 | 0 | EL Kanal 5 |
| L | 0 | L | EL-channel 6 |
| L | L | 0 | EL-channel 7 |
| L | L | L | EL-channel 8 |

Table 31: Decoding the random number generator for I1a

Bedeutung = Importance
Vorlaufwort = Advance word

**AZIMUT** Az ZG

(Vorlaufwort 13
bit 5 - 8)

| BIT | | | | BEDEUTUNG |
|---|---|---|---|---|
| B1 | B2 | B3 | B4 | |
| Ø | Ø | Ø | Ø | Az-Kanal 1 |
| Ø | Ø | Ø | L | Az-Kanal 2 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| L | L | L | L | Az-Kanal 32 |

**ELEVATION** EL ZG

(Vorlaufwort 13
bit 2 - 4)

| BIT | | | BEDEUTUNG |
|---|---|---|---|
| B1 | B2 | B3 | |
| Ø | Ø | Ø | EL-Kanal 5 |
| Ø | Ø | L | EL-Kanal 2 |
| Ø | L | Ø | EL-Kanal 3 |
| Ø | L | L | EL-Kanal 4 |
| L | Ø | Ø | EL-Kanal 5 |
| L | Ø | L | EL-Kanal 6 |
| L | L | Ø | EL-Kanal 7 |
| L | L | L | EL-Kanal 8 |

**FREQUENZ**

Da bei Sensor 3 die Energiekanäle durch Frequenzkanäle ersetzt werden und ein Maximum nur in den ersten 16 Kanälen gesucht wird, wird der betreffende Frequenzkanal nach der nebenstehenden Tabelle dekodiert:

(Vorlaufwort 6
bit 1 - 3 und
Vorlaufwort 5
bit 7)

| EL-ZG | | | EN ZG | ZUSAMMENSETZUNG |
|---|---|---|---|---|
| B1 | B2 | B3 | B4 | |
| B1 | B2 | B3 | B4 | BEDEUTUNG |
| Ø | Ø | Ø | Ø | F 1 |
| Ø | Ø | Ø | L | F 2 |
| Ø | Ø | L | Ø | F 3 |
| Ø | Ø | L | L | F 4 |
| Ø | L | Ø | Ø | F 5 |
| Ø | L | Ø | L | F 6 |
| Ø | L | L | Ø | F 7 |
| Ø | L | L | L | F 8 |
| L | Ø | Ø | Ø | F 9 |
| L | Ø | Ø | L | F 10 |
| L | Ø | L | Ø | F 11 |
| L | Ø | L | L | F 12 |
| L | L | Ø | Ø | F 13 |
| L | L | Ø | L | F 14 |
| L | L | L | Ø | F 15 |
| L | L | L | L | F 16 |

Table 32: Decoding the random number generator for sensor 3

Bedeutung = Importance
Vorlaufwort = Advance word
Zusammensetzung = Composition

Translation of text to the left:
<u>Frequncy</u>
As sensor 3 the Energy channels will be replaced by frequency channels and a maximum only in the first 16 channels is sought, the frequncy Channel in question is decoded according to the adjacent Table:

Test cycles were used even before the start for precise control the function of the entire experiment.Qualification and acceptance testing experiment level were the four boxes of each E1-unit connected together, as later in the probe.Their tasks such as power supply, Sun pulse, different pulse of telemetry, data acquisition, housekeeping - words etc., were taken over by a special test device.Here, oversaw a small calculator the data generated and reported unacceptable deviations from the nominal values.The computer simulated also commands that gradually offset the experiment in the various switching States, where it was then tested.A similar test program was also always went with the experiment that is integrated in the probe.These system tests, the test program by the "HELIOS test set" (HTS) was controlled and evaluated.

After starting, a similar test program was commanded initially, as when the functional tests on the ground.Since then is commanded in routine operation only once per day a test cycle, recorded in real-time as a paper copy, then sent with the post and evaluated "by hand".

*This is entirely sufficient; a transition to tape recording and computer analysis was planned for some time, then it was allowed to be dropped again . Still, the sharp eye of a savvy connoisseur of instruments is irreplaceable...*

## 5. Description some important assemblies

### Channeltron Amplifier

The Channeltron amplifier is a charge sensitive amplifier, which produces an exit voltage proportional to the charge. Within certain limits, the exit voltage is independent of the stray capacitance found at the entrance of the device.
The Channeltron amplifier (see Figure 26) have a protective circuit at the entrance, Prevent damage to the entry level at any high voltage excess shock at the Channeltron.This is followed by the charge amplifier,

Eingang = Input
Schutzschaltung = protection circuit
Linearer Ladungsverstärker = Linear charge amplifier
Totzeit generator = dead time generator
Impulsbreiten Einstellung = Pulse width setting
Ausgang = Output

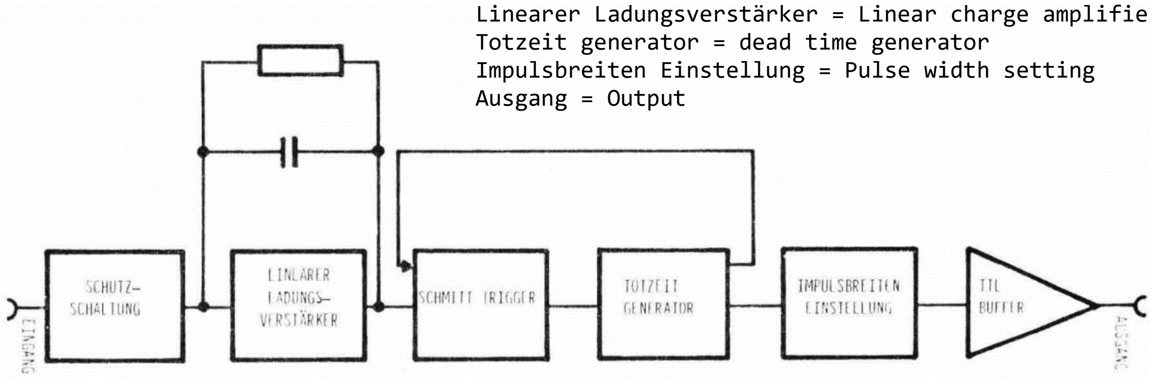



Figure 26: Channeltron amplifier, block diagram

Resistance is parallel to its recovery capacity.The time constant is designed for the highest frequency of 2 MHz.

The following circuit is a threshold discriminator which sets the input sensitivity.It is uniformly $8 \times 10^{-14}$ As, corresponding to a minimum reinforcement of channeltrons of $5 \times 10^{5}$. With the subsequent dead time stage the entrance of the discriminator for a period of time – so called "Dead time" - is blocked.This should amount to at all amplifiers $5 \times 10^{-7}$ s ± 10%.The subsequent pulse Shaper stage ensures a defined output pulse width at different heights of the charge pulses.The subsequent TTL fitting circuit finally ensures the required decoupling, as well as the TTL - compatibility of the output pulses.

Alongside the invariance of the time constant to threshold and temperature, a particular emphasis in the design of the amplifier was to obtain a high overloading threshold since the circuit is considerably overloaded at full Channeltron amplification.

*Unfortunately, the amplifier not all fulfilled requirements to it.We would like the dead time now even shorter.*
*Because in some extreme cases, up to 75% measurement time of the individual channels through dead time was blocked, so that an extrapolation to the real particle flows can be just inaccurate.Although the dead time of the amplifier with the help of artificial pulse from the pulse generator was measured and adjusted.These values were also controlled at the calibration in the realistic interaction of Analyzer, channeltron, amplifiers and counters.Today a more accurate measurement in the finished instrument is desirable us but, with a possible tour of the temperature and the influence of modified Channeltron amplification - both occurs in the course of the mission - should be investigated.*

Electrometer

The block diagram of the Elektrometers is shown in Figure 27.The circuit as it can be seen, divided into two parts: the actual electrometer amplifier and a quantizer facility on the basis of a CCO (current controlled oscillator).
The signal current from the catcher flows to the entrance of the electrometer amplifier and there compensates with the power supplied across the feedback resistor. A corresponding current in the Integrator flows proportional to output voltage arising depending on the size of the input current. the output voltage of the Integrator exceeds a threshold value of the discriminator, the quantizer is appealing and is a counter-pole charge stored in a capacitor in the Integrator, which resets the output voltage of the Integrator to zero.At the same time with the activity of the quantizer a is pulse generated at the output led to a counter.The each output Pulse associated quantization unit QE amounts to $1.6x10^{-16}$ Asec, are 1000 elementary charges .

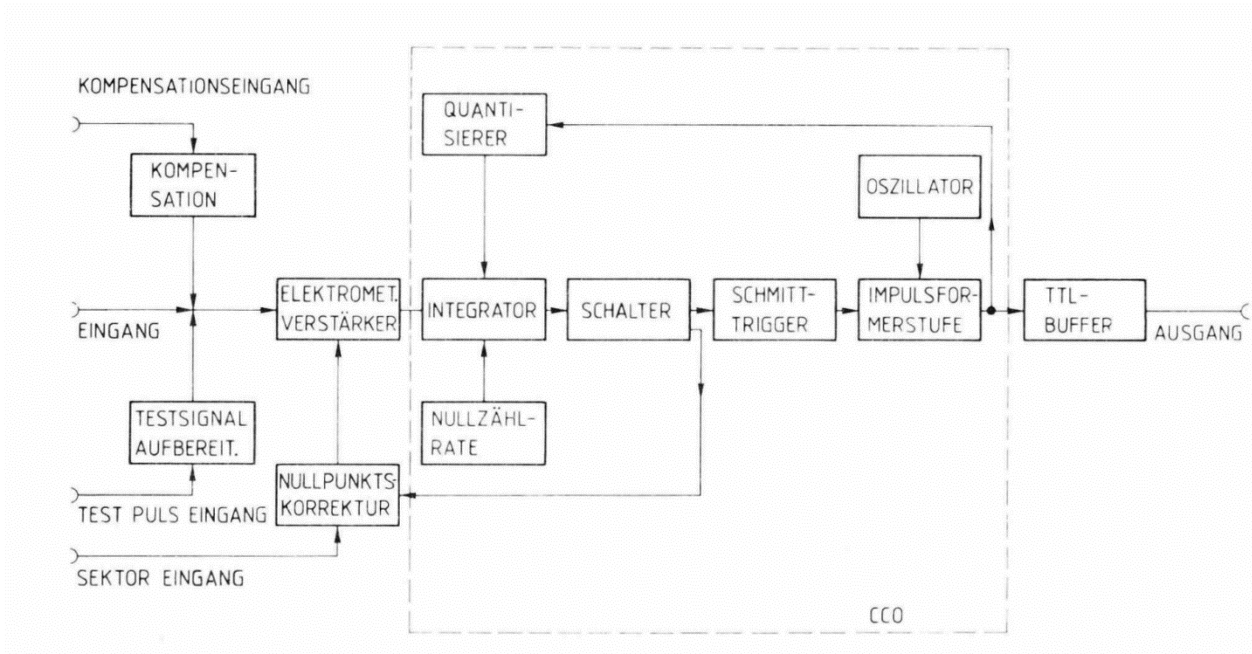



Fig. 27: Electrometer for I1b, block diagram

Kompensationseingang = Compensation input
Quantisierer = Quantiser
Eingang = Input
Verstärker = amplifier
Schalter = switch
Impulsformerstufe = pulse shaper
Ausgang = Output
Aufbereitet = processed
Null zähl rate = Zero count rate
Nullpunktskorrektur = Zero point correction

A larger influx of false interferes with at a logarithmic presentation of results, as she here must be applied, even if it is temporally constant, since small measures are then no longer.For this reason one is so called "zero point correction" is provided.It exploited the fact that only during approximately a half of probe rotation is measured, while in the remaining time, no particles reach on the collector, because of the Sun facing direction occur no particles in the Analyzer.In this phase, an additional feedback when switched on via the switch forces the amplifier output to zero.Thus the second amplifier input input correction voltage remains effective through the store property of the capacitor during the subsequent test phase.

The calibration of the Electrometers is possible with the help of a linearly increasing voltage across a capacitor as a constant influx in the amplifier input and generates a certain count rate at the output.

There a certain capacitive penetration of to the Analyzer plates;
the plate voltage on the collector cannot be avoided, the inverted and

steamed history of Analyzer voltage is applied via the compensation input.This compensates the charge created when switching the plate voltage on the collector.
To achieve integration over the amplifier noise - in particular for small count rates –a so called zero count rate of approx. 20 per measurement channel is set on the electrometer.

*The electrometer works in a manner similar to a capacitor microphone: before the Ion collector a grid with negative potential must be cocked, driving back electrons to the catcher.If this mesh is shaken mechanically, capacitively couples it to the collector and deceptive charges.It is here of course undesirable.But soon after the start of HELIOS 1 the motor for the high-gain antenna in motion was used as "heard"*
*I1b unfortunately very clearly the apparently through friction arising structure-borne sound: the set zero count rate of 22 counts, which previously ranged on average only about 1-2 counts, now jumped between 5 and 40 counts.Later these spread declined somewhat, but it remained an uncertainty for each measured value of about ± 5 counts. This means nothing other than a reduction in sensitivity, and approximately by a factor of 5.For HELIOS 2, hastily made some changes to the I1B amplifier.The fluctuation of the count rates is here less than 1 count.As a result, the high sensitivity of the Electrometers by I1B can be exploited fully.*

*A temperature dependence was measured by the manufacturer for the size of the test charge fed into the flight test. During flight it is however found that the coupled test charges don't decrease with increasing temperature, but the sensitivity of the amplifier does. This is clear from comparison of the measured plasma concentrations of I1a and I1b.Of course, the instrument I1A counting particles has no temperature response.Therefore can from the ratio $V_D$ of the densities, which has a value of 1 at 1 AU and decreases in perihelion to approximately 0.6, the*

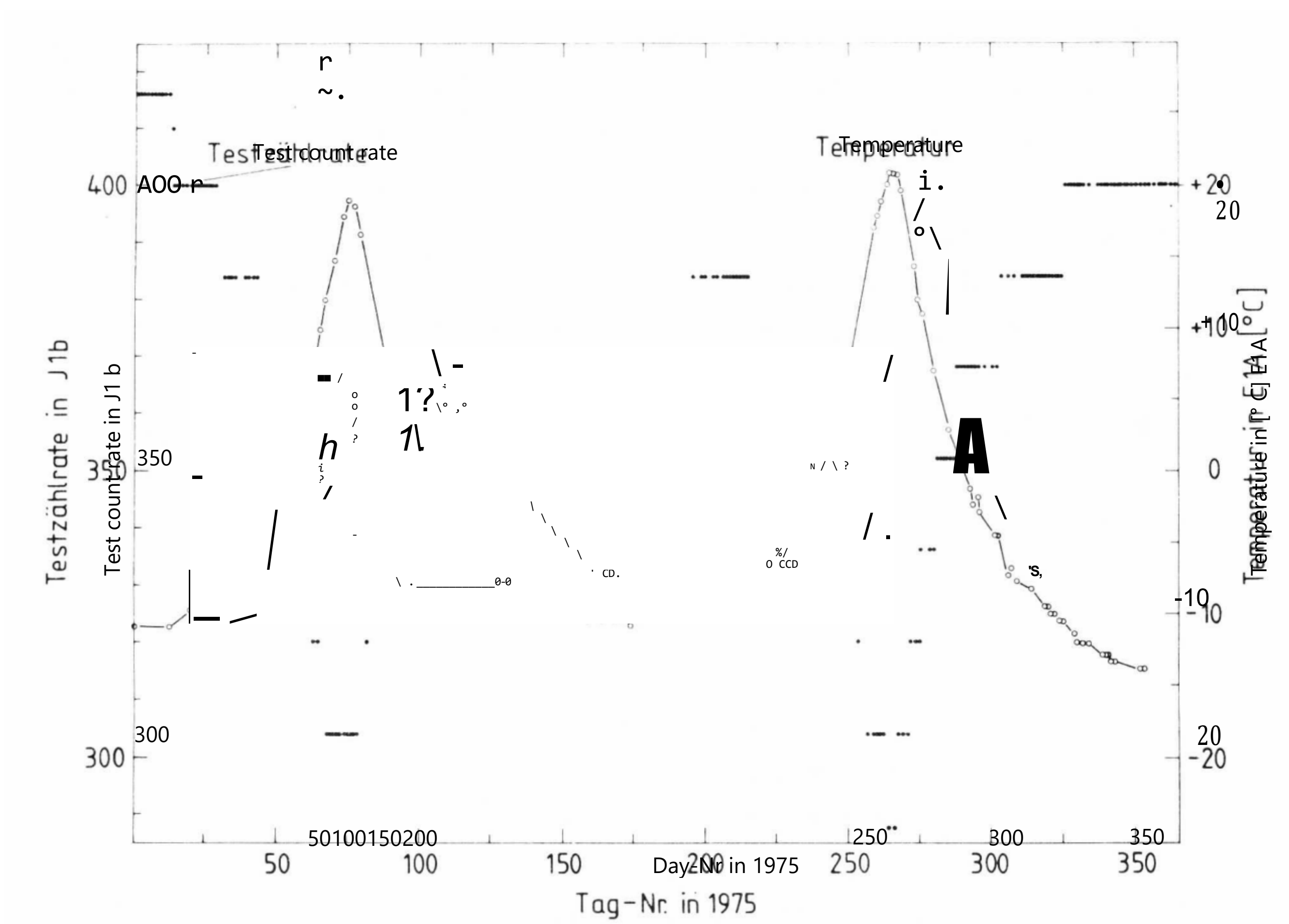
*Changing the I1b sensitivity with the temperature directly derive.It showed view, that $V_D$ (see fig. 28) follows exactly the change the test count rate in relation to their value at 1 AU.Since the test count rate at the inflight tests is regularly measured, one can derive easily the actual sensitivity of the electrometer for I1B.Therefore, this weakness of the instrument has no serious consequences.*

*To find this effect before the launch, we had also realistic operating with particle - temperature tests other than assessing the technical function E.g. need to perform the calibration system -.*

Some characteristics of the Electrometers:

| | | |
|---|---|---|
| Input sensitivity | Eingangsempfindlichkeit | : $1{,}6 \cdot 10^{-15}$As |
| Dynamic range | Dynamikbereich | : $1{,}6 \cdot 10^{-15}$As ... $4 \cdot 10^{-11}$As |
| Output frequency range | Ausgangsfrequenzbereich | : 10 Hz ... 250 kHz |
| Quantization unit (QE) | Quantisierungseinheit (QE) | : $1{,}6 \cdot 10^{-16}$As |
| time constant | Zeitkonstante | : < 60 ms |
| Accuracy | Genauigkeit | : ± 10 % für Q $1{,}6 \cdot 10^{-14}$As |
| | | : ± 8 % für Q $1{,}6 \cdot 10^{-13}$As |
| Set zero count rate | Eingestellte Nullzählrate | : 15 - 20 QE/Messung |
| zero point consistency | Nullpunktskonstanz | : 1 QE |

Messung = Measurement




Test zählrate = Test count rate

Tag = Day

Fig. 28: Changes in test counting rates of I1b, the ratio of the measured per-proton density I1a/I1b and the I1b-temperature during the first year of the mission by HELIOS 1.

Analyzer high-voltage generation

This high-voltage generators work according to the principle of the operational amplifier (see block diagram of Fig. 29). The connection type is not inverting . This means that the transfer function is

$$U_a = U_e \cdot (1 + \frac{R_f}{R_e})$$

Thus, the circuit works as follows:
A reference voltage $U_e$ (switchable for operation cases "shift" and "without") is applied to the noninverting input of the differential amplifier using a voltage divider. The output operates an actuator, which controls the amplitude of the voltage of a resonant converter. The sinusoidal output voltage transforms up into a multiplier cascade. The output voltage $U_a$ is now fed back via high-impedance resistance $R_f$ to the inverting input of the differential amplifier, where the single feed resistance is to ground. Is switched on the 32 logarithmically scaled output voltages such that for each a group of eight consecutive channels a certain reference voltage is applied (by switching on a specific divider resistor). So that means:

$Ue_1$ for channels 1 - 8
$Ue_2$ for channels 9 – 16
$Ue_3$ for channels 17 – 24
$Ue_4$ for the channels 25 - 32
and 0V for 0V output voltage.

The respective 8 individual channels within the 4 groups are set by adjusting 8 different amplifications (switching of $R_e$). This should now be made clear with an example: it should be e.g. Channel 12 will be set. $Ue_2$ is applied and $R_e$ No.4 switched on. Through this type of connection the decoding effort for the channels simplified considerably, since only 8 + 3 = 11, information must be decoded yet another "Shift" or "without". The voltage $Ue_4$ is the full reference voltage, thereby saving a switch.

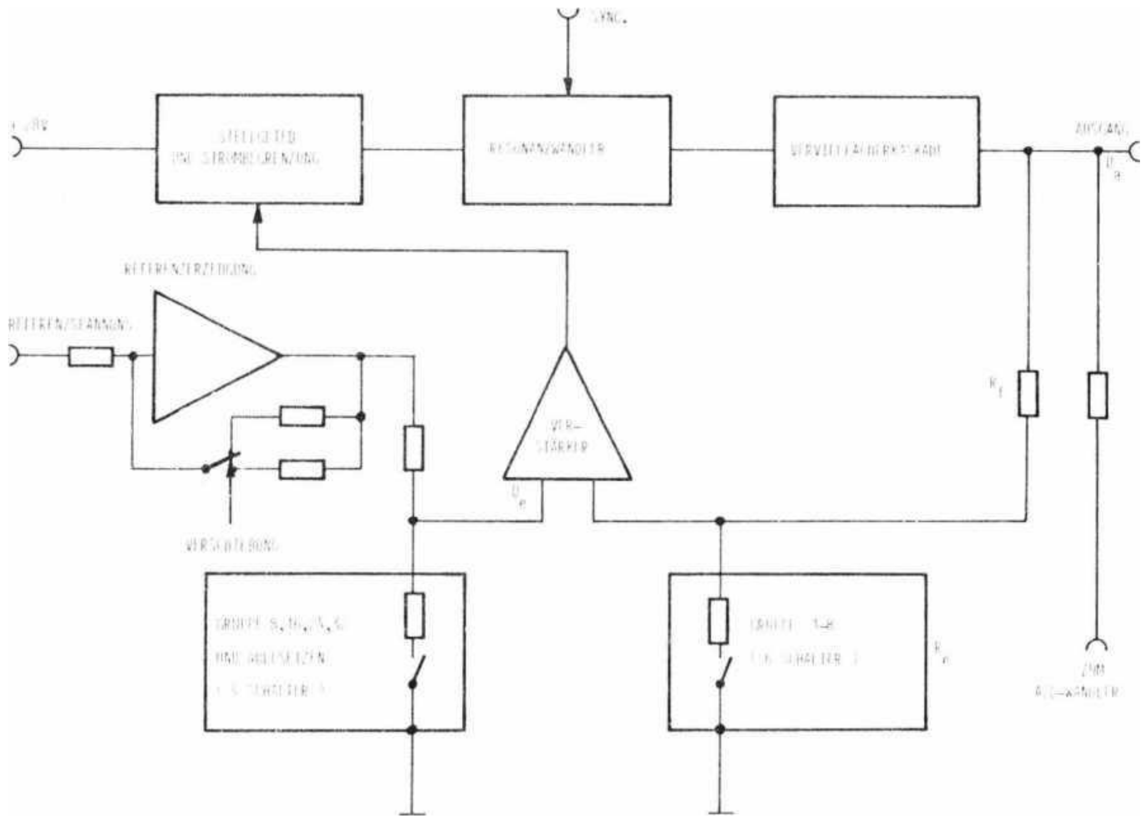



Fig. 29: Analyzer high-voltage generation,
block diagram

60 kHz was chosen as chopping frequency and thus the resonance frequency of the circuit.At this frequency, the stray capacitance of the transformer is still sufficiently small, sufficiently fast diodes are available and the capacity of the cascade can be small enough be selected in order to ensure the required suppression of the ripple of the output voltage on the one hand and on the other hand a fast loading and unloading of the cascade to make sure.The charge current and the cascade capacity are decisive for ramping up the voltage at the output, the feedback resistor and the cascade capacity are decisive for resetting the output voltage from the highest to the lowest value.In the interest of extremely low current consumption and low switching surge, Cascade capacities must thus as small as possible and the feedback resistor to be as large as possible.The actuator of course includes a current limiter which limits the charging current at start-up the voltage and allows only a certain current in the event of a short circuit on the high voltage side.

Some characteristics of the Analyzer high-voltage generation:

| | |
|---|---|
| - 64 switchinhg stages logarithmic ranked | |
| - Output voltage accuracy | : better than 1% |
| - Temperature dependence of the output voltage for sensor 1a and sensor 2 | : ±1% ± 50 mV (-30°C ./. +60°C) |
| - Temperature dependence of the output voltage at sensor I1b | : ±1% ± 250mV (-30°C ./. +60°C) |
| - Output ripple voltage | : 2 % ss |
| - Waste time constant of K32 after K1 | : 200 ms |
| - Settling time | : 3 ms |

In the part of the program A I2, the maximum plate voltage is only 3.33 V (see table 5).The reference voltage is applied directly for these low voltages.To the HV cascade will be shut down via a relay.The Mercury thread relay used has typical switching times of less than 100 ms and is characterized primarily by, that it contains no magnetic components.The relay consists of a glass capillary tube, where a mercury thread by heating a small volume of gas is moving and this connects switching contacts or separates.The reset after shut-down of the filament is due to cooling of the heating volume. The cut-off speed depends only on the degree of cooling, what is normally sufficient the air.For operation in vacuum the glass tubes in a metal sheet sleeve must be matched exactly.This made unexpected difficulties of various kinds.Just a few keywords to name a few: changing heavy thermal loads, extreme requirements for components in the Interior of the sensor and finally the sudden death of the manufacturer of this relay shortly before completion. That’s why we eventually had to do the assembly. While still an Indium-ring was squashed for improving the heat transfer between glass and metal. In the rest position of the relay, runs I2 in program part B, when not connected heaters in part A.

*This old was declared so as fully to explain the failure of I2 on HELIOS 2.Here the heat transition described deteriorated after approx.18 months of Mission so that the switch from program of A to B, i.e.the switch-off of the relay always* *went slower.In each measurement cycle, the relay switch is independent of measurement program and data rate.Therefore, more and more energy channels of part B were now missing in all cycles. Finally, the contact was so bad that the idle state of the relay is probably at all never achieved.Therefore works since that time (about September 77) I2 HELIOS-2 in the A program only.*

## Channeltron high voltage generation

Therefore here only a few characteristics:

| | |
|---|---|
| - 4 gears | : 0 V; 3,3 kV; 3,7 kV; 4,1 kV |
| - Accuracy | : ± 50 V |
| - Internal resistance | : $1\,M\Omega$ |
| - Nominal load at I1a and I3 | : $1{,}6 \cdot 10^8\,\Omega$ |
| - Nominal load at I2 | : $1{,}5 \cdot 10^9\,\Omega$ |
| - Temperature dependence of the output voltage at nominal load | : ± 1% (-30°C ./. +60°C) |
| - Output ripple voltage at nominal Load | : 1,5 $V_{SS}$ |

## Current controlled oscillator (CCO) to the Channeltron Amplification Measure

This circuit is used together with the Channeltron amplifier during the Infiight test to measure the Channeltron amplification.The operational principle of the amplification measurement is as follows: output pulses of a channeltrons (stimulated by the calibration sources) are registered on the one hand about the Channeltron amplifier and counted in the following counters, on the other hand, the charge contents of Channeltron impulse will be transformed into a proportional number of pulses.The charge pulses of channeltrons by the catcher run to first an integrator, whose integration capacitor, as soon as the output voltage exceeds a certain threshold, again will be emptied.

At the same time a pulse is generated at the output, which can be counted.Thus, a current / frequency conversion occurs so.

The relationship between reinforcement of channeltrons and the input current of the CCO is

$$\bar{G} = \frac{i}{e \cdot f_{CEM}}$$

with $\bar{G}$ Channeltron amplification, i the generated electricity, e the electron charge (e = 1.6 x $10^{-19}$ As) and $f_{CEM}$ the number of Channeltron impulse per second.The conversion of the current i in a frequency $F_{CCO}$ on the output of the CCO in accordance with the transfer constant

$$1\,Hz \;\widehat{=}\; 5\,pA.$$

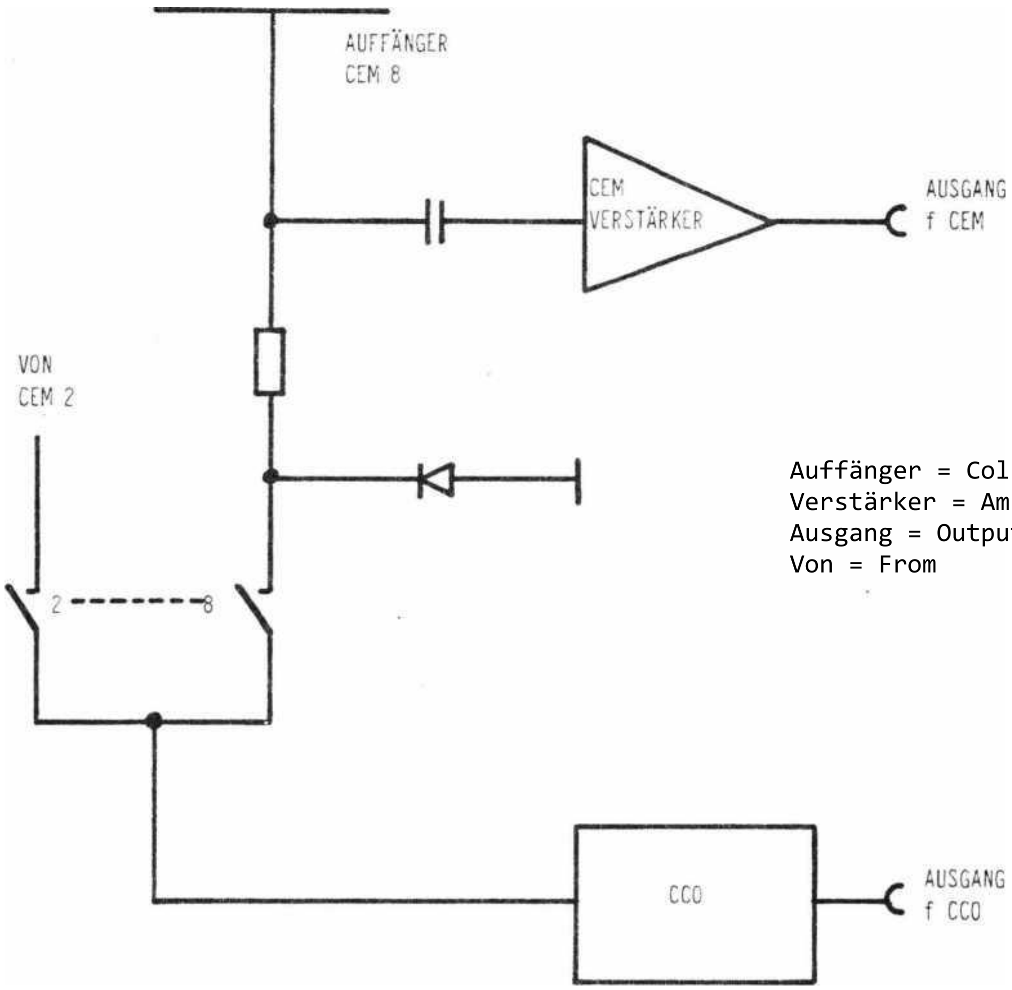
Thus

$$\bar{G} = \frac{5 \cdot 10^{-12}\,Asec\ \cdot f_{CCO}}{1{,}6 \cdot 10^{-19}\,Asec\ \cdot f_{CEM}} = 3{,}12 \times 10^{7} \cdot \frac{f_{CCO}}{f_{CEM}}$$

By replacing each 1 sec-related frequencies occurring during Inflight-test with count results $n_{CCO}$ and $n_{CEM}$, this is the formula

$$\bar{G} = 1{,}248 \times 10^{6} \cdot \frac{n_{CCO}}{n_{CEM}}$$

During the inflight test, depending on the value of the random generator, a Channeltron of number 2 to 8 is switched onto the CCO via a multiplexer. This multiplexer includes management while still a DC limiter.The connection of the CCO in conjunction with the channeltron amplifier is shown in Figure Figure 30.The temperature dependence of the implementation of current in frequency of the CCO is low (~ 4% between - 40° and + 50 ° C).




Auffänger = Collector
Verstärker = Amplifier
Ausgang = Output
Von = From

Fig. 30: Amplification measurement of channeltrons

*Efforts to measure the Channeltron amplification on the fly have paid off greatly.For the first time this long time behavior of channeltrons in outer space could be directly and quantitatively tracked while previously only indirect methods for the quality control of the function were common.This data can certainly considered important independent result that is for future experiments of great importance.*

Ä

High frequency generator

The operational principle of the high-frequency generator was already discussed in chapter I3.It should be entered here only on some important details.
The block diagram of the high-frequency generator is shown in Figure 31.You can see the two interlocking circuits in turn

- the amplitude control circuit and
- the frequency control circuit

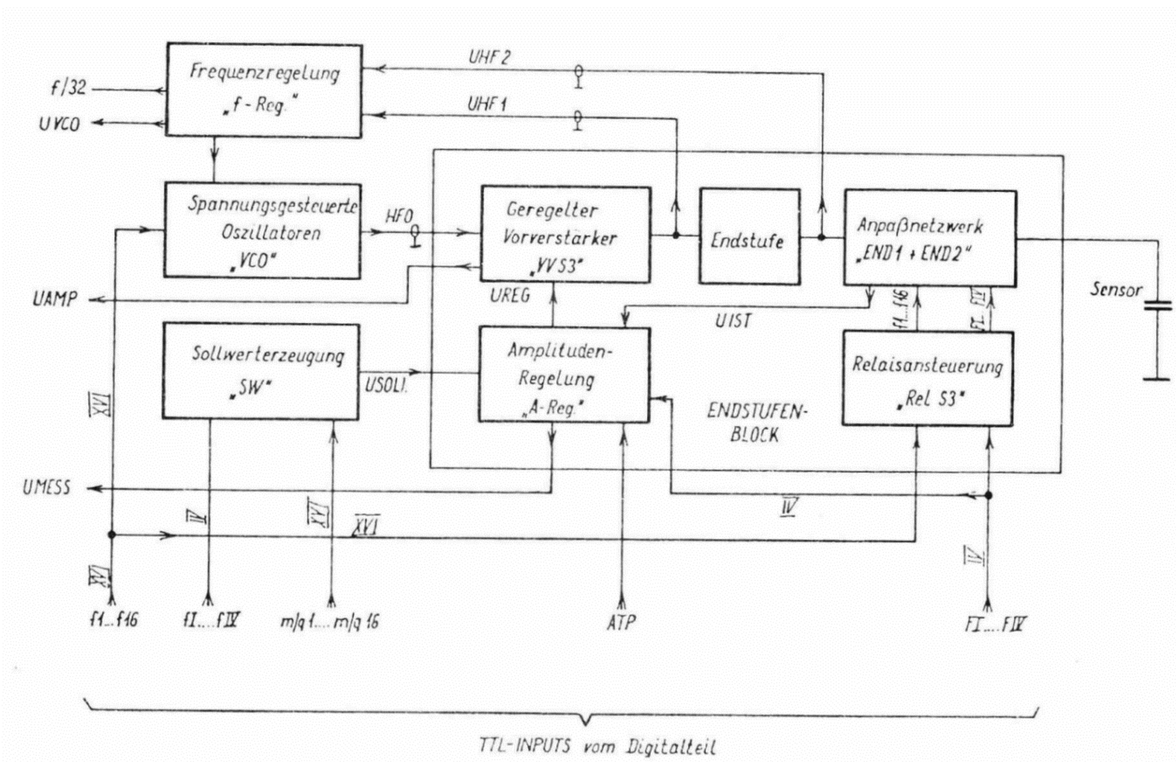



Figure 31: high frequency generator for I3, block diagram

Frequenzregelung = frequency control
Spannungsgesteuerte Oszillatoren = Voltage Controlled Oscillators
Geregelter vorverstärker = Regulated preamp
Endstufe = output stage / amplifier
Anpaßnetzwerk = matching network
Sollwerterzeugung = Setpoint generation
AmplitudenRegelung = amplitude regulation
Endstufenblock = output stage block / amplifier block
Relaisansteuerung = relay control
vom Digitalteil = the digital part

The amplitude control circuit receives its reference from the set value generation and the controlled preamp, where a gain control by means of a FET is performed (AGC) as actuator.The frequency control circuit receives its reference from the resonance frequency of the amplifier and has as

Actuator 16 voltage controlled oscillators, where the frequency is returned by means of a capacity diode.

A waiver on the frequency control was not possible due to the requirement for extremely low power consumption and the required amplitude accuracy of ± 1% (a slight variation of the control frequency compared to the resonance frequency of the amplifier increases power consumption at the high quality of the power amplifier circuit dramatically). The use of 16 crystals were eliminated for the same reason.The use of only one VCO for all 16 frequencies was not possible because of the wide required frequency range and the required fast settling time of for each channel.Therefore, 16 single VCO were employed, which also have the advantage of a considerably higher reliability.

The amplifier circuit is series resonance circuit, controlled by the output stage transistor base, educated. Here a capacitor is used as a plate capacitor and the inductor is an air inductor which is located in a separately screened enclosure. This inductance, together with the disk capacity, the stray capacitance, the adjustment capacity and the load capacity of the capacitive part of output voltage, determines the highest frequency.To further explain of the frequency switch and the recovery of the control voltage for the frequency control circuit and the amplitude control circuit a principle diagram is specified in Fig. 32.From this it appears that the frequency is adjusted by 16 capacity, which the coil in parallel.This reduces the required performance of the power amplifier.The control voltage for the frequency control is created by 4 capacitive divider.This division into 4 groups is necessary to keep the output amplitude range of the control voltage within appropriate limits.The same division into 4 frequency group will also acquiring the control voltage for the amplitude control circuit.It a special capacitive divider with rectification is on each per group, whereas only a divider capacitor with the same relay is switched on in the frequency control.At the same time this relay sets the capacitors for determining the appropriate group of four frequency at the output.A relay is used to keep the capacitive load at the output through the deactivated divider, which sets the not activated groups to ground.Thus.

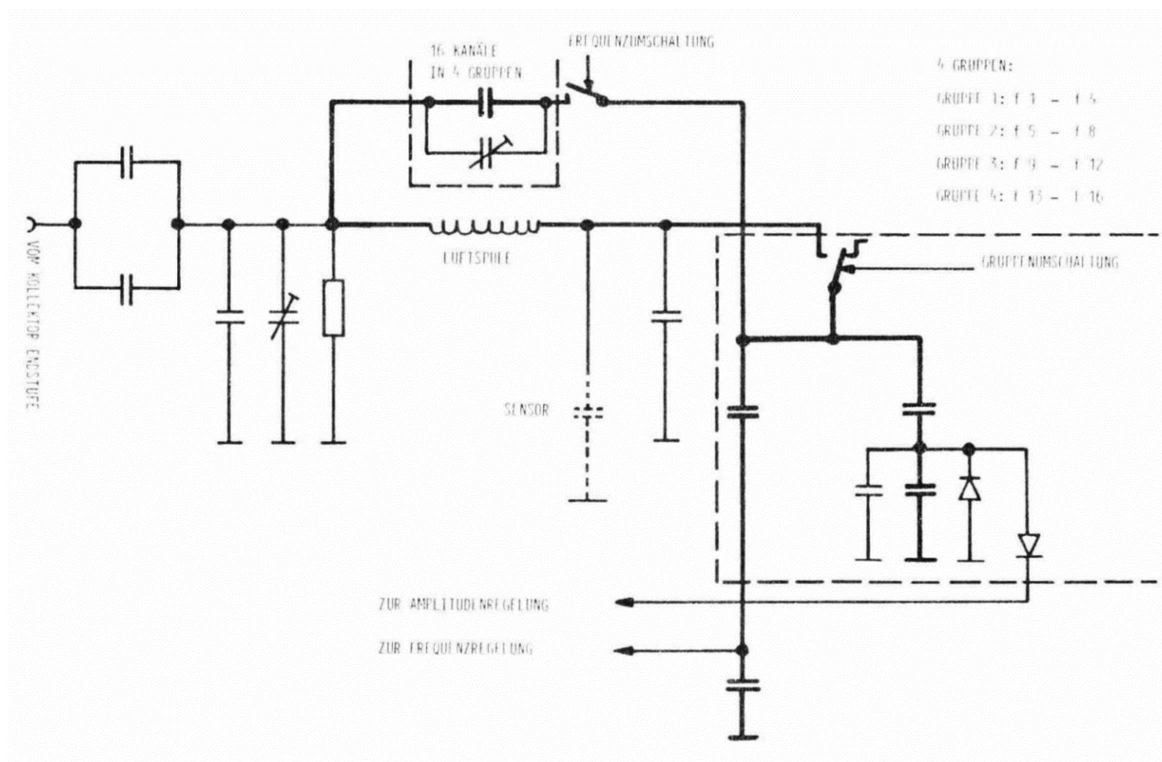



Figure 32: high frequency generator for I3, end circle

von kollektor endstufe = from collector output stage
Frequenzumschaltung = frequency switching
Luftspule = air coil
Gruppenumschaltung = group switchover
Zur = to
Amplitudenregelung = amplitude control
Frequenzregelung = frequency control

the at the same time the not switched capacitors for determining frequency also grounded.Here, the already mentioned mercury relays were also used.The thermal contact improved here with a normal Tin soldering because these relays are in the electronics section.

*Yet none has failed so far.*

Another important facility of the high-frequency generator, which is housed in the amplitude control is used to keep the output voltage during the frequency switch to zero.This is necessary to switch the relay off.At the same time ensured that the amplifier only works if is also measured.This reflected positively on the average power consumption as well as on the EMC behavior.The release of the RF-generator is performed with ATP, with the release

takes place in sufficient time before the start of the first channel of the azimuth that the RF generator has settled, but switching the relay is guaranteed complete. To measure the frequency of the output voltage during the Inflight test, the frequency of from HF voltage by a factor of 32 is divided and led to a counter. To measure the amplitude of the output voltage during Inflight test the decoupled control voltage of the end circle is fed to an analog - to-digital converter. The release of amplitude control voltage in 4 frequency groups facilitates production of 16 x 16 = 256 nominal voltages (see table 8).First, the voltages corresponding to the 16 M/q ratios are generated from a reference voltage by means of 16 switches.Now turning to this reference voltage with the frequency to get the necessary combinations.It found only four switches are required, namely for the four frequencies within the groups of four, because the groups of four switching is done by switching the output voltage divider.
To better understand the decoding of the energy channel counter is specified for the labels used in the block diagram of Fig. 31 table 33.This decoding worried yet another feature, namely the exclusion of certain frequency M/q combinations.The maximum power consumption is limited, voltage amplitudes specified in table 8 can not be exceeded.The institution now ensures that the each last permissible M/q channel remains switched on. Thereby, instead of carrying out measurements in the non-permitted channels, these are performed in those M/q channels where measurements were last permitted.

Some characteristics of the high-frequency generator

- Frequency range : 1 MHz ./. 4 MHz
- Number of channels : 16
- Max.Output voltage (load = 75pF) : 720 $V_{SS}$
- Number of voltage channels : 16 x 16 = 256

| EN | m/q | f arab. | f röm. | F röm. | BEMERKUNKEN |
|---|---|---|---|---|---|
| 1 | 3 | 1 | I | I | FREQUENZEN VON |
| 2 | 3 | 2 | II | I | f 1 BIS f 16 BEI |
| 3 | 3 | 3 | III | I | m/q-KANAL 3 |
| 4 | 3 | 4 | IV | I | |
| 5 | 3 | 5 | I | II | Frequencies of f 1 to f 16 |
| 6 | 3 | 6 | II | II | in m/q channel 3 |
| 7 | 3 | 7 | III | II | |
| 8 | 3 | 8 | IV | II | |
| 9 | 3 | 9 | I | III | |
| 10 | 3 | 10 | II | III | |
| 11 | 3 | 11 | III | III | |
| 12 | 3 | 12 | IV | III | |
| 13 | 3 | 13 | I | IV | |
| 14 | 3 | 14 | II | IV | |
| 15 | 3 | 15 | III | IV | |
| 16 | 3 | 16 | IV | IV | |
| 17 | 1 | 6 | II | II | FREQUENZ NACH MAXIMUM- |
| 18 | 2 | 6 | II | II | REGISTER BEI NDM, |
| 19 | 3 | 6 | II | II | NACH HDM-ZÄHLER BEI |
| 20 | 4 | 6 | II | II | HDM ( ANGENOMMEN f 6 ) |
| 21 | 5 | 6 | II | II | m/q-KANAL VON 1 BIS 16 |
| 22 | 6 | 6 | II | II | |
| 23 | 7 | 6 | II | II | Frquency to maximum |
| 24 | 8 | 6 | II | II | register at NDM, according |
| 25 | 9 | 6 | II | II | to HDM counter at HDM |
| 26 | 10 | 6 | II | II | (adopted f 6) m/q channel |
| 27 | 11 | 6 | II | II | from 1 to 16 |
| 28 | 12 | 6 | II | II | |
| 29 | 13 | 6 | II | II | |
| 30 | 14 | 6 | II | II | |
| 31 | 15 | 6 | II | II | |
| 32 | 16 | 6 | II | II | |

Table 33: Decoding to the control of the
high-frequency generator for I3

Bemerkunken = Remarks

- Settling Time : 30 ms
- Accuracy of output voltages : ± 1 %
- Temperature dependence of the output voltages : ± 1 % (-25°C ./. +55°C)
- Accuracy of frequencies : ± 0.5 %
- Temperature dependence of the frequencies : ± 0.5 % (-25°C ./. +55°C)
- Harmonic content of the output voltage : -34 dB compared to the fundamental wave

Counter

The meters are built as a 16-stage binary counter, whose opening time is determined by the control flow.It also controls the parallel transfer of the count results in a shift register which is read serially.This solution is selected for one to keep the wiring costs within limits, on the other hand, the serial transfer of counting results for the production of a quasi logarithmic compressed 8-bit representation is required.
The meters were not built to reduce the effort required and the power consumption as self-reducing meters, but it usesa central reduce plant for all 12 counter.

Reduce plant

The reduce plant has the task to carry over a binary counting result with 16-bit in a display with 4-bit exponent and 4-bit mantissa.As a result, the required data transfer rate is halved, with a minimal reduction in accuracy.
The exponent is determined by finding the number of zeros between the highest-value bit and the leading "L" in the 16-bit word that is to be reduced, not exceeding 16-4=12. The mantissa consists of the 4 bits following the leading "L".

Decoding is performed by the formula

$$\text{Count rate} = \begin{cases} (M+16)\cdot 2^{11-E} & \text{for } E \leq 11 \\ M & \text{for } E = 12 \\ \text{Faulty} & \text{for } E > 12 \end{cases}$$

The number 17 for example is represented as follows:

L Ø L L Ø Ø Ø L

Table 34 shows the appearance of all counting results can occur.You can see from the fact that when count rates from 32 which decoded values in the Middle will be lower than the original. E.g.the numbers are encoded 64, 65, 66, 67 all 64.During the evaluation we make the value 66, according to the center of the area.The maximum deviation from the true value is 3.1% in the worst case.
The technical implementation looks like this:
The counting process is completed in one sector, gets the core of reduce plant by the sequencing of the statement to evaluate a particular counter.To do this, the contents of the counter is applied to the Counter shift register (the counter can then be already put back and called again).Now, the information is moved as long as, until the leading "L" is found, or only 4 bit is not tested.It counts the number of shifts in the numerator of the exponent.There are now 2 cases to distinguish:

a) it became a "L" within the first 12-bit found:

The counter register is pushed on a bit, but not the exponent count.As a result, the leading "L" is eliminated; their existence and exact location has already registered the exponent count.Now the binary exponent counter state is taken parallel to the exponent register (4 bit).Exponent and counter registers are switched in series and this 8 bit is then pushed into the memory input register and stored.Then, the process can start it again if a group of counters will be reduced (at I1a or I3).

| | | | |
|---|---|---|---|
| LLOOOOOO | 0 | LOLOOOOO | 32 |
| LLOOOOOL | 1 | LOLOOOOL | 34 |
| LLOOOOLO | 2 | LOLOOOLO | 36 |
| LLOOOOLL | 3 | LOLOOOLL | 38 |
| LLOOOLOO | 4 | LOLOOLOO | 40 |
| LLOOOLOL | 5 | LOLOOLOL | 42 |
| LLOOOLLO | 6 | LOLOOLLO | 44 |
| LLOOOLLL | 7 | LOLOOLLL | 46 |
| LLOOLOOO | 8 | LOLOLOOO | 48 |
| LLOOLOOL | 9 | LOLOLOOL | 50 |
| LLOOLOLO | 10 | LOLOLOLO | 52 |
| LLOOLOLL | 11 | LOLOLOLL | 54 |
| LLOOLLOO | 12 | LOLOLLOO | 56 |
| LLOOLLOL | 13 | LOLOLLOL | 58 |
| LLOOLLLO | 14 | LOLOLLLO | 60 |
| LLOOLLLL | 15 | LOLOLLLL | 62 |
| LOLLOOOO | 16 | LOOLOOOO | 64 |
| LOLLOOOL | 17 | LOOLOOOL | 68 |
| LOLLOOLO | 18 | LOOLOOLO | 72 |
| LOLLOOLL | 19 | LOOLOOLL | 76 |
| LOLLOLOO | 20 | LOOLOLOO | 80 |
| LOLLOLOL | 21 | LOOLOLOL | 84 |
| LOLLOLLO | 22 | LOOLOLLO | 88 |
| LOLLOLLL | 23 | LOOLOLLL | 92 |
| LOLLLOOO | 24 | LOOLLOOO | 96 |
| LOLLLOOL | 25 | LOOLLOOL | 100 |
| LOLLLOLO | 26 | LOOLLOLO | 104 |
| LOLLLOLL | 27 | LOOLLOLL | 108 |
| LOLLLLOO | 28 | LOOLLLOO | 112 |
| LOLLLLOL | 29 | LOOLLLOL | 116 |
| LOLLLLLO | 30 | LOOLLLLO | 120 |
| LOLLLLLL | 31 | LOOLLLLL | 124 |

Table 34: Quasi-logarithmic compression
(numbers 0 - 124)

| | | | |
|---|---|---|---|
| LOOOOOOO | 128 | OLLOOOOO | 512 |
| LOOOOOOL | 136 | OLLOOOOL | 544 |
| LOOOOOLO | 144 | OLLOOOLO | 576 |
| LOOOOOLL | 152 | OLLOOOLL | 608 |
| LOOOOLOO | 160 | OLLOOLOO | 640 |
| LOOOOLOL | 168 | OLLOOLOL | 672 |
| LOOOOLLO | 176 | OLLOOLLO | 704 |
| LOOOOLLL | 184 | OLLOOLLL | 736 |
| LOOOLOOO | 192 | OLLOLOOO | 768 |
| LOOOLOOL | 200 | OLLOLOOL | 800 |
| LOOOLOLO | 208 | OLLOLOLO | 832 |
| LOOOLOLL | 216 | OLLOLOLL | 864 |
| LOOOLLOO | 224 | OLLOLLOO | 896 |
| LOOOLLOL | 232 | OLLOLLOL | 928 |
| LOOOLLLO | 240 | OLLOLLLO | 960 |
| LOOOLLLL | 248 | OLLOLLLL | 992 |
| OLLLOOOO | 256 | OLOLOOOO | 1024 |
| OLLLOOOL | 272 | OLOLOOOL | 1088 |
| OLLLOOLO | 288 | OLOLOOLO | 1152 |
| OLLLOOLL | 304 | OLOLOOLL | 1216 |
| OLLLOLOO | 320 | OLOLOLOO | 1280 |
| OLLLOLOL | 336 | OLOLOLOL | 1344 |
| OLLLOLLO | 352 | OLOLOLLO | 1408 |
| OLLLOLLL | 368 | OLOLOLLL | 1472 |
| OLLLLOOO | 384 | OLOLLOOO | 1536 |
| OLLLLOOL | 400 | OLOLLOOL | 1600 |
| OLLLLOLO | 416 | OLOLLOLO | 1664 |
| OLLLLOLL | 432 | OLOLLOLL | 1728 |
| OLLLLLOO | 448 | OLOLLLOO | 1792 |
| OLLLLLOL | 464 | OLOLLLOL | 1856 |
| OLLLLLLO | 480 | OLOLLLLO | 1920 |
| OLLLLLLL | 496 | OLOLLLLL | 1984 |

Table 34 (Continued): Quasi-logarithmic compression (numbers 128 - 1984)

| | | | |
|---|---|---|---|
| OLOOOOOO | 2048 | OOLOOOOO | 8192 |
| OLOOOOOL | 2176 | OOLOOOOL | 8704 |
| OLOOOOLO | 2304 | OOLOOOLO | 9216 |
| OLOOOOLL | 2432 | OOLOOOLL | 9728 |
| OLOOOLOO | 2560 | OOLOOLOO | 10240 |
| OLOOOLOL | 2688 | OOLOOLOL | 10752 |
| OLOOOLLO | 2816 | OOLOOLLO | 11264 |
| OLOOOLLL | 2944 | OOLOOLLL | 11776 |
| OLOOLOOO | 3072 | OOLOLOOO | 12288 |
| OLOOLOOL | 3200 | OOLOLOOL | 12800 |
| OLOOLOLO | 3328 | OOLOLOLO | 13312 |
| OLOOLOLL | 3456 | OOLOLOLL | 13824 |
| OLOOLLOO | 3584 | OOLOLLOO | 14336 |
| OLOOLLOL | 3712 | OOLOLLOL | 14848 |
| OLOOLLLO | 3840 | OOLOLLLO | 15360 |
| OLOOLLLL | 3968 | OOLOLLLL | 15872 |
| OOLLOOOO | 4096 | OOOLOOOO | 16384 |
| OOLLOOOL | 4352 | OOOLOOOL | 17408 |
| OOLLOOLO | 4608 | OOOLOOLO | 18432 |
| OOLLOOLL | 4864 | OOOLOOLL | 19456 |
| OOLLOLOO | 5120 | OOOLOLOO | 20480 |
| OOLLOLOL | 5376 | OOOLOLOL | 21504 |
| OOLLOLLO | 5632 | OOOLOLLO | 22528 |
| OOLLOLLL | 5888 | OOOLOLLL | 23552 |
| OOLLLOOO | 6144 | OOOLLOOO | 24576 |
| OOLLLOOL | 6400 | OOOLLOOL | 25600 |
| OOLLLOLO | 6656 | OOOLLOLO | 26624 |
| OOLLLOLL | 6912 | OOOLLOLL | 27648 |
| OOLLLLOO | 7168 | OOOLLLOO | 28672 |
| OOLLLLOL | 7424 | OOOLLLOL | 29696 |
| OOLLLLLO | 7680 | OOOLLLLO | 30720 |
| OOLLLLLL | 7936 | OOOLLLLL | 31744 |

Table 34 (Continued): Quasi-logarithmic compression (numbers 2048 - 31744)

| | |
|---|---|
| OOOOOOOO | 32768 |
| OOOOOOOL | 34816 |
| OOOOOOLO | 36864 |
| OOOOOOLL | 38912 |
| OOOOOLOO | 40960 |
| OOOOOLOL | 43008 |
| OOOOOLLO | 45056 |
| OOOOOLLL | 47104 |
| OOOOLOOO | 49152 |
| OOOOLOOL | 51200 |
| OOOOLOLO | 53248 |
| OOOOLOLL | 55296 |
| OOOOLLOO | 57344 |
| OOOOLLOL | 59392 |
| OOOOLLLO | 61440 |
| OOOOLLLL | 63488 |

Table 34 (Continued): Quasi-logarithmic
compression (numbers 32768 - 63488)

(b) there has been found no "L":

Then, only four unverified bits are in the counter register.Now becomes the State of Exponent counters (binary 12) taken in the exponent register.Analog then becomes a) procedures.

Due to the serial reduction, which is useful for reasons of simpler wiring and the simple structure of the counter, a bottleneck is created with regard to the reliability. This problem was solved because the counter as well as the reducer are built in redundancy.

*The maximum possible result of the count of 63488 proved to be just enough.Only in some cases in the perihelion achieved by I2 values of over 50000, but never over 63488.the full dynamic range of I2 of over $10^5$ (high counting rates the amp dead time is already a significant part) was thus fully exploited.*

<u>memory</u>

The measuring cycle of the sensors and thus of the experiment is spin synchronous, the transfer of the measurement results to the telemetry, however, time-synchronous.This resulting in a continuous shift of measuring cycles within the time grid of telemetry.The two experiment stores that take per a whole block of data are used to compensate for this delay.The amount of memory is by the boundary conditions of the telemetry system i.e.set the length of a data frame:

- Normal data mode: 432 words = 3456 bit
- High Data mode: 504 words = 4032 bit

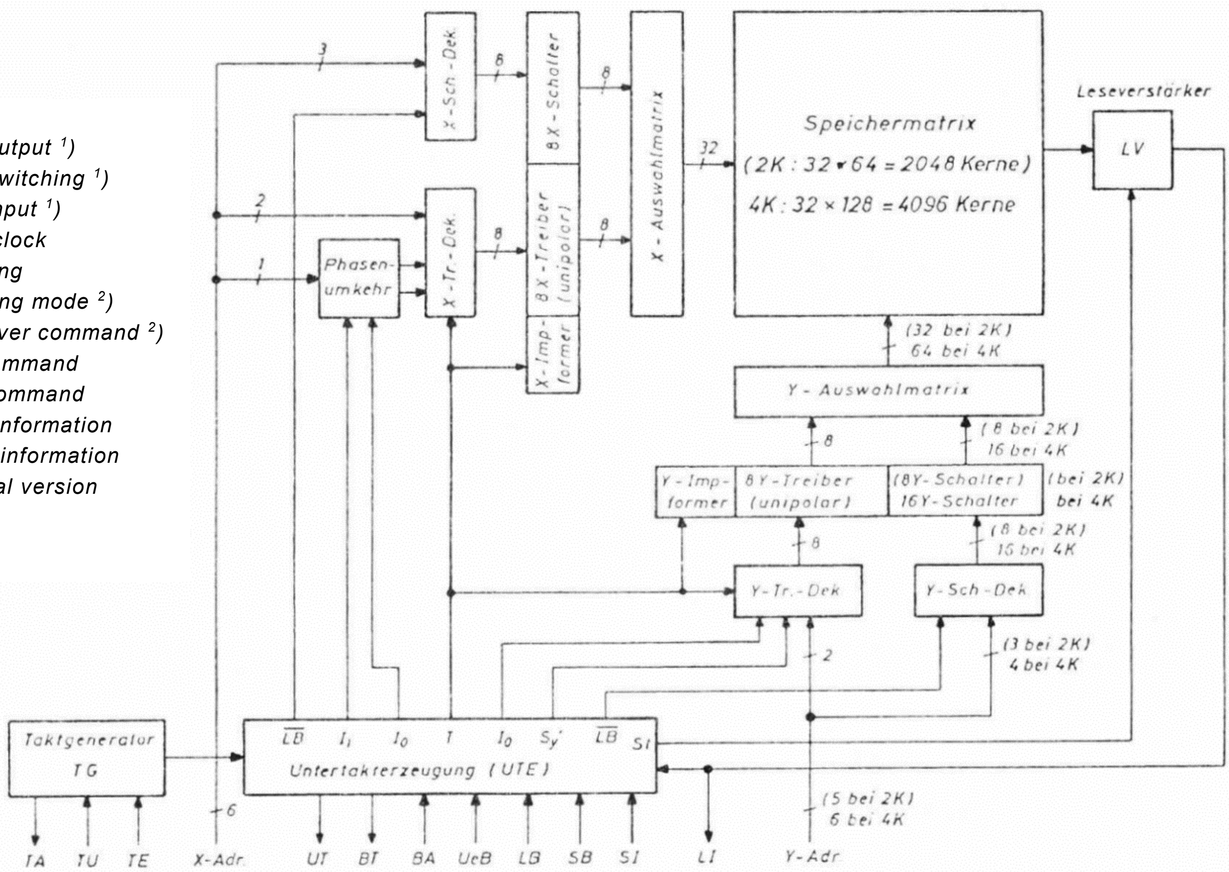
Therefore, a memory size of 4096 bits per memory selected.

While data are inscribed in a store, the other memory is read by the telemetry. Semiconductor memory originally scheduled for COSMOS engineering, which are characterized by extremely low power consumption.At the time, appointment reasons, the execution had to be set, as the qualification procedure for the detection of airworthiness for the building blocks of the COSMOS was not yet completed.From project management COSMOS logic was decided completely excluded from use.This made us see considerable additional costs to switch to core memory, as well as low-power TTL technology.This caused also the power consumption of the plasma experiment increased by approx.6 W.

*That turned out to be unexpectedly view advantage later in the mission: If at 1 AU available power is no longer enough to to operate of the heating mats in the central part of HELIOS, E1 is greatly appreciated in his capacity as a stove and enjoys high priority...*

The inner structure of the memory for the block diagram is shown in Fig. 33.As in any current coincidence core memory, the information from a core of memory matrix is read using each one half stream on an X and a Y-range line in temporal coincidence.At the same time, this operation is equivalent to writing a '0'.To write a "1" in the same core the same selection lines with each a half power of opposite polarity must be excited at the same time.When reading the selected memory core is switched to it‘s "O"-State .Depending on the stored information, the core produces a different reading signal being queried in the read amplifiers according to amplitude and temporal location. The digitised signal is provided to flip flop which comes after the input sensor amplifier and is available until the next cycle in the memory on data ouput LI. If the information read is to be saved further, this is performed immediately after the reading process by writing it into the same memory cell. Instead of the read information, the information on the data in the SI can be written either.

*Legend*
*TA: clock output [1])*
*TU: clock switching [1])*
*TE: clock input [1])*
*UT: under clock*
*BT: Bit timing*
*BA: operating mode [2])*
*UeB: takeover command [2])*
*LB: read command*
*SB: write command*
*SI: writing information*
*LI: reading information*
*[1]), [2]) Special version*




```
Schalter = Switch
Phasenumkehr = phase reversal
Treiber = Driver
Auswahlmatrix = selection matrix
Speichermatrix = memory matrix
Kerne = cores
Leseverstärker = read amplifier
Bei = at
Taktgenerator = clock generator
Untertakterzeugung = Under clock generation
```

Figure 33: Block diagram of the core memory

The required current pulses are generated for each coordinate of the storage matrix from one of 8 unipolar power drivers, which are logically grouped together for 4 pairs of bipolar driver and with the help of 8 or16 existing switch across the related selection matrix on the storage matrix selection lines.The selection matrices are specially adapted decoding circuits, that guide the driver current with the specified polarity in the corresponding selection wire of the memory matrix to each driver-switch combination power control.
The control of the driver and switch is done via a decoding of the address with Lp TTL gates.Also the impulses came from the lower clock generation are fed into this decoding, which cause the correct timing of the memory cycle.To reduce the number of inputs by selecting lines on the half in a coordinate, the store works on the principle of the phase reversal, the

later explained.The phase reverse control is the X-driver - decoding is placed in position.
Two memory can be operated synchronously to a clock generator and the entire data processing (data transfer, reducing plant, storage control), output the output signal of the clock generator.
With the help of the clock switch TU can be toggled between internal and external clock.Details on this are in the technical description of the core memory with operating and handling instructions.

## Memory Controller

During the writing of data to the memory clock, the memory controller has the following tasks:

- Formatting the data in memory
- Calling the appropriate memory locations
- Providing data to the store

While reading out a store by the telemetry, the memory controller has the following tasks:

- Serial selection control of individual memory locations
- Control by the telemetry clock
- Submission of data to the telemetry.

Memory formatting was shown in figures 21 and 22 for the two data formats.These formats, as well as the importance of individual data have been explained already in detail.The writing of the "first runnings" - General data about the status of the instruments are, time information, as well as code words - is carried out parallel data transfer and serial output of the memory in the memory clock.This, the value will be held in the registers, in which the advance is made, which is when the first channel of a measurement cycle is turned on.

This also applies to the S/C-time.A counter is intended for selecting the memory locations, which is one of the 15 words.
Concerning the data, the control flow together with program control Announces originate from which sensor the currently available data.Each instrument and the integration counter is associated with a counter, from whose state the corresponding space selected.
The counter is advanced after writing of each word, with each counter being assigned a specific memory location. The distribution of the memory slots on the individual instruments is also shown in figures 21 and 22.The number of words is different in the two modes of data.The required counter length and set of the Word numbers range is performed by the program control.
When reading the memory the individual counters are connected in series now, and with each so called "Word transfer control pulse" (WTC) is forwarded this total counter by a Word.So the memory is read serially.The following signals are used to control readout of the satellite telemetry:

- BTC (block transfer control signal)
  It says when the telemetry begins reading from a store, and when she's done.
- WTC (Word transfer control signal)
  It says the same thing as above, only based on a single 8-bit word.With this, the memory controller is switched.
- BSP (bit shift pulse)
  This is the data transfer clock, with which also the timing of the store takes place.

Maximum viewfinder and data control

The maximum viewfinder is a part of the program control for the most data-intensive tools I1a or I3.

- Finding the channel with the highest count rate
- Save the address of this channel
- Selecting the next measuring cycle according to this address to be memorized data

If all 4608 count rates (9 elevation channels, 16 channels of azimuth, 32 energy) a measurement of I1A or I3 to earth should be delivered, a totally inadequate temporal resolution would be achieved at the specified rate of telemetry.Therefore, only a specific selection of data is transferred, which contains the most important parts of a spectrum.This will be explained later.Initially only the technique.

During a measuring cycle of the sensor 1a or 3 the highest result of the count and the corresponding address is determined from all counting results first.This address is then used in the next measuring cycle, in which of course the address of the channel with the highest count rate determined for the selection of to be memorized data.Are the three coordinates of the maximum address EL ($\xi$), AZ ($\beta$) and EN ($\alpha$), so then the channels with the following addresses stored:

EL ($\xi - 2$), EL ($\xi - 1$), EL ($\xi$), EL ($\xi + 1$), EL ($\xi + 2$),
So 5 elevation channels

AZ ($\beta - 2$), AZ ($\beta - 1$), AZ ($\beta$), AZ ($\beta + 1$), AZ ($\beta + 2$),
So 5 azimuth channels

EN ($\alpha - 2$), AZ ($\alpha - 1$), AZ ($\alpha$), .... , AZ ($\alpha + 6$)
So 9 energy channels.

[Please note: The line beginning with EN has been written as it appears in the original report, however it is believed that the AZ on this line should be replaced with EN.]

That’s a total of only 5 x 5 x 9 = 225 words from the original 4608.For those cases in which the maximum address as close to the edge of the measuring range, that not the entire frequency range in the measuring range would fall, the block is moved so that its edge to fall along with the edge of the measuring range. The address of the channel of the highest count rate is calculated with a binary comparator.The counting result, which has been identified so far as largest is located in a register.The new result is loaded in a second register.This is greater, the comparator shall inform.Then loaded the status of the three channel counter (EL, AZ and EN) into the so called Address register ( EL, AZ and EN).At the end of a measurement cycle, the status of this search register is loaded in the work register and the search register deleted.This latter is looking for the address of the maximum channel again in the next cycle.The work register is counting backwards now to 2 cycles and can control the storage of the data.It starts so two channels before the maximum.The respective end of transmission (5 bars at EL, 5 bars in AZ and 8 bars in EN) are hard-coded.The addresses to close on the edge (see above) so is, if they are at the end, as long as back clocked until the last channel can be transmitted, If they are at the beginning, is only to register status 0000..., which corresponds to the first channel.The data control is done now so that the maximum-working register is compared with the elevation channel counter, azimuth channel counter and energy channel counter.The channel number of the maximum of work register in EL, AZ and EN is reached, which is determined by the default as a starting point for the data storage, the registry runs with with the channel counters.A data storage is done whenever the register level is within the programmed range.

Flow Control

The control has the following tasks:

- Generation of the angle grid (open and close the counter)
- Production of the grid to read and reset of the counter
- Production of the channel grid (EN)
- Production of the measuring cycle times
- Creation of all necessary pulses to control the sensors

They essentially used the spin-synchronous pulse chain offered by the probe system from 512 pulses per revolution.Thus, a part of the control of flow consists of a counter that counts this 512 pulses per revolution.It decodes all sectors (AZ), also all impulses that are required to control the sensors.In table 9 all important angles were represented for HELIOS 1, (in table 10 for HELIOS 2).After a measurement on an azimuth channel nine counters must be read at sensor 1a and 3.This is done by means of the lower clock of the memory clock.The latter is the transmission of serial data, while the lower clock synchronously Gets each single counter.
The second part of the control of flow consists of 3 counters:

- the elevation channel counter
- the azimuth channel counter
- the energy channel counter

The elevation channel counter is a modulo 9-counter, which is timed by the memory sub clock after each azimuth channel of each energy channel.
The azimuth counter is a modulo-16 counter that is clocked by the azimuth sector impulses and counts once per each energy channel.
The energy channel counter counts up to 32 and thus indicates the end of a cycle.This is clocked by the solar impulse "see sun pulse", which increases the counter per satellite revolution by one.

Construction technology

The basic construction technology of electronics is based on using bi layers with plated version with arrangement of elements on a page.Figure 34 shows such a version with digital components (integrated circuits), while Figure 35 shows a design with discrete components.

The following should be entered only on some special solutions of construction technology.

This one is first so called "Motherboard" plug-in to mention, which was used in the construction of nine Channeltron amplifier.It was a motherboard used here, which includes all inputs, outputs and connectors and the wiring of the individual boards with each other.At the same time, this Board is carrier of the nine CEM amplifier, ten shields, as well as of the CCO.These boards are plugged with plugs into the motherboard.On the individual boards, appropriate spacer rollers are applied to the intervals so that the installation of the entire "Channeltron amplifier block" in the sensor electronics housing by means of bolts can be performed.Figure 36 shows this block.

Another special form of the building represents the electrometer that was housed in a cavity created by the hemispherical plates to ensure minimum distance between catcher and electronics.The building had to be so round and semi-spherical.Figure 37 shows this structure.

A special building technique was to apply when the high-voltage equipment in the interests of weight savings and the required safety of high-voltage equipment.Compared to the conventional encapsulation technique of the Cascades and the high-voltage transformer, following solution was chosen:

- Transformer with maximum 350 V peak voltage
- Ceramic thick film circuits with soldered concentrated components for the Cascades

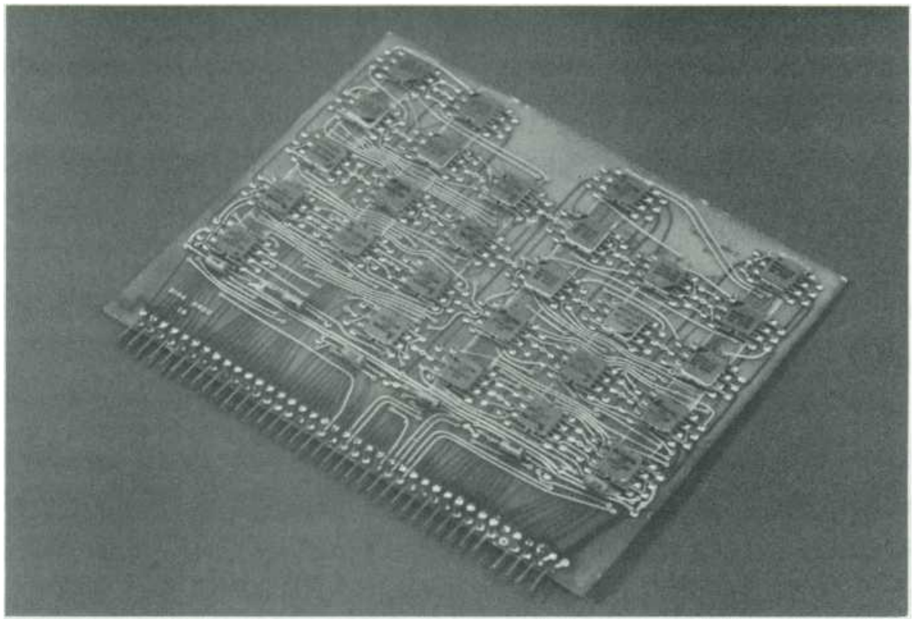


Figure 34: digital Board

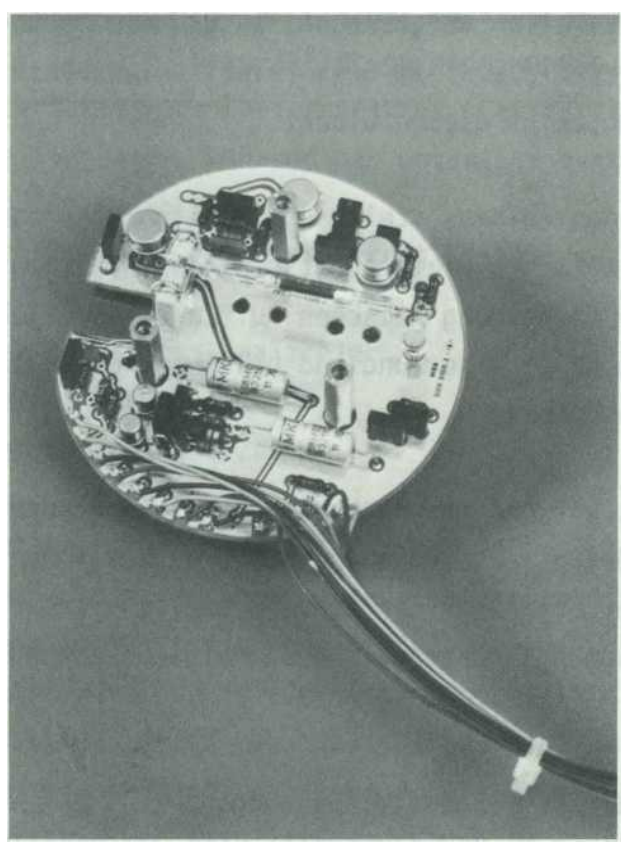


Figure 35: Analogue Board

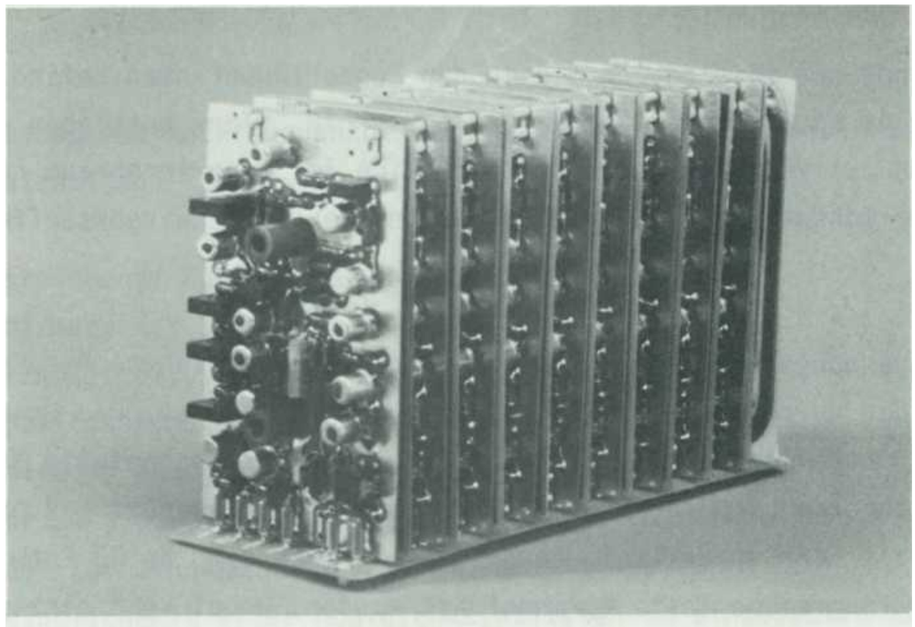


Figure 36: Channeltron amplifier block

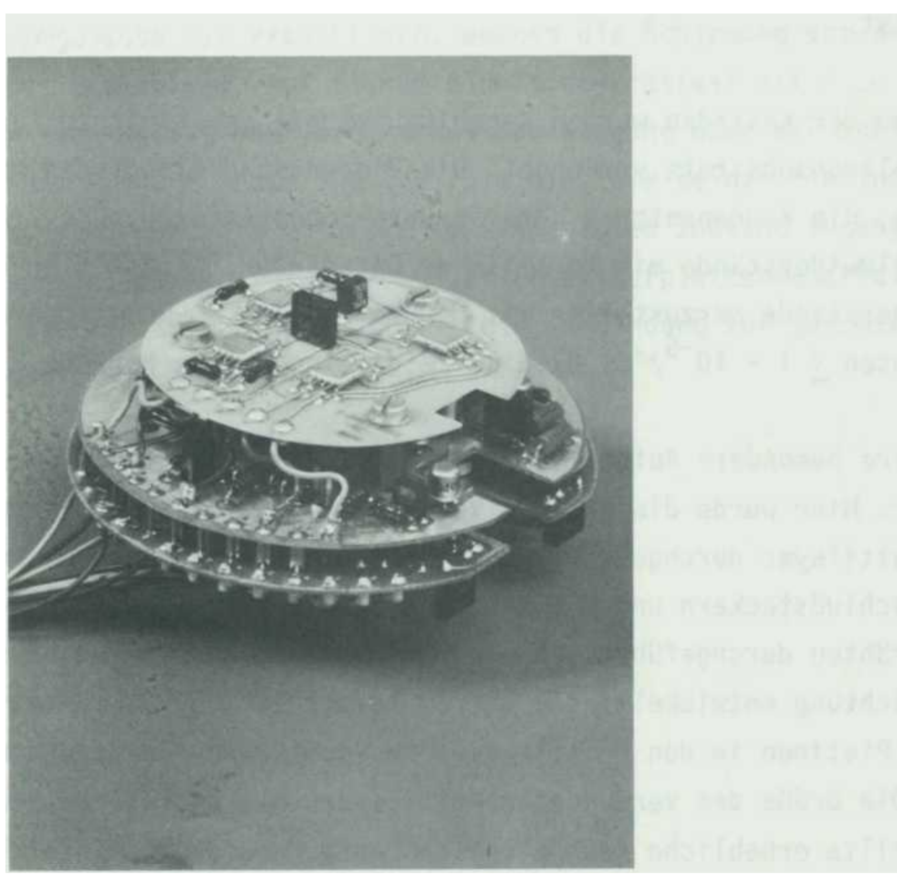


Figure 37: Electromechanical meter

- Accommodation of the Cascades in the Interior of the sensor
- Unforgotten vented high-voltage transformer

This solution is offered here in the Interior of the sensor located Channeltrons can only be operated in a vacuum by better $10^{-6}$ Torr and contamination inside the sensor uses only materials to avoid any hydrocarbons evapourating.

The high-voltage transformer were carried out unshed.The ferrite cores are sufficiently vented through the center hole.The wire insulation is double silk, the layer of insulation is performed with Kapton film, where the location voltage is only 20 V.This type of construction has proven very reliable.Extensive tests, carried 20 development patterns where there was not a single failure.36 transformer were installed in each model, where is also still not a single failure.

Ceramic substrate of the same shape were used in the construction of the Cascades as the Channeltron substrate. The diodes are glass diodes without varnish, the capacitors are ceramic chip capacitors without seal, the thick film resistors are with thick covering glazing. Here, succeeded high ohm resistors to produce values of 180 $m\Omega$ and Temperature coefficients $\leq 1 \cdot 10^{-6} / {}^{\circ}C$ .Figure 38 shows such a cascade.

Another special building technique is the wiring of the electronic box.Here, the entire wiring of the boards was conducted with each other on the multilayer.Only the wiring of the multilayer to the connectors and the wiring of the power supply was carried out using wires.In this context, a special connector equipment was developed, which is extremely light and allows us to insert the individual boards in the multilayer without use of plugs.The size of the used multi layers with five levels of wiring was significant technological development and production requirements.The size and complexity is shown in Fig. 39.The installation in the electronics box is shown in figs. 40 (from below) and 41 (from above).

There were following aspects be taken into account in the development of the high-frequency generator:

- sufficient cooling of the power transistor
- Shielding of the coil
- shortest lines in the end circle
- Capacity-poorest construction of the end circle
- Screening of the entire amplifier compared to the other electronics
- Arrangement of mercury relay in a particular location (perpendicular to the z axis and parallel to the Y-axis)
- Accessibility of all adjustment capacity in the installed condition

This has led to a building, which is shown in Figure 42.The separate housing of the screen is shown, as the shield before the two boards of the final circuit.On this part of aluminum milling also the final transistor for cooling is mounted, the input is on the screen plate and the output down to towards the end circle.The two circuit boards of the final circuit, of which the bottom in the installed state is accessible, are made from our special low-capacity Teflon head plate material.The plug at the side represents the connection to the entire box wiring.

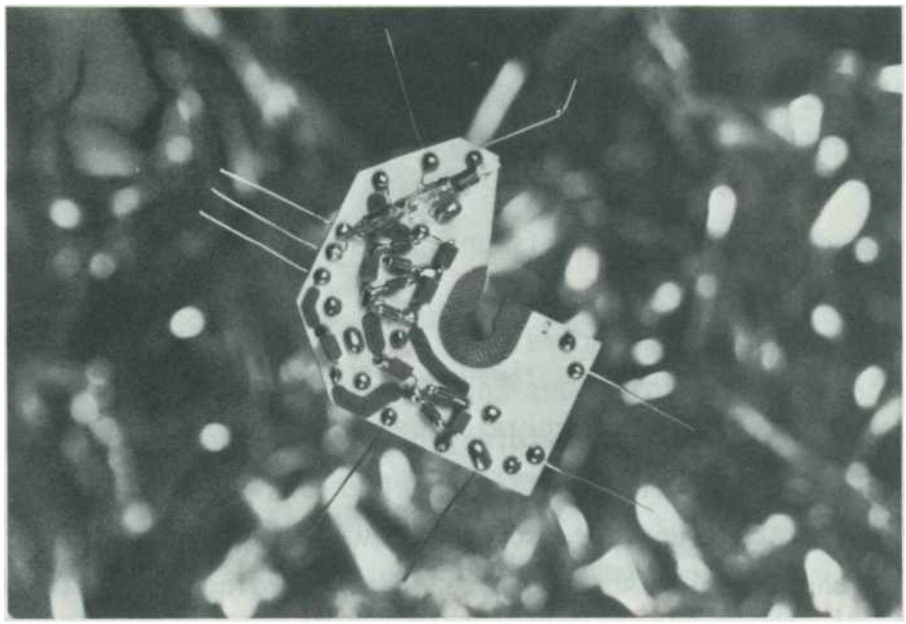


Figure 38: high voltage cascade in ceramic thick-film technology

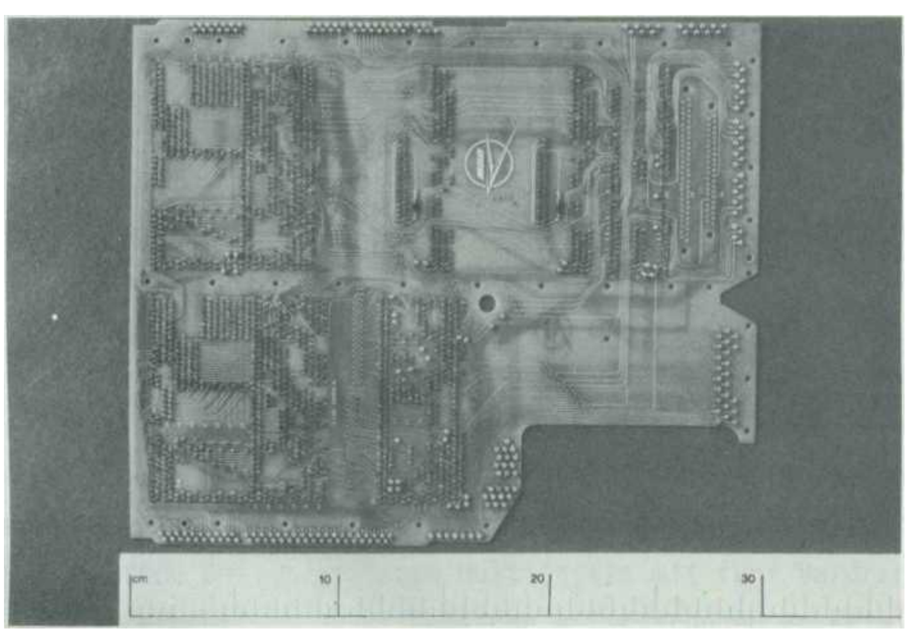



Figure 39: multilayer

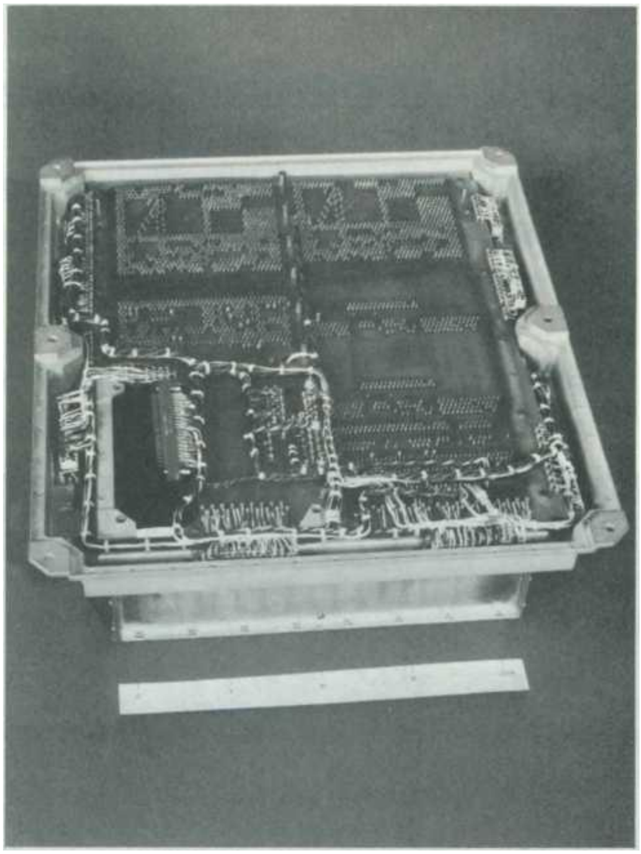


Figure 40: Electronics box (from the bottom)

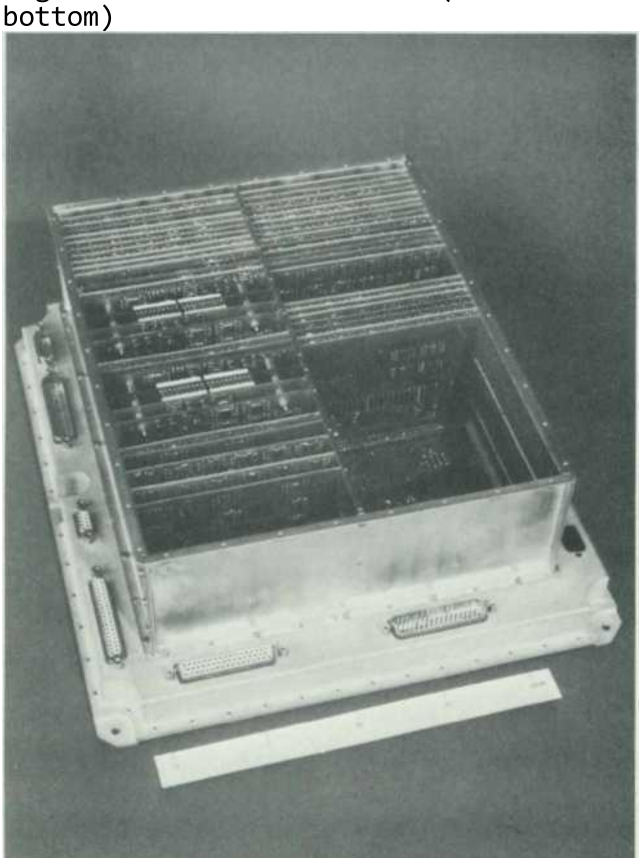


Figure 41: Electronics box (from above)

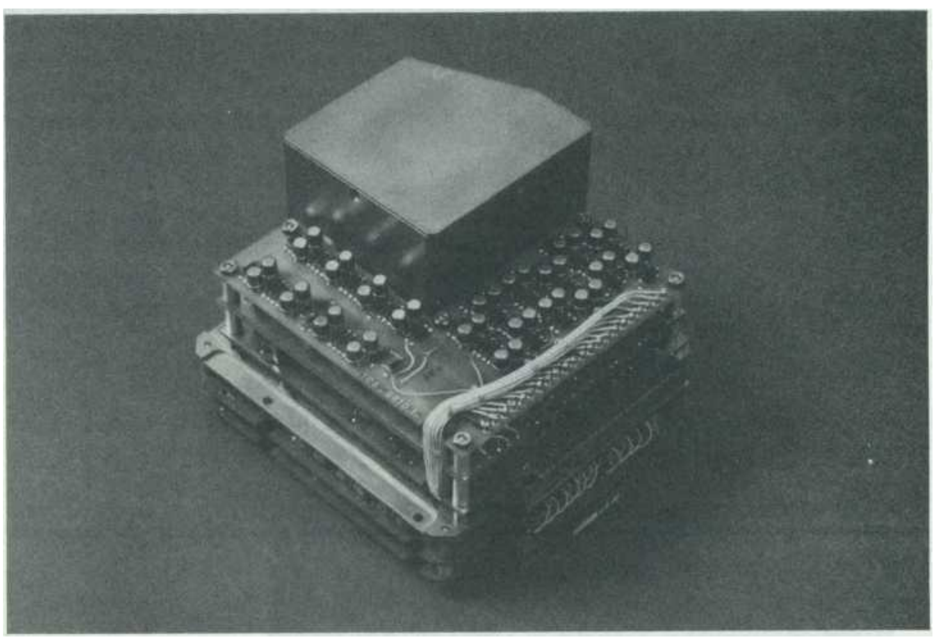


Figure 42: RF generator

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Electromagnetic compatibility

That all known rules to achieve the required electromagnetic compatibility were applied in the construction of the experiment, such as

- Twisting of power supplies
- Shielding of HF sources
- Shielding of sensitive analog lines
- galvanic separation of "power ground" and "signal ground"
- HF-leakage of the boxes
- Special training of the cover flanges
- Gilding the box surfaces

may be assumed as known and need no further explanation.

Channeltrons

The channeltrons (CEM) were purchased by the MPE for a division of the Bendix company, then later as "Galileo Optics" became self-employed.After appropriate selection tests at MPE, they were then passed to MBB for installation.

A protocol was created for each CEM that reveals the individual steps.

1. Incoming inspection at MPE.
   First, each CEM was examined for visible defects or impurities with magnifying glass or microscope.
2. First test.
   Then began the preparation for the first duration test.12 CEM were individually fitted with springs made of V4A on brackets.A small electron source (a Glow lamp with separate glass) faces each CEM funnel.The power supply for all 12 CEM is common, but pulse releases and the heater power supplies of the electron sources are individually accessible.The whole test arrangement is initially at least 10 hours in an oil-free UHV vacuum system at approx.150° heated.Then begins the constant load rest pressure from $\sim 10^{-8}$ Torr.After applying the HV (3.0 kV) the zero count rate of all CEM is first of all measured.Then is the electron source of every single CEM so high regulated, that an output current I of usually 3 x $10^{-7}$ A (other values can be selected) is kept constant.Which according to the average gain $\bar{G}$ is adjusting count rate is regularly registered and plotted as a function of the charge $Q = I \cdot t$ from the CEM.The test is terminated when $Q \approx 0.05\,\mathrm{Cb}$ is reached, so after about two days.Usually in $Q \approx 0.01\,\mathrm{Cb}$ the initial steep drop by $\bar{G}$ has come to a standstill. After, a weak increase of $\bar{G}$ occurs in good CEM, with bad a further drop.

   Before the venting of the test Chamber, yet pulse height analysis (PHA) of CEM pulses at different HV between 3.0 and 4.1 kV be made and the dependency of $\bar{G}$ examined by the count rate.Before and after the test the ohmic resistance of the CEM is measured and recorded.

3. Soldered onto Ceramic substrates

   The CEM passed the sub-contractor by MBB, the company Lewicki microelectronics to be soldered.The soldering is carried out under protective atmosphere and without any flux with a particularly low melting solder.The prepared ceramic substrate and the CEM be slowly brought to a temperature just a few degrees below the melting point of the solder.A fine hot air allows then a fast, clean and almost completely stress-free soldering to the three gold-plated contact surfaces of the CEM as well as also the ceramic tube with a metal plate serving as electron collector.

4. Another stress test

   This test is similar to the first test under point 2, but usually shorter, because the still in the running CEM here mostly achieve a stable end state at 0.02 Cb.The final PHA measurements are used as criteria for the final selection.

5. Shake test

   At MBB, the CEM on a shaking device be mounted and shaken with the strength required for the qualification.There was initially so much break, that we had to ask for to minimize the amount of stress.This was fortunately possible.

   *Here would very much effort to nerves, work and money can be saved if the project would be in time determined by itself to the rectification of the claims, instead of always only on urgent request and much too late.*

6. Installation

   The now leftover CEM were selected according to their qualities of the individual instruments and finally installed.It was off not without soldering fluxes.Therefore the entire sensor area with freon was flushed at the end of the Assembly firmly, to remove all residues.

7. Tests in installed state

   Each system test $\bar{G}$ was measured with the help of the automatic Infiight tests.When the calibration at MPE was again each PHA and HV-

Dependency is recorded.For this purpose, the CEM outputs of the instruments from the outside are accessible and can be separated from the built-in amplifiers.This process was repeated a few days before starting the "final test" once again even the instruments integrated in the probe.

In the course of the work, we gained a lot of experience and often changed the procedure.So, steps 4 and 5 were often reversed, step 2 do not even have time pressure.Step 4 has been repeated several times for many CEM, however, for various reasons.

Behavior CEM in laboratory tests and in flight should be illustrated by a typical example from I1a Helios 1.Figure 43 shows the time-dependence of $\bar{G}$ in the stress test (step 4) for the CEM No.C 163, measured on 27.8.1973. At $Q \approx 0.01\,Cb$ a "plateau" is reached.It is with $\bar{G} = 2 \times 10^7$ for 3,0 kV relatively low.This was similar for all CEM of this delivery.The resistance was relatively low at all this CEM: $8.2 \times 10^8\,\Omega$ (before the test $8.55 \times 10^8\,\Omega$), while in the CEM from other Deliveries usually higher values have been achieved (up to $1.5 \times 10^9\,\Omega$).But, low resistance favor the ratio at high count rates: the drop in $\bar{G}$ is only noticeable at $n > 50\,kHz$.In Figure 44, we see the HV - dependence of amplification of the CEM No.163. Here, even $G_m$, the maximum gain due to the PHA as well as the half-width of the PHA is applied (in % of $G_m$) except $\bar{G}$. The curves show the typical rise of $\bar{G}$ and $G_m$ by about a factor of 2 per 300 V voltage boost; also occur a minimum of half-width of $\approx 25\%$ at $\approx 3.5\,kV$ can be regarded as typical for a"good" CEM.

The behavior is interesting now this (and other) CEM after launching.In Fig. 45, $\bar{G}$ measurements of CEM by I1a are shown on HELIOS 1 (with the exception of the two outermost).Place L6 the previously described CEM no.163 is located on.The rapidly changing $\bar{G}$ values before the start the CEM stemming probably differences in the times of the pump and the responsive during various system testing.After the start but you can see the usual "curing behavior" of all CEM.

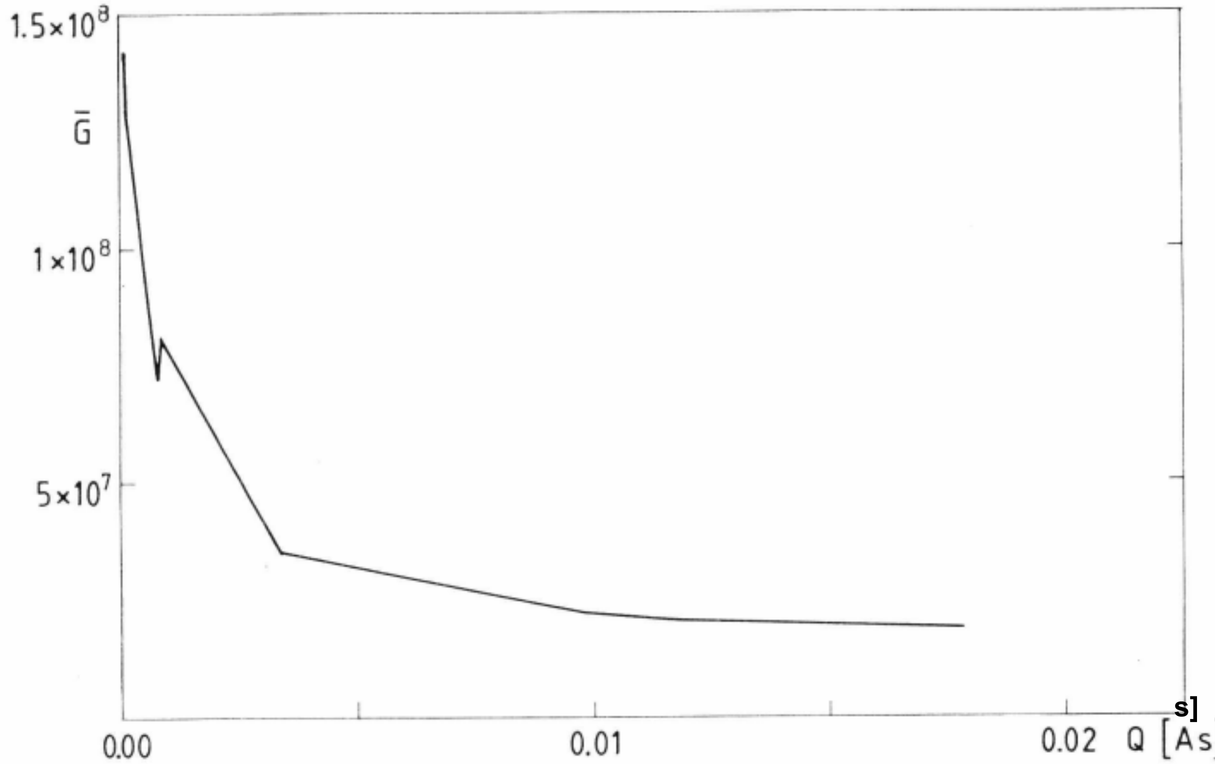


Figure 43: The dependence of the average gain $\bar{G}$ of the total charge Q flowed through the CEM No.163.

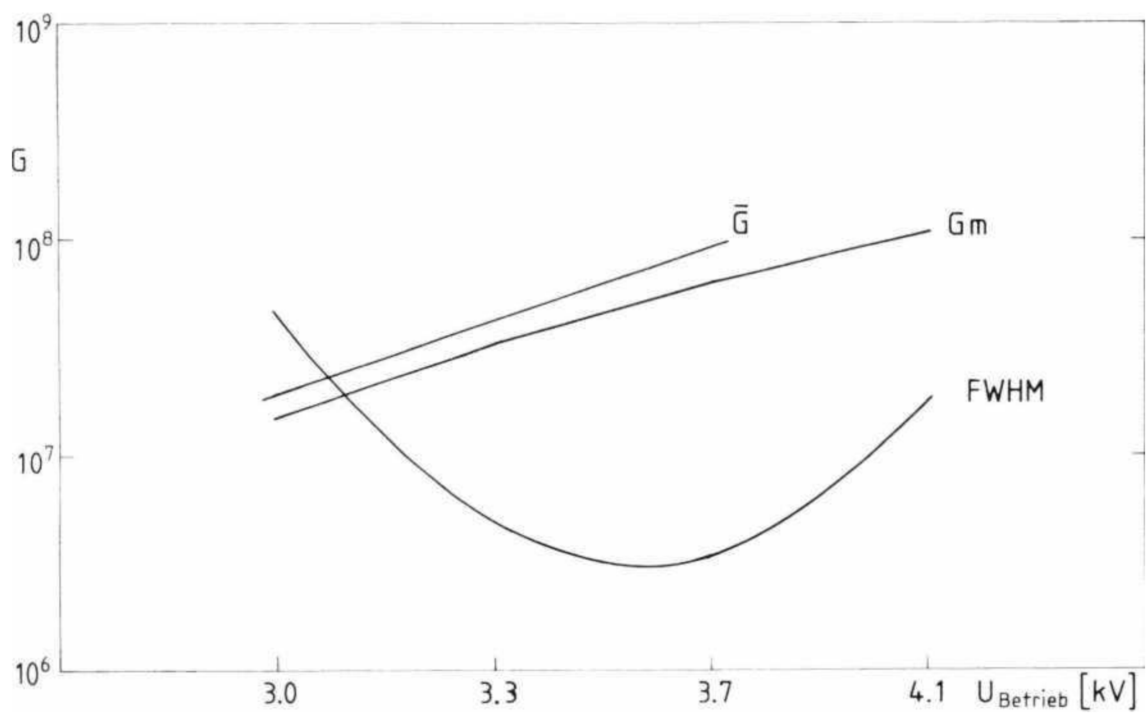


Figure 44: Depending on medium-gain $\bar{G}$, maximum gain $G_m$, as well as the half-width of pulse height distribution of the operating voltage. The recorded measurement on CEM No.163 after permanent load.

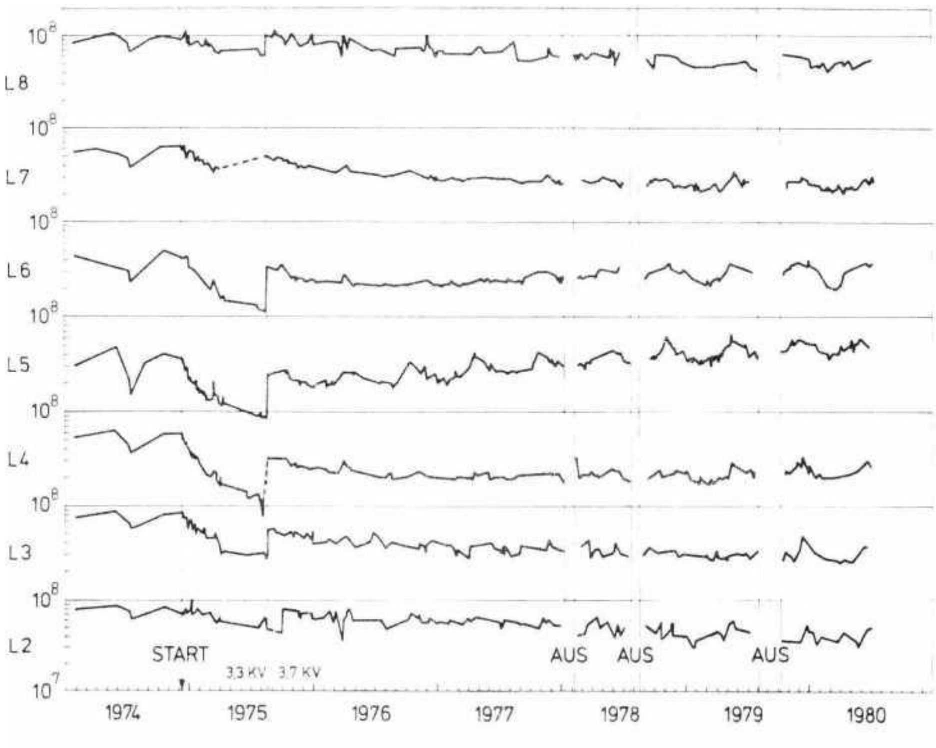


Figure 45: The average amplification $\bar{G}$ the CEM in I1a Helios 1 from 1974 to 1980, L5 is the average CEM, looking in the ecliptic

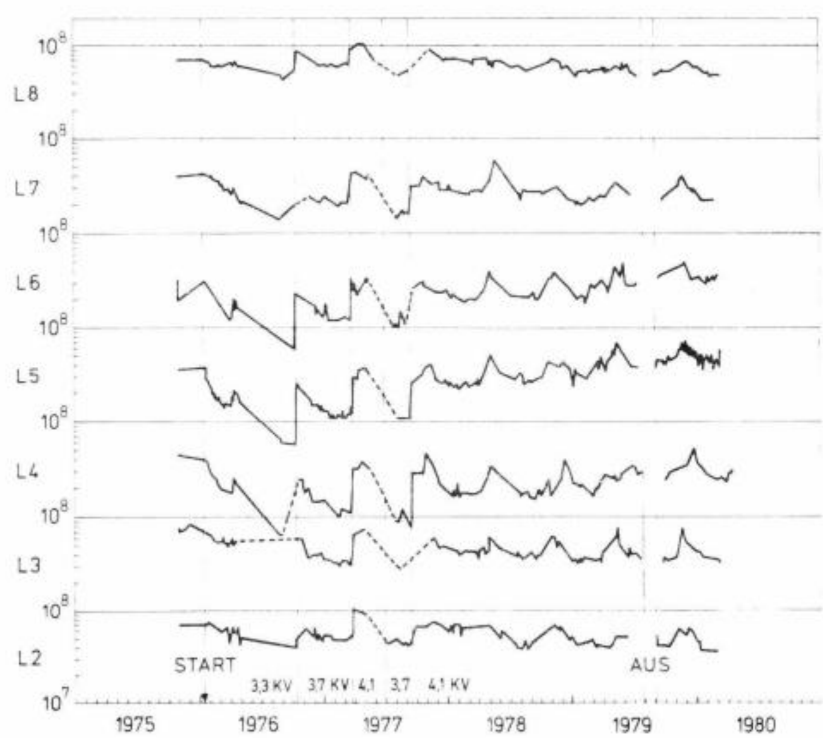


Figure 46: As picture 45 however for I1a Helios 2

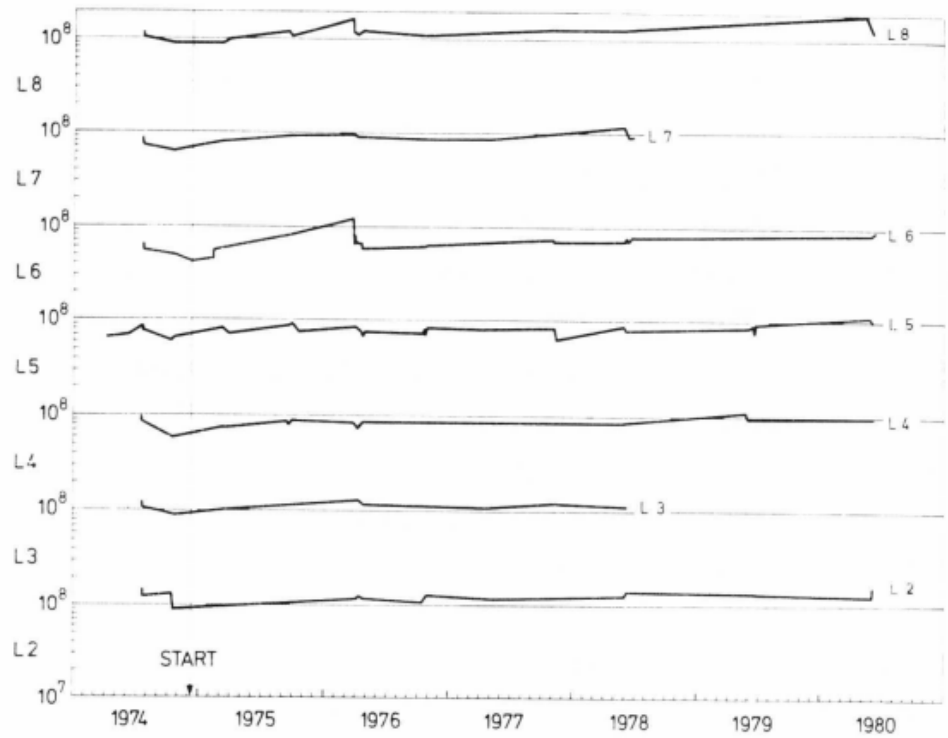


Figure 47: As picture 45, but for I3 of the HELIOS 1

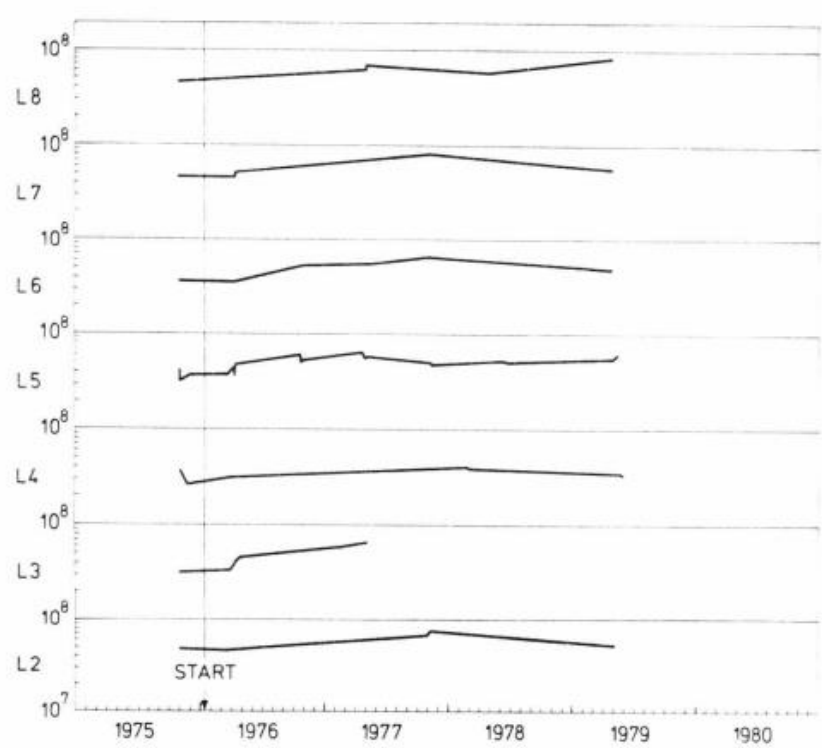


Figure 48: As picture 45, but for I3 of the HELIOS 2

Of course, $\bar{G}$ decreases at L5, the Cem, which looks to the ecliptic, and the great majority of particles counts, the fastest off a bit slower on its neighbours L4 and L6. The CEM on the edge of L2 and L8 have not yet reached the "plateau" because of low stress today.Especially at L5, a clear upward trend can be observed already since 1976.The plateau of L6 $\bar{G} \approx 2.5 \times 10^7$ in the summer of 1976 is significantly lower than in the endurance test (fig. 43).Similar was observed in all CEM on HELIOS 1 and HELIOS 2.The reason for this is unclear; Perhaps the different residual gas atmosphere in sensor and test facility plays a role.Also the periodic fluctuations are striking by $\bar{G}$, especially clearly visible at L5.The maxima of $\bar{G}$ coincide fairly well with the Periheidurch-courses, can be so close to a temperature effect.Appropriate laboratory tests are pending.

Figure 46 shows for the CEM in I1a on HELIOS 2 very similar behavior.Here $\bar{G}$ declined however more after the launch, and the HV had to be set to 4.1 kV (3.7 kV for HELIOS 1).With the I3-CEM, yet nothing has changed due to the extremely low load: $\bar{G}$ remained anywhere about at $10^8$ (figures 47 and 48).Due to these images no doubt, that the lifetime of E1 at least should not be restricted by the degradation of the CEM.

This can be not so self-evident for the CEM built in I2.

Here is $\bar{G}$ not measured directly, but qualitatively ensured only through comparison of the count rates at different amplifier thresholds, that $\bar{G}$ still is sufficient.Two probes we have switched up the HV now to 4.1 kV, because the mentioned difference was increased slightly.The much more sensitive test, we occasionally conduct comparison of electron count rates with different HV, which would not require this increasing, but we know so that the measurements are guaranteed unaffected with 4.1 kV.

The zero count rates (NZR) CEM show a few characteristics.In the integration counter by I1a we find as NZR at HELIOS 2 average 1 count; that means 16 AZ x 9 EL channels with 10 ms measuring time a NZR less than 1 $s^{-1}$. At HELIOS 1, the NZR is about 2 $s^{-1}$.

It is striking that after some particularly strong flares the NZR sharply rises to the Sun, in individual cases to over 200 $s^{-1}$.The reason for this are high-energy particles, may be electrons with several MeV energy.The drop to normal levels takes usually from several hours up to several days. On 13th February 1978, went after such an event, the NZR not quite returned but is since approximately 2$s^{-1}$. An investigation about whether this increase is based on only a CEM or more, was still not carried out.

## 6.Calibration of the instruments

The instruments I1a, I1b, and I3 have been calibrated at MPE system built specifically for this purpose.This procedure and the necessary evaluations are described in detail in a separate report, containing all technical data.Here will be outlined only the principle and the results listed.

### The calibration system

Figure 49 shows a glimpse of the heart of the plant, which is in a container that is converted to the cleanroom.The upper end of the approx.3 m-long vacuum system (with an ion getter pump) contains an ion source.Electrons from a hot cathode, on approximately 200 eV accelerates, ionize flowing through hydrogen gas in a field-free-held space.Result in particular $H_2^+$ ions, but also $H_2O^+$ and $H^+$ ions.They are sucked by a few volts from the effective area by a voltage of draw out and then accelerated to the desired just energy.Thus arises a very largely mono-energetic flow of ions, which energy per charge can be varied from 100 V up to 20 kV.

At the bottom of calibrating instrument is by means of a metal bellows moving in both directions.The suspension can unfortunately be no gimbal design reasons, i.e.the two axes of rotation and the inlet are not in the same plane.In turns, the instrument moves thus to the side.Possible Inhomogeneities of the particle beam must be compensated so carefully. These serve two channeltrons, that are brought 50 cm in front of the instrument from both sides up to approx.1 cm on the beam path.Registered here count rates are converted into a voltage and supplied via a control unit of the heaters of the ion source.So, the radiant intensity over hours can be kept over very exactly stable.Lateral movements of the instruments in both directions, the control channeltrons run with, so the radiant intensity is also spatially constant.

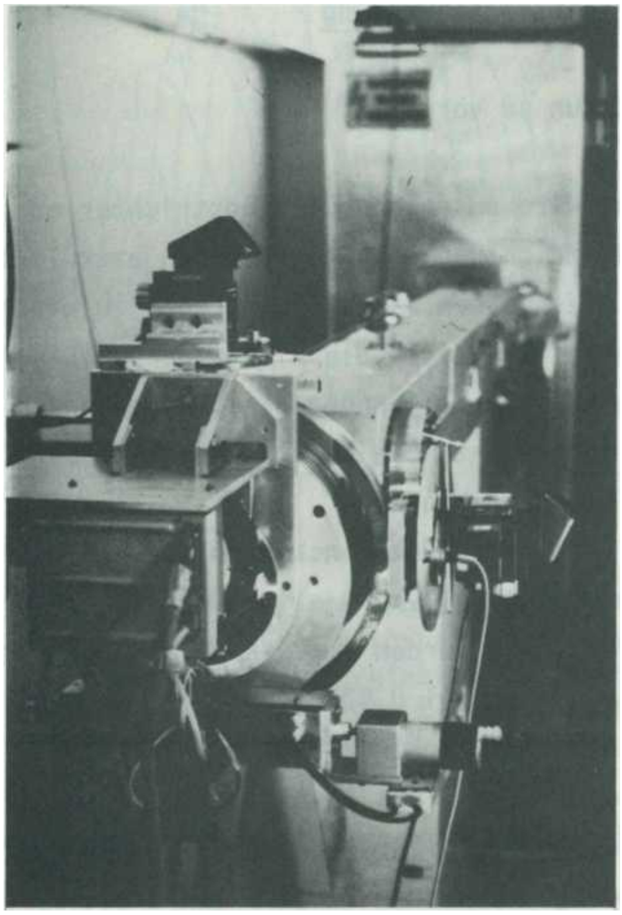

Figure 49: The calibration system for the ion instruments.
Left you can see the box F1-E1A which is
bolted on a portable system of bellows to
a 3 m-long vacuum system.
At the front end, this contains an ion source
that provides Mono-energetic ions with E/q
values from 100 V up to 20 kV.

The angle can be read with a accuracy of 15" and also reproducibly adjusted.Actuators that are controlled by the "green step machine" developed by M. Bechly serve.

Trace of an instrument calibration

a calibration is going now so on:

1.) The instrument is at its entrance funnel system flanged (Indium seal), then thoroughly evacuated.At the same time, already the necessary cables are manufactured connections to a specific interface plate, replaced the electronics box E1D.So get the necessary operating voltages, pulse frequency, and command information in the instrument; the standard pulse outputs the CEM are connected with electronic meters.
2.) Thorough electrical function test of the instrument.
3.) Turn on the ion source and all circuits.
The most calibrations were carried in the EN Channel 13 so in particle energies of nominally 0.978 kV.
4.) Is the so-called relative calibration for the determination of the relative Response probability of the instrument as a function of particle energy and both directions of incidence.In a fully automatic running measurement program, the corresponding counting rates Z (EN, AZ, EL) recorded in the entire three-dimensional measuring range (EN, AZ, EL) and registered along with their addresses on a data tape.Figure 50 shows a series of measurements for a single value of EL, i.e. $\epsilon = 5.07\,°$.The entire EN range in steps of 3 V was driving for a detained each azimuth angle.The azimuth angle is in increments of approx.0,3 ° changed.Measuring ranges and increments can be varied.That often emerges naturally count rate zero on.To save time, count rates were noted at all only then when Z in a first "search period" of 0.1 sec exceeded a limit (adjustable).Nevertheless, such a verification takes a long time.10 x 25 x 20 (EN x AZ x EL) significant values will on average be recorded per CEM; these 5000 sec comes around again the same time for many

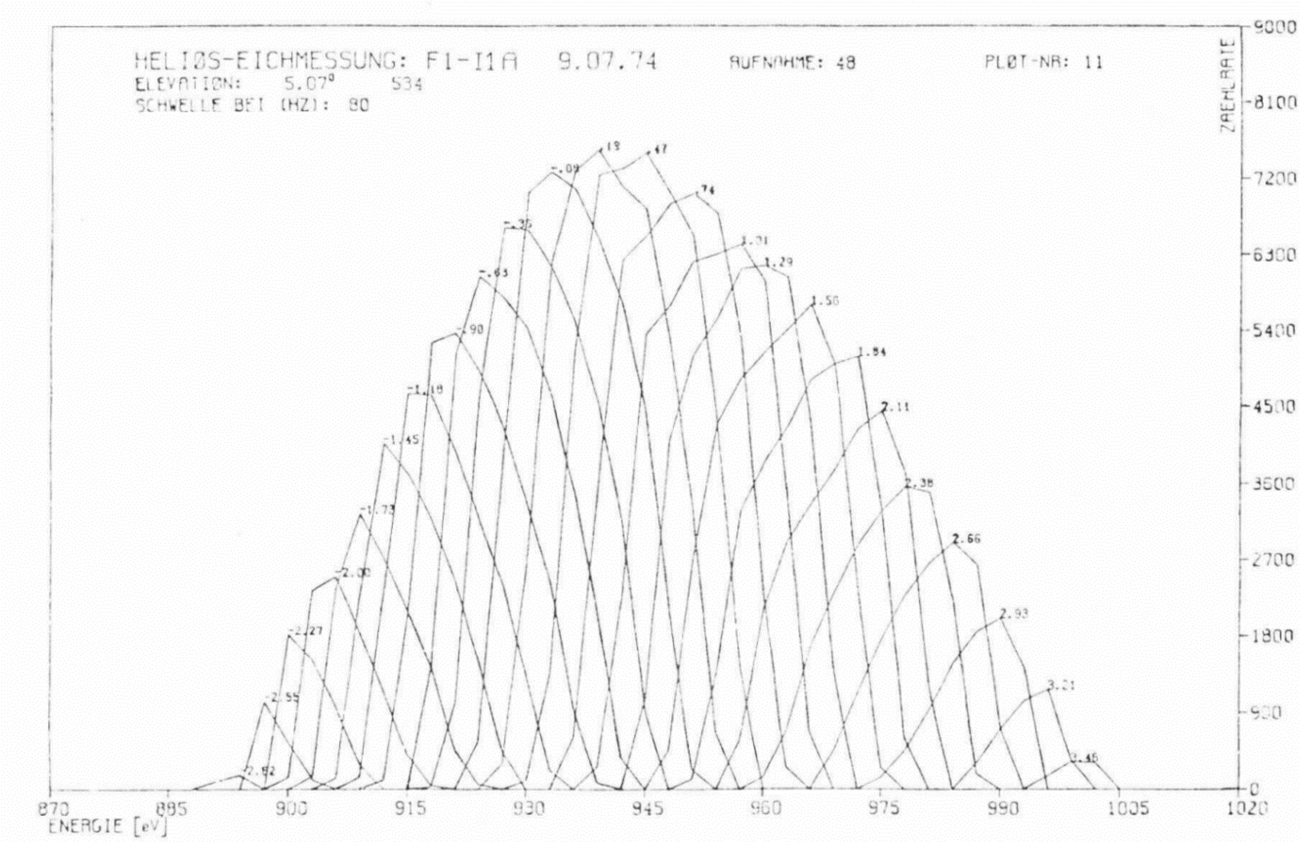


Figure 50: A series of measurements from the relative calibration of F1-I1A. The entire energy sector will pass for a detained each azimuth angle. Until then, the elevation angle - here 5.07 ° - is changed.

Search phase, the motor running times, belt change etc.So 9 x 2 x 5000 sec takes this most important step of the complete calibration of instrument I1a or I3, just 25 hours, with 45000 significant count rates are to record.

5.) The so-called absolute calibration.

With unchanged is running on ion beam, the absolute intensity of the beam used for the relative calibration is now measured.This is a precisely calibrated electrometer, which directly measures the ion current true on a special collector.This collector is mounted by means of a swivel arm in the beam path of the instrument, immediately behind the two Stabilisation channeltrons.The ion current measured is a measure of the flow of particles falling on the inlet opening of the instrument.

Thus, the actual calibration is finished.

6.) Determination of dead time.For each CEM of the instrument is the count rate as Function of the incoming stream of particles measured.To do this, the ion beam in a very wide range needs to be changed.This caused problems, on the one hand with the CEM often stabilizing, whose amplifier have also finite dead times, the other source with the ion, which was often overloaded as a result.The HELIOS instruments I1a this measurement has never led to satisfactory results, and finally then the nominal value was used for the data analysis of 500 ns, of which the electronically certain values only marginally different ($\leq 10\,\%$).

7.) Some special function checks of the instruments operating in the Mission-like State, i.e.When exposed to particles.This includes a careful control of excessive coupling properties of CEM: when a CEM is under fire, none of them may say something.

*This simple-sounding requirement caused much trouble during the course of the project.Already at the EM by I1a, there was over coupling effects.Then the CEM were sealed the exits completely.P-I1a there was over coupling again, this time apparently electronically.Then the pulse lines were that of the CEM lead through ducts in the sensor housing to the Preamps in the electronics section, modified.When the problem occurred again at F1-I1a, only a vigorous bailout helped literally last-minute: A detailed analysis showed that the CEM-pulse capacitively coupled to the common HV-supply and from there turn on the other pulse lines.This disorder of course strongly depends on flanking slope (rise times of $\sim 1\,ns$) and amplitude of CEM-pulse. These properties were especially good in the F1-CEM, easily understanding reasons; the "tired" CEM of EM and also at P such effects were not more achieved.The pulse releases were changed again to the remedy; also, shielding plates have been inserted between the relatively densely stacked substrates of CEM.The story of this issue illustrates lot significantly, as necessary thorough tests under realistic conditions are, because in the laboratory and with simulated CEM pulses were not to uncover problems.*

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More functional tests concerned mainly the CEM. Besides the usual measurements of amplification and pulse height distribution was among othersexamines whether in constant flux of particles the count rates may change with the CEM-HV.This can't be happening naturally.Nevertheless, it was, especially when new CEM with particularly strong and long pulses.Here, the CEM amplifier tended to overload, which is expressed in the distribution of double pulses.Also this error was to be found only through realistic operation.

*At I2 this weakness of the amplifier, which is slightly different than that of I1A and I3, was particularly tough, not to say: tricky, and this has led even after the launch of HELIOS 1 be a radical change for F2. Double pulse occurred only in a specific counting rates range between approx.1 to 5 kHz, and were therefore on the usual function checks with approx.20 kHz not been discovered.The adulteration of the count rates was 10 % to 20%, and was similar in all remaining copies of this amplifier, in principle, probably even with the already flying F1 model. The amplifier of F2 and P were in an unusual Act of force, especially by H. Rosenbauer and the electronics by MBB, yet redeveloped and repaired.Comparative measurements between HELIOS 1 and HELIOS 2 show fortunately that distortions in the unamended F1-I2 are not recognizable.*

8.) Before removing the calibrated instrument, yet its location must be determined relative to the calibration system.The smooth polished surface of the instrument rests completely flat on the attachment flange.On the same front surface a solid lid is later screwed flat, a mirror cube is glued on the front.

The cover is by Dowel pins secured against twisting.The location of the instrument in the probe can be determined, so that ultimately a more accurate relationship between calibration system and viewing direction of the probe can be made with the mirror. For technical reasons, when mounting the sensor on the calibration system, minimal distortion of the instrument to the surface normal can not be excluded.Therefore, the position of the instrument over the dowel pins that secure the cover later, is measured with a special ruler.

9.) Finally, even the exact direction of the calibration beam must be determined relative to the normal to the flange.To do this, a kind of "Scope" was built.It consists of a 20 cm-long tube that is closed-ends with flat plates on both.In both plates centers, fine 0.5 mm diameter holes are drilled.Particles that pass through both holes, are registered in a CEM.The telescope is mounted instead of the instrument and into the beam path.With the help of the turning device it is panned as long as until a maximum of particles through; the direction of the then reached will be recorded.Then the scope is removed by 180 ° around its axis rotated and mounted again.Then again determines the direction.The average of two measurements give exactly the desired direction of the beam to the mounting level of scope (and instrument).Usually, the beam direction deviated by only a few arcseconds from the direction of the axis.

The duration of the whole procedure was per instrument per one Week where some night shifts were required.

Calibration data

In the following we the main calibration data summarize without further explanation in some tables, how they are used for the data analysis.We evaluate all data according to moment process where only the zero and first moments of the device function enter $G(\vec{v})$

Thus arises E.g.for the density

$$n = \int G(\vec{v}) \cdot f(\vec{v})\, d\vec{v}$$

the proximity

$$n = C \cdot \int f(\vec{v})\, d\,\vec{v}.$$

It is

$C = \frac{DELEL \cdot DELAZ}{DELZ} \cdot \frac{1}{G_o}$ with the 1D analysis, or

$C = \frac{1}{DELZ} \cdot \frac{1}{G_o}$ with the 3D-analysis

C is as it were a measure of the ISO setting of the instrument.The verification has revealed the following values:

$G_o$ = $4 \cdot 10^{-7}$
DELEL = 0,08727
DELAZ = 0,09774
DELZ = 0,01

They apply to the I1a instruments by F1, F2 and P. $G_o$ must be each corrected inversely proportional to the deviation of the spin rate of the nominal value of 60.1 per minute.

The 1D analysis of the proton density of the measured individual counting $Z_i$ of the integration counter of I1a or I3 is then e.g. according to the formula

$$n = C \cdot \sum_{i=1}^{N-1} \frac{1}{2} \left(\frac{Z_i}{v_i^2} + \frac{Z_{i+1}}{v_{i+1}^2}\right) \cdot (v_{i+1} - v_i).$$

The $v_i$ are the centres of the speed channel are also determined by the calibration (see below).

The sum must span only the count rates, really stemming from protons.The distinction of different types of ion from the measured data represents a fundamental evaluation problem, on which we can here no further go.
The other parameters such as speeds, temperatures, etc., and also the 3D-data capture is calculated after basically similar formulas.There are other procedures, E.g. whereanalytic functions are adjusted to the measured count rates.All of this may be not the subject of this report.

The instruments I1b and I3 have different values for $G_o$, with same values of DELEL, DELAZ, DAKTARI:

I3 $G_o = 0{,}1628 \times 10^{-7}$

I1b $G_o = 0{,}877 \times 10^{-7}$

For the 3D-evaluations, the slightly different "sensitivities" of individual CEM are taken into account.You can express themselves through corrections of $G_o$, are specified in table 35.

| | HELIOS 1 | | HELIOS 2 | |
|---|---|---|---|---|
| | I1a | I3 | I1a | I3 |
| CEM 1 | 4,626 | 0,151 | 4,039 | 0,163 |
| 2 | 4,956 | 0,159 | 4,540 | 0,159 |
| 3 | 4,687 | 0,174 | 4,622 | 0,168 |
| 4 | 4,527 | 0,172 | 4,673 | 0,162 |
| 5 | 4,393 | 0,156 | 4,876 | 0,162 |
| 6 | 4,588 | 0,171 | 4,748 | 0,162 |
| 7 | 4,730 | 0,180 | 4,768 | 0,166 |
| 8 | 4,591 | 0,153 | 4,609 | 0,163 |
| 9 | 4,915 | 0,147 | 4,532 | 0,161 |

Table 35: The $G_o$ values of the CEM in I1A and I3.
All values are $10^{-7}$ to multiply by.

The layers of the measuring channels are given by the 1st moments of the function.All values are summarized in table 36 (for F1) and 37 (for F2).

There are two further points should be noted: as already mentioned, the verification was limited to the E/q-Channel 13.Immediately before the start of the final test, we measured more closely again all plate voltages.The relative position of the E/q channels was then calculated from the ratio of plates voltages to which channel 13.The azimuth channels are given solely by the calibration measurement, as well as the electronic set channel spacing.Here is to be observed that at HELIOS 2 the situation of all azimuth channels of all 4 instruments can be shifted command 130-1AVL by 7.03 ° (see table 10).

J

KANAELE FUER INSTRUMENT 1A * HOS1 *
GESCHWINDIGKEITSKANAELE OHNE SHIFT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 177.4205 | 190.8127 | 205.2966 | 221.0240 | 237.4854 | 255.4281 | 275.0674 | 295.9394 | 317.7935 |
| | | | | | | | 569.2461 | 612.1265 | 658.5171 |

KANA-eleven CABIÄET INSTRUMENT 1A * 11OS 1 ► GESCHViINFIGKEITSKA NÄSLE OHME SHIFT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 177.4205 | 190.8127 | 205.2966 | 221.0240 | 237.4854 | 255.4281 | 275.0674 | 295.9394 | 317.7935 |
| 341.7998 | 367.646? | 395.6724 | 425.2297 | 457.3389 | 492.62 94 | 529.9421 | 569.2461 | 612.1265 | 658.5171 |
| 7C8.8071 | 761.7083 | 819.1196 | 882.2610 | 948.7708 | ! 021.8484 | 1098.7119 | 1181.7590 | 1271.2358 | 1365.5386 |
| 1463.47 38 | 1580.5919 | 16 ° 9.9663 | | | | | | | |

GESCHWIMC IGKF ITSKANAELF WITH SH I CT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 171.0150 | 183.9177 | 197.8OE89 | 2. 2.9468 | 228.9476 | 246.1972 | 265.2112 | 285.3137 | 306.3555 |
| 329.4919 | 354.5015 | 311.4312 | 409.9836 | 440.8940 | 474.9219 | 510.9014 | 548.8286 | 590.1736 | 634.9353 |
| 683.5317 | 734.4736 | 789.7634 | 830.4597 | 914.9817 | 985.1646 | 1059.4478 | 1139.4680 | 1225.8027 | 1317.2397 |
| 1416.1432 | 1 524.6316 | 1639.36 ° 6 | | | | | | | |

AZI MUTH CHANNEL WITHOUT SHL ^ T:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | -54.56A | -48.939 | 4 3.314 | -37.689 | -32.064 | -26.439 | -20,814 | -15.189 | -9.564 |
| -3.93 ° | 1.606 | 7.31 1 | 12.936 | 18.561 | 24.186 | 29.811 | | | |

AZI MOTH CHANNEL SHIFT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | -51.751 | -46.126 | -40.501 | -34.876 | -29.251 | -23.627 | -13.002 | -12.377 | -b. 752 |
| -1,127 | 4.498 | 10.123 | 15.748 | 21.3 73 | 26.998 | 32.623 | | | |

11 DAD CMS CHANNEL:

20.76 15.69 10.6 1 5.56 0.52 4. 57-9. 65-14. 72-19.75

KANAELE FUER INSTRUMENT 3 * HOS1 *
GESCHWINDIGKEITSKANAELE :

KANAFLE DRIVING TOOL 3 ' - HT'SL '
G'-SfH'rtIndigkfitskanafle:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 192.9609 | 211.0055 | 230.8934 | 252.8186 | 276.6838 | 302.7808 331.3999 | | 362.6384 | 396.8343 |
| 4P4.2315 475.1746 | 519.9051 | 569.0342 | 622.7327 | 681.4263 | 745.6497 | | | |

AZI MUTH CHANNEL OHME SHIFT:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| -54.7439 | -49.1190 | -43.4940 | -37.8690 | -12.2440 | -26.6190 20.9940 | | -15.3691 | -9.7441 |
| -4.1191 1.5058 | 7.1308 | 12.7558 | 18.3008 | 24.0057 | 29.6307 | | | |

A 7IMUTH-KANAL WITH SHIFT:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| -51.9314 | -46.3065 | -40.68] 5 | -35.0565 | -29.4315 | -23.8065 18.1815 | | -12.5566 | -6.9316 |
| -1.3066 4.3183 | 9.9433 | 15.5683 | 21.1 9 33 | 26.8182 | 32.4432 | | | |

ELFVAMCNS CHANNEL:

20.913 1 5.843 10.823 5.793 0.823-4. 267 - 9.297 - 14.377 -19.457

KANAELE FUER INSTUMENT 1B * HOS1 *
GESCHWINDIGKEITSKANAELE OHNE SHIFT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 171.7435 | 185.2370 | 198.7062 | 214.0882 | 230.3004 | 247.0319 | 265.6782 | 286.6697 | 307.5335 |
| 331.8147 | 355.5197 | 383.5547 | 412.4998 | 442.4983 | 477.6255 | 513.3958 | 551.4827 | 594.7793 | 637.9971 |
| 687.3589 | 739.4268 | 793.0391 | 856.0723 | 920.1711 | 988.0325 | 1066.0488 | 1143.4380 | 1231.6724 | 1324.6543 |
| 1420.3792 | 1532.5949 | 1647.4070 | | | | | | | |

GESCHWINDIGKEITSKANAELE MIT SHIFT:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 165.4039 | 178.4133 | 191.4100 | 206.2247 | 221.8374 | 237.9380 | 255.8806 | 276.1287 | 295.1537 |
| 319.4558 | 342.7881 | 369.2900 | 397.1763 | 426.0525 | 459.9438 | 494.3591 | 530.9666 | 572.7212 | 614.2681 |
| 661.8203 | 711.5856 | 763.5676 | 824.2412 | 885.9976 | 951.3682 | 1026.1824 | 1100.6946 | 1185.9590 | 1275.3436 |
| 1367.6501 | 1476.1721 | 1586.4722 | | | | | | | |

Table 36: The location the measuring channels for the ion instruments on HELIOS 1 taking into account the calibrations.

Kanäle = channels
Geschwindigkeits = speed
Mit = with
Ohne = without

```
HOS 2  KANAELE FUER INSTRUMENT 1A
GESCHWINDIGKEITSKANAELE OHNE SHIFT:
              178.1586    191.4310    205.6029    221.1543    237.8146    254.8014    274.9546    295.6865    317.5559
   341.4294   366.8901    394.7363    424.3289    455.3274    491.4431    528.6404    568.4856    611.1689    657.0166
   707.2490   760.2402    815.8066    880.4482    947.2307   1019.8423   1096.6001   1178.5918   1268.6731   1363.6038
  1463.2292  1578.9460   1673.5481
GESCHWINDIGKEITSKANAELE MIT  SHIFT:
              171.8321    184.6332    198.3019    213.3009    229.3697    245.7532    265.1907    285.1865    306.2891
   329.3052   353.8618    380.7192    409.2607    439.1584    473.9915    509.8679    548.2983    589.4661    633.6853
   682.1343   733.2437    785.8369    849.1831    913.5937    983.6270   1057.6594   1136.7397   1223.6218   1315.1814
  1411.2693  1522.8767   1638.2312
AZIMUTH-KANAL OHNE SHIFT 0 V.:
               39.756      34.136      28.516      22.896      17.276      11.656       6.036       0.416      -5.204
   -10.824    -16.444     -22.064     -27.684     -33.304     -38.924     -44.544
AZIMUTH-KANAL MIT  SHIFT 0 V.:
               42.566      36.946      31.326      25.706      20.086      14.466       8.846       3.226      -2.394
    -8.014    -13.634     -19.254     -24.874     -30.494     -36.114     -41.734
ELEVATIONS-KANAL:
              -20.78      -15.70      -10.59       -5.55       -0.51        4.52        9.63       14.69       19.71


HOS 2  KANAELE FUER INSTRUMENT 3
GESCHWINDIGKEITSKANAELE :
              191.5390    209.4506    229.1920    250.9557    274.6450    300.5496    328.9578    359.9661    393.9597
   431.1311   471.6731    516.1633    564.8909    618.1440    676.4050    740.1553
AZIMUTH-KANAL OHNE SHIFT 0 V.:
               39.9838     34.3638     28.7438     23.1238     17.5038     11.8838      6.2638      0.6438     -4.9752
   -10.5962   -16.2162    -21.8362    -27.4562    -33.0762    -38.6962    -44.3161
AZIMUTH-KANAL MIT  SHIFT 0 V.:
               42.7938     37.1738     31.5538     25.9338     20.3138     14.6938      9.0738      3.4538     -2.1552
    -7.7862   -13.4062    -19.0262    -24.6461    -30.2661    -35.8861    -41.5061
ELEVATIONS-KANAL:
              -20.548     -15.473     -10.443      -5.413      -0.395       4.694       9.777      14.837      19.924


HOS 2  KANAELE  FUER INSTUMENT 1B
GESCHWINDIGKEITSKANAELE OHNE SHIFT:
              174.2491    187.9659    201.7763    216.9383    234.0746    250.5906    270.4561    290.6262    311.4346
   335.7917   360.7571    388.2131    417.9998    448.1162    483.3787    519.7019    557.7451    601.4404    645.8123
   655.0132   748.5520    802.6470    865.6333    930.7544   1000.0188   1078.4387   1157.9849   1246.2710   1342.2422
  1439.1499  1552.1416   1668.6924
GESCHWINDIGKEITSKANAELE MIT  SHIFT:
              168.1128    181.3466    194.6706    209.2987    225.8315    241.7659    260.9319    280.3916    300.5156
   323.9666   348.0527    374.5420    403.2793    432.3352    466.3560    501.4004    538.1040    580.2603    623.0596
   670.5378   722.1914    774.3813    835.1978    897.9775    964.8027   1040.4609   1117.2056   1202.3831   1294.9744
  1388.4692  1497.4817   1609.9287
```

Table 37: The location of the measuring channels for the ion instruments on HELIOS 2, involving the calibrations.

Kanäle = channels
Geschwindigkeits = speed
Mit = with
Ohne = without

Calibration of I2

The calibration of I2 was on the one hand difficult because to a mono-energetic beam of electrons with low energies of exactly known direction was needed.This required special measures due to the deflection of electrons by the Earth's magnetic field and other fields.On the other hand, only one-dimensional, pretty rough direction resolution is required.

To do this, we built a separate facility: the instrument is hung up as a whole pivots in a large vacuum vessel.An electron beam from a specially developed source runs from there through a screening tube $\mu$-metal up in the inlet.Also here there are again stabilisation and control electronics.

In these measurements, there was e.g.especially on the following points to:

By changing the ratio of two plates voltages on plate and sphere analyser had to ensure that the field of view of the instrument as possible perpendicular to the spin axis and thus almost parallel to the ecliptic is located.The necessary to trimming resistor was only afterwards still attached.

Measurements with very low-energy electrons had to prove that the relative flow characteristics are independent of particle energy, as usual in all electrostatic analyzers.At I2 local charges of the baffle plates of the magnitude of mV might cause but in principle already distortions.Fortunately, this was not the case.

The insensitivity of I2 compared with UV light had to be checked.

During the flight, the count rates Z (i, k) as functions of energy (index i) and the azimuth angle (index k) are measured.From this we calculate the values for the speed distribution function f (i, k) according to the following

Formula:

$$f(i,k) = CR \cdot \frac{Z(i,k)}{v^4(i)}$$

Where $v_i$ is the value of the electron velocity corresponding to the i-th energy channel.CR describes the device constant, which was determined by the calibration.It is

$$CR = 1 \,/\, (AREA \cdot EK \cdot DELEPS \cdot DELPHI \cdot EFFABS \cdot TAU)$$

The individual sizes are

| | | |
|---|---|---|
| AREA | = 0,3744 | Entrance surface |
| EK | = 0,03035 | determined from the relative calibration |
| DELEPS | = 0,117 | |
| DELPHI | = 0,094 | |
| EFFABS | = 0,9 | |
| TAU | = 0,078 (HELIOS 1) | Fraction of the measurement time, |
| | = 0,031 (HELIOS 2) | per full rotation. |

Still the amp dead time must be considered in the count rates.
It is $0.55 \times 10^{-7}\,s$ at HELIOS 1 and HELIOS 2.

The values measured at the calibration for the positions of the measuring channels are summarized in table 38.

For Table 38a is also to be noted that due to the Special Assembly of I2 in the probe the Middle direction of I2 from the radial direction differs by 11.25 ° .Therefore must be deducted from all values for HELIOS 1 still 11.25 °, for HELIOS 2 11.25 ° added.

A more detailed description of this setting, a discussion of the problems it encountered, as well as details of appropriate transmission characteristics are discussed in a separate publication.

| Energiekanal | Programm A | Programm B |
|---|---|---|
| 1 | 0.00039 | 10,69 |
| 2 | 0.468 | 14,93 |
| 3 | 1,150 | 20,94 |
| 4 | 1,726 | 29,26 |
| 5 | 2,317 | 40,96 |
| 6 | 3,116 | 57,75 |
| 7 | 3,914 | 75,80 |
| 8 | 4,723 | 112,38 |
| 9 | 5,518 | 157,82 |
| 10 | 6,687 | 220,56 |
| 11 | 7,835 | 309,30 |
| 12 | 9,012 | 432,11 |
| 13 | 10,151 | 604,68 |
| 14 | 11,882 | 852,47 |
| 15 | 13,586 | 1186,06 |
| 16 | 15,457 | 1657,94 |

Table 38a: Location of the energy channels of I2; all information in keV.

| Azimutkanal | HELIOS 1 | | HELIOS 2 | |
|---|---|---|---|---|
| | NS | WS | NS | WS |
| 1 | 168,75 | 171,55 | 167,345 | 189,845 |
| 2 | 213,75 | 216,55 | 122,345 | 144,845 |
| 3 | 258,75 | 261,55 | 77,345 | 99,845 |
| 4 | 303,75 | 306,55 | 32,345 | 54,845 |
| 5 | 348,75 | 351,55 | - 12,655 | 9,845 |
| 6 | 33,75 | 36,55 | - 57,655 | - 35,155 |
| 7 | 78,75 | 81,55 | -102,655 | - 80,155 |
| 8 | 123,75 | 126,55 | -147,655 | -125,155 |

Table 38b: location of Azimuth channels of I2; all data in degrees, relative to the see-sun-pulse.At HELIOS 2 all channels by 7.03 ° towards negative values can be moved by command 130-1AVL (knowable to DHK Word BO.. bit 4 in position "PEHEL" instead of "APHEL").

# 7. Tests

Were at all stages of the project and be tested again and again:

- Design and development: Testing of components, sub-assemblies, circuits
- Manufacturing phase: Ongoing functional and environmental testing of components, assemblies and the integrated instruments.After qualification tests of the prototype instruments (P type) orAcceptance testing of the flight instruments (F type).
- Integration phase: Running functional tests in the integrated system of HELIOS, in the framework of the qualification and acceptance tests of the probe
- Phase of flight: Detailed function tests after the first turn and for future special occasions, in addition to daily regular test cycles (Inflight-tests).

Here will be given only on tests of the finished instruments.Inflight-tests have been described.

## Test device

The experiment is so extensive in its entirety and complicated that a relatively costly test device is necessary to test the functionality of the entire experiment sufficiently after environmental testing as well as against the total integration.

The task of the test device is, in simple design and ease of use, the supply voltage and all signals supplied by the probe on the experiment to replicate (S/C-Simulator), to record all the data of the experiment and to evaluate such that a statement about the proper or improper function of the experiment can be made.In all operating conditions must be examined successively.Both the control of the instruments as well as the

Test data evaluation is carried out by a small computer (HP 2100).

The test set should perform this function tests under laboratory conditions, with nominal voltage, nominal-TTL data etc.

All cables between test equipment and experiment are guided over interrupting jacks that allow an interruption of lines feeding of additional or other signals, current and voltage measurements, etc.

The tester has to simulate the automatic test cycle (Inflight test), built into the experiment and evaluate.Also, it must allow also hand-controlled testing.

Each of the four boxes of the experiment has, in addition to the interface connectors, a test plug, to which the most important voltages are introduced. The individual pins of the test plug are listed in appropriate adapter bushings on the test device.These test plugs are not used in flight and were covered so shortly before the start with special caps.All test analog voltages occurring in are also fed to the computer via an extensive interface (multiplexing).

The power supply of the entire test device including the peripheral is designed so that the power is distributed to all devices requiring mains power via a switchable between 115 V and 220 V isolation transformer. In the actual power supply, the DC voltages required for S/C Simulator and the special test units, as well as special - test units are produced.

The block diagram of the test device in connection with the experiment is shown in Figure 51.Figure 52 shows a photographic representation of the test device.The test device is housed in a total of 6 Kayser racks, which also serve as transport boxes.A complete set was stationed in the final phase (integration and last function test before the start) at the Kennedy Space Center (KSC), an identical set remained in Germany for simultaneous testing of the other models.A further description of the test unit should, abandoning here since a detailed "description of the test device for experiment 1/HELIOS part A, B and C"already exists.

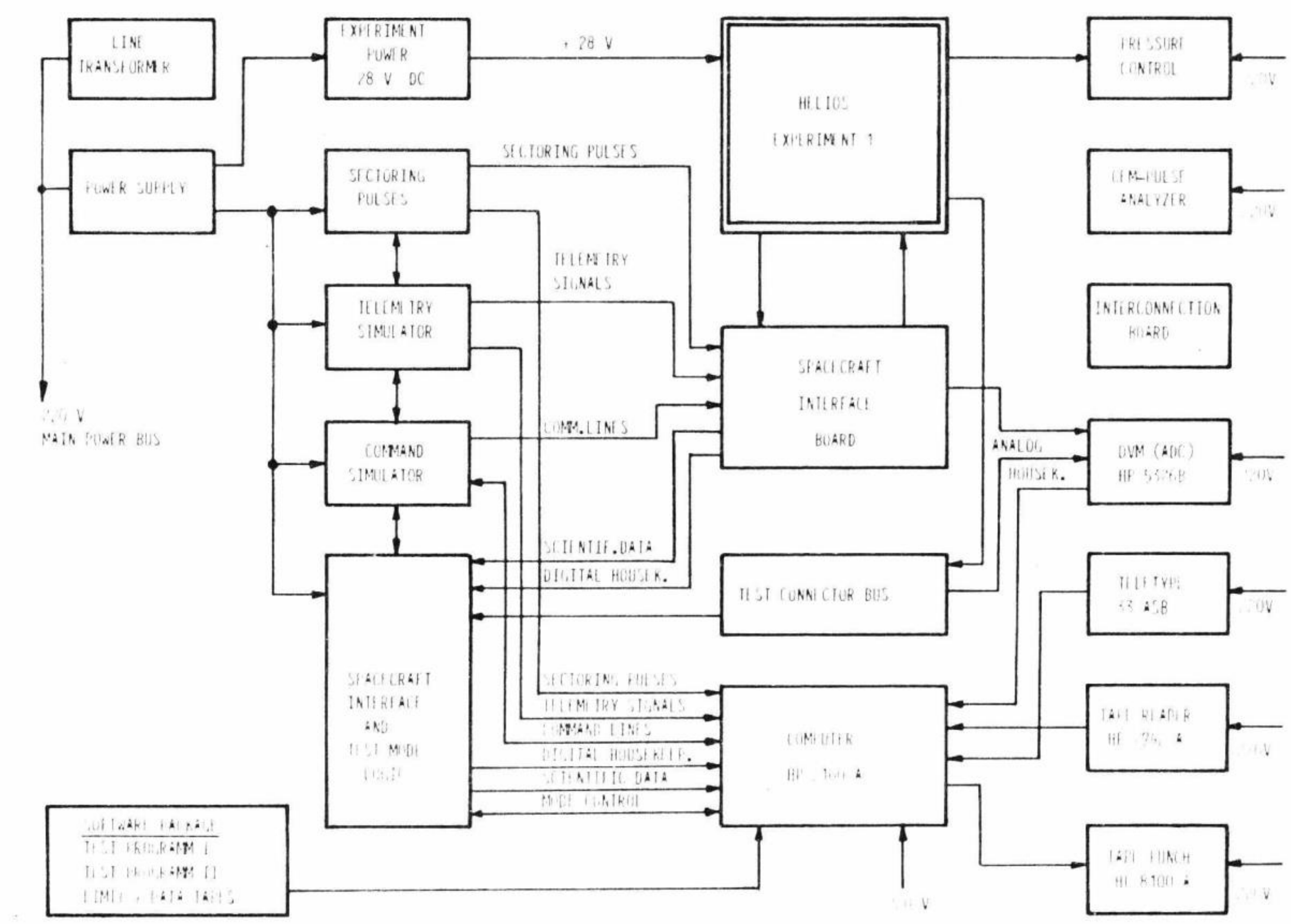



Figure 51: Test device, Block diagram

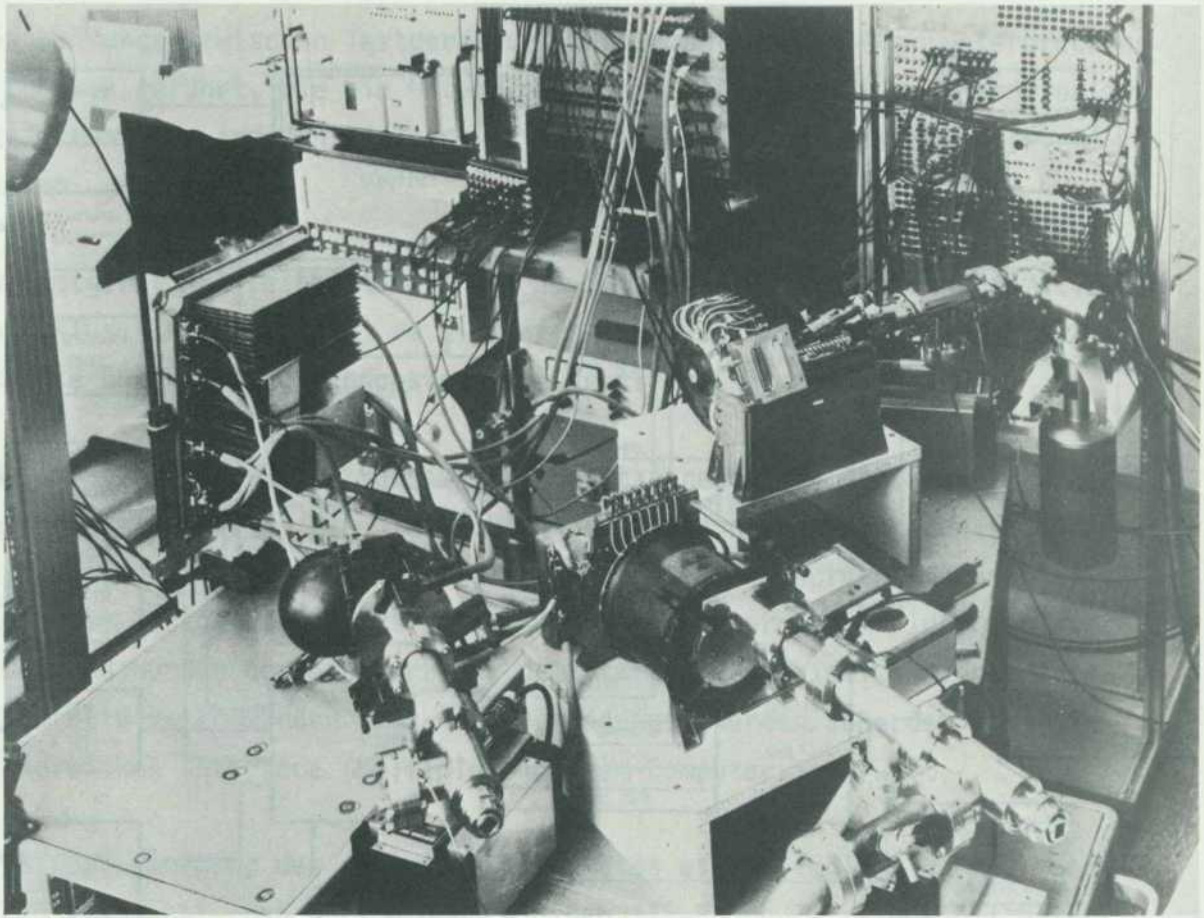


Figure 52: The test device at one of the first total tests of the engineering model of E1.Far left above the teletype for control and data output, in addition the process computer (HP 2100).Top center the "breakout box" for all instrument cables.Right the unit for "hand-controlled" special tests.

Qualification and acceptance tests

The environmental test facilities of the IABG in Ottobrunn were used for the qualification and acceptance tests of all HELIOS experiments, which were rented by the GfW for these purposes.

The engineering model (EM) was used primarily for development testing individual modules.The findings inspire in the construction of subsequent proto - and flying types.

*Unfortunately that's true only conditionally because the schedule was too tight and the EM "necessarily" had to be ready for the integration into the probes EM. There were long waiting times, where our EM unused lying around.We would learn much in other tests can and must.Today we would attach this stage much more importance.*

The qualification tests of the prototype instruments (P type), the test requirements were higher than for acceptance tests of the aircraft (F type).

*Here, too, there was virtually no repercussions on the construction of the F-types due to time constraints.So it was possible that some errors only or even after the acceptance tests were discovered and then often only in "Night and fog action" could be eliminated.*

The environmental tests of E1-HELIOS were conducted upon the test regulation PV-E1-100.After orduring environmental testing, a complete functional test of the experiment with the computer-controlled test device was carried after test specification "E1-HELI0S test program 1".

The experiment boxes were mounted to in a special test rack in the configuration in which they are located also in the probe.On the funnel of the sensors an adsorption pump system was flange mounted.

The interiors of the sensors were evacuated ($< 10^{-6}$ Torr), so that the high voltages and the function of the Channelmultiplier could be tested.This oil-free vacuum was needed to avoid contamination of the channeltrons.

In many cases, the evacuation was not possible due to time constraints.Then, special test plug were used where, suitable jumpers made for the artificial suppression of high voltages.So, then at least the electronic function of the experiment could be tested.

The test procedures are given in table 39.

The errors occurred during the qualification and acceptance tests are summarized in the following tables of 40-42.

The P-type was converted after the start of F1 with HELIOS 1 to the flight spare unit F2 on HELIOS-B and is therefore identical to F2.To do this, P had to pass also again acceptance tests.

<u>Qualification (with prototype instruments)</u>

- Function test
- Mass properties
- 1st magnetic measurement
- Functional testing
- Vibration (sine and random)
- Function test
- Linear acceleration
- Function test
- Temperature test and functional test
- Thermovakuum and function test
- EMV test and functional test
- 2nd Magnetic survey *
- Function test

<u>Acceptance (with the flight and flight spare units)</u>

- Function test
- Mass properties
- Vibration
- Function test
- Thermovakuum and function test
- EMV test and functional test
- Magnetic survey*.
- Functional testing

* experiment is turned, but not a function test.

Table 39: test procedure
Qualification and acceptance

| Test | Disorder | Remedial measure |
|---|---|---|
| 1st Magn. surveying | Short circuit in box E1C | improved isolation of the RF generator block against housing |
| Temperature test | Threshold exceedance of the sensor data at-20 °, + 55° | Exchange of Electr.Components and 1 card.Repetition of the temperature test, degradation of test temperature on + 50 ° |
| Vibration test | Fracture of connections in box E1C | Improvement in support of the electronic block, repeat the test only with E1C |
| Repeat temperature test | Faulty switching time of the mercury relay | No. Improvements for model aircraft |
| TV test | Faulty mercury relays in E1A | Exchange |
| | Border crossings at-20 °, -30 ° for E1C | No |
| | Clipping in the A/D converter | circuit modification |
| EMV test | Local exceedances | No, as not critical |

Table 40: Errors during the qualification prototype

| Test | Disorder | Remedy |
| --- | --- | --- |
| Vibration | Loosen the screws in E1C | tightened, secured |
| | Broken bolt in E1C | replaced |
| TV test | voltage converter in E1D does not turn on at -20 ° | no error in the experiment, an inappropriate external power supply |
| Magn. Surveying | Exceeding of the permissible Magn.Field after magnetisation | Waiver approved.No change. |

Table 41: Errors during the acceptance, F1 type

| Test | Disorder | Remedial Measure |
| --- | --- | --- |
| TV-Test | Screw on the funnel canceled E1C through handling errors<br><br>Failure of the power supply in the E1B | Replacement<br><br>Replacement of faulty components<br>Repetition of the test |
| EMC-Test | Interference by radiation electric fields in the range of 2-10 MHz | missing ground connection made (also in the F1, P) repetition of the test |

Table 42: Errors during the acceptance, F2 type

## Integration of E1 in the probe and system tests

After successfully completed qualification or acceptance and verification, the relevant model officially in the responsibility of the project manager and from this to the prime contractor (MBB) for integration into the probe was handed over.The most important part of the incoming inspection was a spacecraft Simulator test for the direct examination of all interface cables.After installation in the probe, E1 could be operated and tested like all other experiments only on the probe systems.These integrated system tests (IST) were now at probe level the function tests after each individual qualification and acceptance steps. Similarly as the E1 Tester was also the HELIOS test set (HTS) commands to E1, launched test cycles, evaluated the data and examined one at a time about 25 different operating States of E1. After the most important environmental tests, the E1 instruments were evacuated for the IST, with the help of the pump flange mounted on the front of the funnel (fig. 53).

Before the final completion of the probe there is still a special test, the so-called final test, for E1 at KSC.The speakers built into the probe were again separated from the probe systems and associated with the test device.Then all voltages were tested on the evacuated instruments in manual mode again progressively measured, the amplification of channeltrons with the lot channel Analyzer etc.Analyzer voltages measured in this final test serve as reference data for the calibration of the energy channels.Then came the final Assembly of the whole probe.

Immediately before countries impose the rocket top on the finished probe the airtight lid screwed on the E1 funnels were removed and replaced by lightweight dust cover held by spring-loaded.After putting the top together with the HELIOS on the rocket this lid with a gripping tool were removed only 20 hours before the start through again through a special opening in the top of the rocket. In this way we could the risky blasting off the lid or other

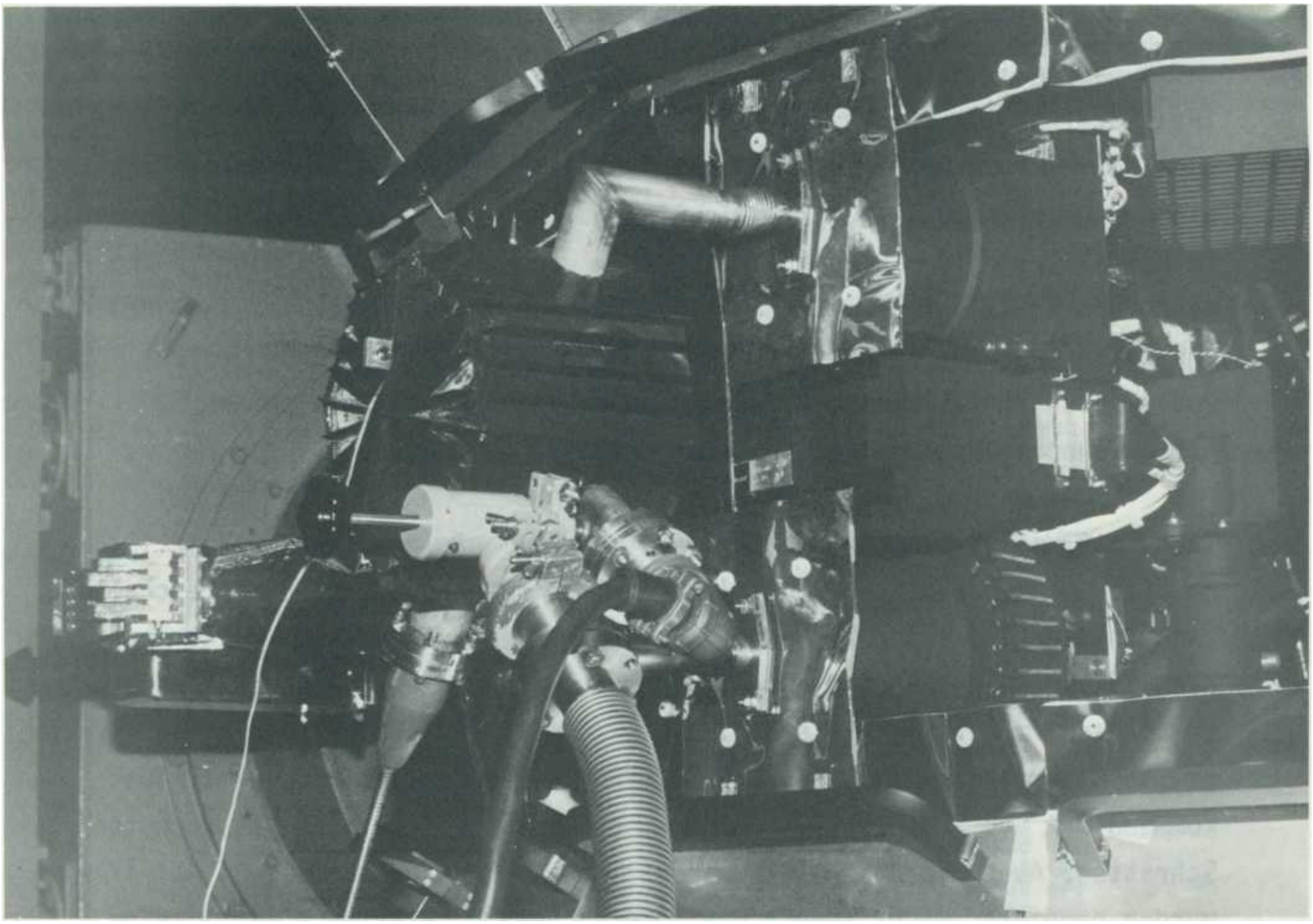


Figure 53: The vacuum pump to the test of the instruments built into the probe of E1.

avoid complicated actions in flight and yet the instruments protect quite well from contamination and dust.

*On the other hand, the enforcement of this whole procedure the development of the cover and the gripping tool, the training of the gripper (with replacement), study of interface requirements, as well as the NASA-safety regulations and last but not least, the negotiations and the paperwork with all stakeholders has requires some grotesque efforts. Perhaps there is yet easier techniques...*

## First turn on the instruments

Two days after the launch of HELIOS 1 on the 10.12.1974 the involvement of the E1 instruments started.Until then, all sensors and electronics were evacuated safely enough.The power-up sequence was established long before in detail.Parts of it were tested during the "end to end test" of spacecraft (at that time still at the KSC) and mission control (at the JPL) and later during the "operational demonstration test" already and were used mainly to teach the participants (K.Müller and R. Schwenn) in dealing with the mission control systems.

Table 43 shows an excerpt from the command log book of the 12.12.1974.
At 0115 GMT, the power supply of E1 was connected with CMD 004-E10N.This is followed by the actual E1 command.Each instrument was examined first individually exactly, namely the AHK and DHK channels on the screen were tracks (see Figure 31), and the scientific data directly to the quick printer.After each change a test cycle was each commanded and waited, then only carried out the release of the next step.Also the shut-off commands for the high voltage (E.g.151-1V1R) have been tried, but not the higher voltage levels.Although no sufficient count rates were to be expected, we investigated also I3 and switching between I1a and I3.Then came still switching between NDM and HDM and the Digital electronics.There were no anomalies during the entire procedure, everything was exactly the last ground tests, with the exception of the last visible solar wind particles.Until recently all instruments were turned on, and the actual mission operation could begin at 0255 GMT.

| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
|---|---|---|---|---|---|---|---|
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL V | 940 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL V | 970 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL V | 980 601 | | |
| 90 | 50 | 346-74 01/15/00 | 000/16/40/49.5 | 004-E1ON | | 120 | 601 |
| 90 | 51 | 346-74 01/15/20 | 000/16/48/12.8 | 004-E1ON | V | 120 | 601 |
| 90 | 51 | 346-74 01/16/10 | 000/16/48/12.8 | 374-1SOF | | 130 | 601 |
| 90 | 51 | 346-74 01/16/28 | 000/16/49/21.4 | 374-1SOF | V | 130 | 601 |
| 90 | 51 | 346-74 01/17/50 | 000/16/49/21.4 | 066-1DE1 | | 140 | 601 |
| 90 | 52 | 346-74 01/18/09 | 000/16/51/01.5 | 066-1DE1 | V | 140 | 601 |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL N | 970 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.2 | MANUAL N | 980 601 | | |

| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
|---|---|---|---|---|---|---|---|
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL N | 70 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL N | 80 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL V | 70 601 | | |
| 90 | 0 | 0- 0 00/00/00 | 000/00/00/00.0 | MANUAL V | 80 601 | | |
| 90 | 52 | 346-74 01/20/20 | 000/16/51/01.5 | 122-1HDM | | 150 | 601 |
| 90 | 54 | 346-74 01/20/51 | 000/16/53/43.5 | 122-1HDM | V | 150 | 601 |
| 90 | 54 | 346-74 01/22/00 | 000/16/53/43.5 | 024-1S1B | | 160 | 601 |
| 90 | 55 | 346-74 01/22/32 | 000/16/55/24.8 | 024-1S1B | V | 160 | 601 |
| 90 | 55 | 346-74 01/23/40 | 000/16/55/24.8 | 332-1TCY | | 170 | 601 |
| 90 | 56 | 346-74 01/24/13 | 000/16/57/06.0 | 332-1TCY | V | 170 | 601# |
| 90 | 56 | 346-74 01/27/20 | 000/16/57/06.0 | 374-1SOF | | 180 | 601 |
| 90 | 57 | 346-74 01/27/56 | 000/17/00/48.8 | 374-1SOF | V | 180 | 601 |
| 90 | 57 | 346-74 01/29/00 | 000/17/00/48.8 | 066-1DE1 | | 190 | 601 |
| 90 | 58 | 346-74 01/29/37 | 000/17/02/30.0 | 066-1DE1 | V | 190 | 601 |
| 90 | 58 | 346-74 01/31/30 | 000/17/02/30.0 | 122-1HDM | | 200 | 601 |
| 90 | 59 | 346-74 01/31/59 | 000/17/04/52.9 | 122-1HDM | V | 200 | 601 |
| 90 | 59 | 346-74 01/33/10 | 000/17/04/52.9 | 003-1S1A | | 210 | 601 |
| 90 | 60 | 346-74 01/33/40 | 000/17/06/33.0 | 003-1S1A | V | 210 | 601 |
| 90 | 60 | 346-74 01/34/50 | 000/17/06/33.0 | 332-1TCY | | 220 | 601 |
| 90 | 61 | 346-74 01/35/21 | 000/17/08/14.3 | 332-1TCY | V | 220 | 601 |
| 90 | 61 | 346-74 01/38/30 | 000/17/08/14.3 | 107-1V11 | | 230 | 601 |
| 90 | 62 | 346-74 01/39/04 | 000/17/11/57.0 | 107-1V11 | V | 230 | 601 |
| 90 | 62 | 346-74 01/40/10 | 000/17/11/57.0 | 332-1TCY | | 240 | 601 |
| 90 | 63 | 346-74 01/40/45 | 000/17/13/38.3 | 332-1TCY | V | 240 | 601 |
| 90 | 63 | 346-74 01/42/20 | 000/17/13/38.3 | 151-1V1R | | 250 | 601 |

| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
|---|---|---|---|---|---|---|---|
| 90 | 64 | 346-74 01/42/47 | 000/17/15/39.8 | 151-1V1R | V | 250 | 601 |
| 90 | 64 | 346-74 01/44/00 | 000/17/15/39.8 | 374-1SOF | | 260 | 601 |
| 90 | 65 | 346-74 01/44/28 | 000/17/17/21.0 | 374-1SOF | V | 260 | 601 |
| 90 | 65 | 346-74 01/45/40 | 000/17/17/21.0 | 066-1DE1 | | 270 | 601 |
| 90 | 66 | 346-74 01/46/09 | 000/17/19/02.3 | 066-1DE1 | V | 270 | 601 |
| 90 | 66 | 346-74 01/48/10 | 000/17/19/03.4 | 122-1HDM | | 280 | 601 |
| 90 | 66 | 346-74 01/48/31 | 000/17/21/24.0 | 122-1HDM | V | 280 | 601 |
| 90 | 66 | 346-74 01/49/50 | 000/17/21/24.0 | 353-1SE2 | | 290 | 601 |
| 90 | 67 | 346-74 01/50/12 | 000/17/23/05.3 | 353-1SE2 | V | 290 | 601 |
| 90 | 67 | 346-74 01/51/30 | 000/17/23/05.3 | 332-1TCY | | 300 | 601 |
| 90 | 68 | 346-74 01/51/53 | 000/17/24/46.5 | 332-1TCY | V | 300 | 601# |
| 90 | 68 | 346-74 00/10/59 | 000/17/24/46.5 | U | 1 601 | | |
| 90 | 69 | 346-74 01/54/29 | 000/17/27/21.8 | U | N 1 601 | | |
| 90 | 69 | 346-74 01/54/40 | 000/17/27/24.0 | 172-1V21 | | 310 | 601 |
| 90 | 69 | 346-74 00/10/59 | 000/17/27/58.9 | U | 1 601 | | |
| 90 | 70 | 346-74 01/55/16 | 000/17/28/09.0 | 172-1V21 | V | 310 | 601 |
| 90 | 70 | 346-74 00/03/35 | 000/17/28/20.3 | U | 1 601 | | |
| 90 | 70 | 346-74 01/55/30 | 000/17/28/22.5 | U | N 1 601 | | |
| 90 | 70 | 346-74 01/55/43 | 000/17/28/42.8 | U | 1 601 | | |
| 90 | 70 | 346-74 01/56/20 | 000/17/29/18.8 | 332-1TCY | | 320 | 601 |
| 90 | 71 | 346-74 01/56/57 | 000/17/29/50.3 | 332-1TCY | V | 320 | 601 |
| 90 | 71 | 346-74 01/59/30 | 000/17/32/28.9 | 234-1PGA | | 330 | 601 |
| 90 | 72 | 346-74 01/59/59 | 000/17/32/52.5 | 234-1PGA | V | 330 | 601 |
| 90 | 72 | 346-74 02/01/10 | 000/17/34/07.9 | 332-1TCY | | 340 | 601 |
| 90 | 73 | 346-74 02/01/41 | 000/17/34/33.8 | 332-1TCY | V | 340 | 601 |

Table 43: This snippet from the command log by HELIOS 1 shows  of the 12.12.1974 power up for the E1 instruments.

| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
|---|---|---|---|---|---|---|---|
| 90 | 73 | 346-74 02/04/20 | 000/17/37/20.3 | 247-1PGB | | 350 | 601 |
| 90 | 73 | 346-74 02/04/44 | 000/17/37/37.2 | 247-1PGB | V | 350 | 601 |
| 90 | 74 | 346-74 02/06/00 | 000/17/38/58.2 | 226-1V2R | | 360 | 601 |
| 90 | 75 | 346-74 02/06/26 | 000/17/39/18.4 | 226-1V2R | V | 360 | 601 |
| 90 | 75 | 346-74 02/07/40 | 000/17/40/39.4 | 374-1SOF | | 370 | 601 |
| 90 | 76 | 346-74 02/08/06 | 000/17/40/58.5 | 374-1SOF | V | 370 | 601 |
| 90 | 76 | 346-74 00/03/35 | 000/17/41/27.8 | U | 1 | 601 | |
| 90 | 76 | 346-74 02/09/20 | 000/17/42/18.4 | 066-1DE1 | | 380 | 601 |
| 90 | 77 | 346-74 02/09/47 | 000/17/42/39.8 | 066-1DE1 | V | 380 | 601 |
| 90 | 77 | 346-74 02/11/50 | 000/17/44/48.0 | 122-1HDM | | 390 | 601 |
| 90 | 77 | 346-74 02/12/10 | 000/17/45/02.7 | 122-1HDM | V | 390 | 601 |
| 90 | 78 | 346-74 02/12/55 | 000/17/45/55.5 | U | 1 | 601 | |
| 90 | 78 | 346-74 02/13/30 | 000/17/46/28.2 | 045-1SE3 | | 400 | 601 |
| 90 | 78 | 346-74 02/13/50 | 000/17/46/42.8 | 045-1SE3 | V | 400 | 601 |
| 90 | 79 | 346-74 02/15/10 | 000/17/48/09.4 | 332-1TCY | | 410 | 601 |
| 90 | 79 | 346-74 02/15/31 | 000/17/48/24.0 | 332-1TCY | V | 410 | 601 |
| 90 | 80 | 346-74 02/18/20 | 000/17/51/20.7 | 107-1V11 | | 420 | 601 |
| 90 | 80 | 346-74 00/10/59 | 000/17/51/20.7 | U DTV OVER | 1 | 601 | |
| 90 | 81 | 346-74 02/18/54 | 000/17/51/46.5 | 107-1V11 | V | 420 | 601 |
| 90 | 81 | 346-74 02/20/00 | 000/17/52/58.5 | 332-1TCY | | 430 | 601 |
| 90 | 82 | 346-74 02/20/36 | 000/17/53/28.9 | 332-1TCY | V | 430 | 601 |
| 90 | 82 | 346-74 02/23/10 | 000/17/56/08.7 | 151-1V1R | | 440 | 601 |
| 90 | 82 | 346-74 01/55/43 | 000/17/56/08.7 | U DTV OVER | 1 | 601 | |
| 90 | 83 | 346-74 02/23/37 | 000/17/56/30.0 | 151-1V1R | V | 440 | 601 |
| 90 | 83 | 346-74 02/24/50 | 000/17/57/48.8 | 374-1SOF | | 450 | 601 |
| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
| 90 | 84 | 346-74 02/25/18 | 000/17/58/11.3 | 374-1SOF | V | 450 | 601 |
| 90 | 84 | 346-74 02/26/30 | 000/17/59/30.0 | 066-1DE1 | | 460 | 601 |
| 90 | 85 | 346-74 02/27/01 | 000/17/59/53.7 | 066-1DE1 | V | 460 | 601 |
| 90 | 85 | 346-74 02/28/10 | 000/18/01/07.9 | 311-1DE2 | | 470 | 601 |
| 90 | 86 | 346-74 02/28/42 | 000/18/01/34.9 | 311-1DE2 | V | 470 | 601 |
| 90 | 86 | 346-74 01/55/43 | 000/18/03/34.2 | U | 1 | 601 | |
| 90 | 86 | 346-74 02/30/40 | 000/18/03/39.8 | 122-1HDM | | 480 | 601 |
| 90 | 86 | 346-74 02/31/23 | 000/18/03/55.5 | 122-1HDM | V | 480 | 601 |
| 90 | 87 | 346-74 02/32/20 | 000/18/05/18.8 | 024-1S1B | | 490 | 601 |
| 90 | 87 | 346-74 02/32/44 | 000/18/05/36.8 | 024-1S1B | V | 490 | 601 |
| 90 | 88 | 346-74 02/34/00 | 000/18/06/58.9 | 003-1S1A | | 500 | 601 |
| 90 | 88 | 346-74 00/03/35 | 000/18/06/58.9 | U DTV OVER | 1 | 601 | |
| 90 | 89 | 346-74 02/34/25 | 000/18/07/18.0 | 003-1S1A | V | 500 | 601 |
| 90 | 89 | 346-74 02/35/40 | 000/18/08/40.2 | 107-1V11 | | 510 | 601 |
| 90 | 90 | 346-74 02/36/08 | 000/18/09/00.4 | 107-1V11 | V | 510 | 601 |
| 90 | 90 | 346-74 02/37/20 | 000/18/10/18.0 | 353-1SE2 | | 520 | 601 |
| 90 | 91 | 346-74 02/37/49 | 000/18/10/41.7 | 353-1SE2 | V | 520 | 601 |
| 90 | 91 | 346-74 02/39/00 | 000/18/11/58.2 | 172-1V21 | | 530 | 601 |
| 90 | 91 | 346-74 02/12/55 | 000/18/11/58.2 | U DTV OVER | 1 | 601 | |
| 90 | 92 | 346-74 02/39/29 | 000/18/12/21.8 | 172-1V21 | V | 530 | 601 |
| 90 | 92 | 346-74 02/40/40 | 000/18/13/39.4 | 332-1TCY | | 540 | 601 |
| 90 | 93 | 346-74 02/41/10 | 000/18/14/03.0 | 332-1TCY | V | 540 | 601 |
| 90 | 93 | 346-74 02/44/20 | 000/18/17/18.8 | 213-1NDM | | 550 | 601 |
| 90 | 94 | 346-74 02/44/53 | 000/18/17/45.8 | 213-1NDM | V | 550 | 601 |
| 90 | 94 | 346-74 02/46/00 | 000/18/18/58.9 | 332-1TCY | | 560 | 601 |
| S/C ID | CMD CTR | STATUS TIME | SPACECRAFT TIME | COMMAND | STATUS | CMD MES | FMT |
| 90 | 94 | 346-74 00/10/59 | 000/18/18/58.9 | U TBL OVER | 1 | 601 | |
| 90 | 95 | 346-74 02/46/34 | 000/18/19/27.0 | 332-1TCY | V | 560 | 601 |
| 90 | 95 | 346-74 02/47/10 | 000/18/20/09.8 | 066-1DE1 | | 570 | 601 |
| 90 | 96 | 346-74 02/47/35 | 000/18/20/27.8 | 066-1DE1 | V | 570 | 601 |
| 90 | 96 | 346-74 02/48/50 | 000/18/21/49.9 | 332-1TCY | | 580 | 601 |
| 90 | 96 | 346-74 01/55/43 | 000/18/21/49.9 | U TBL OVER | 1 | 601 | |
| 90 | 97 | 346-74 02/49/16 | 000/18/22/09.0 | 332-1TCY | V | 580 | 601 |
| 90 | 97 | 346-74 02/51/15 | 000/18/24/13.9 | U | 1 | 601 | |
| 90 | 97 | 346-74 02/52/00 | 000/18/24/57.6 | 122-1HDM | | 590 | 601 |
| 90 | 97 | 346-74 02/52/19 | 000/18/25/11.3 | 122-1HDM | V | 590 | 601 |
| 90 | 98 | 346-74 02/54/50 | 000/18/27/48.8 | 332-1TCY | | 600 | 601 |
| 90 | 99 | 346-74 02/55/22 | 000/18/28/14.7 | 332-1TCY | V | 600 | 601 |
| 93 | 99 | 346-74 02/59/02 | 000/18/32/00.8 | 201-0TST | | 610 | 601 |
| 90 | 99 | 346-74 01/55/43 | 000/18/32/00.8 | U DTV OVER | 1 | 601 | |
| 90 | 100 | 346-74 03/00/00 | 000/18/32/52.5 | 201-0TST | N | 610 | 601 |

Table 43: Continuation

Subsequent special tests

Completely trouble-free working of the instruments made virtually unnecessary special tests during the mission.We have changes the channeltrons due to the accurate measurement of gain at the regular conducted daily Inflight test - of which we get each paper prints – safely under control. Nevertheless, we have occasionally commanded test sequences, in which we examined the individual instruments with different Channeltron high voltages.By direct comparison of the measured particle count rates and spreads, we can ensure that at no time to distort the measured particles fluxes entered through changes of channeltrons.

## 8. Flight experiences with E1 instruments

In this last chapter, we want to report much about our experience with the instruments during the mission.Much has been discussed already at the description of the instruments in the form of comments in detail.

The technology of instruments now only much: apart from the failure of the relay in I2 (S.133) there have been no problems so far.The extremes are verified by testing the temperatures were essentially being respected; There have been few exceedances (to-34 ° I1a/b, in operation and -42° when switched off).The thermal design of the I2 had concerned about much before the start because of the large inlet, so still relatively late a large comb-like finned had to be applied (seeFigure 1).The temperature of I2 held indeed within the framework and reached values in the Perihelia of 32,10 ° to 44,44 ° (HELIOS 1) and 36,6 ° to 49,28 ° (HELIOS 2).

Finally illustrate some metrics, what is with these instruments and also where their boundaries lie.

The data collected during the mission are of an extraordinary variety, and even after over five years of mission, there are still new surprises in the form of data, no one could expect.Of course, the solar wind in most cases behaves "normally", and the interpretation of the instruments proves this as excellent.Examples of 'normal' measurements are shown in figs. 54 and 55.Much more interesting but, of course, are those events that deviate from the norm and so far observed in many cases by no one.
It turned out that most of the various extremes our instruments can keep up still and let quite some room for the unexpected. Only been two events our measurement ranges really are no longer sufficient, because in one case the solar winds speed under 170 $kms^{-1}$ (fig. 56) fell, went in the other well over 1700 $kms^{-1}$ (fig. 57).

The selected energy resolution was slightly more painful.It happened occasionally that at extremely low temperatures virtually the entire proton distribution in a single measuring channel fell (fig. 58) or even through the grate fell (fig. 59).Such data are useful only with restrictions.

Well as amazing, however, has the dimensions of sensitivities turned out.So far, the plasma densities varied between 0.1 (fig. 60) and 1500 $cm^{-3}$ (fig. 61), i.e. by a factor of 1.5 x $10^4$.To in all cases still sufficiently accurately to measure, a dynamic range of at least $10^5$ required.Here, the compilation of several instruments made to a 'Package' really paid.I1a covered mainly the area of low particle flows with its high sensitivity at the same time very low NZR.Even such low counting rates in the Proton peak of 10 counts (Figure 60) can yet be evaluated, because the NZR at ≈ 2 is located. I3 was particularly suited to the high flows close to the perihelion.The highest count rate previously measured by I3 of 6656 counts (picture 61) corresponds to I1a a count rate 200 000 counts (measured in 10 ms, i.e. the real count rate would be 20 MHz, which of course the CEM amplifiers with their dead time of approximately 500 ns according to 2 MHz were no longer grown).The simultaneously working in all cases instrument I1b is located approximately in the middle with his sensitivity and enabled precise cross calibrations of instruments on the fly.

Also I2 proved excellent.It can be seen in several of the examples that harmonized the selected sensitivity with the selected energy range: the 1-count level was only reached in the two top channels, while the core of the distribution count rates at the same time delivered up to 50 000 counts (fig. 62).Also I2 so covered a dynamic range of almost $10^5$.by the way, the maximum count rate of 63 488 counts (see table 34 on p. 143 ff) was never exceeded, but in many cases only just missed (61 image).

63 to 68 images show some more eye-catching features in the data, which are each described in the captions.
The shown examples illustrate the diversity of data, which surprised us in the course of the Mission again and again on the new.The expert viewer of these samples is able to avoid hardly the huge stimulus that emanates from them.What does this all mean? Are there "Holes" in the solar wind?Or even solar wind without electrons?Unknown ion?It is tempting to pounce immediately on the evaluation.So fare us even today, after almost six years of mission.And therefore we look forward to further work with this experiment and its data, which will keep some more years in breath.

DFVLR-GSOC 8031 OBERPFAFFENHOFEN GERMAN SPACE OPERATION CENTER 29, 2,80 GMT 4H 46M 54S 428MS PAGE-NO. 3
MISSION HELIOS-B ***AUSGABE GEPUFFERT***
H-91 DSS--11 80 59 21:02:05 B/R 512 FM 1 DM 2-0 FMT 34: EXP1-NOR
SCTIME 26 00:22:39.468 FN : 162 FB/FF= 0/ 1
STATUS: PLA NDM TIME 0 00:51:49.500 MEM2 D1-ON D2-OFF I1A-ON I2-ON I1B-ON WS I3-OFF APHEL

INITIAL DATA W1-8 11110000 11000010 01011000 11110000 10001000 01010111 11110000 00001110
CW: 5 W9-15 11101011 11110000 10001000 01010111 11110000 11110000 11110000

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 23 | 24 (2) | 23 | 24 | 22 | 24 | 25 | 31 | 84 | 240 | 40 | 25 | 25 | 32 | 28 | 25 |
| | EN17-32 | 23 | 23 | 24 | 23 | 24 | 24 | 23 | 23 | 23 | 25 | 24 | 24 | 24 | 25 | 24 | 25 |
| I1A INTEGR. | EN1-16 | 0 | 3 (3) | 2 | 3 | 3 | 7 | 10 | 62 | 496 | 832 | 32 | 4 | 6 | 32 | 8 | 3 |
| | EN17-32 | 3 | 0 | 3 | 5 | 1 | 3 | 5 | 2 | 1 | 2 | 3 | 1 | 0 | 2 | 0 | 3 |
| I2A | AZ1 | 0 | 1 | 1 | 1 | 7 | 6 | 6 | 6 | 13 | 19 | 15 | 17 | 18 | 21 | 18 | 21 |
| | AZ2 | 0 | 0 | 1 | 1 | 2 | 8 | 6 | 10 | 12 | 14 | 16 | 15 | 12 | 15 | 15 | 17 |
| | AZ3 | 0 | 0 | 1 | 2 | 4 | 8 | 14 | 16 | 26 | 24 | 32 | 22 | 24 | 36 | 29 | 38 |
| | AZ4 | 0 | 44 | 124 | 136 | 34 | 60 | 42 | 32 | 50 | 48 | 60 | 54 | 58 | 64 | 76 | 52 |
| | AZ5 | 0 | 112 | 384 (1) | 352 | 240 | 120 | 64 | 54 | 50 | 72 | 72 | 76 | 88 | 96 | 104 | 88 |
| | AZ6 | 0 | 124 | 464 | 416 | 256 | 120 | 68 | 60 | 46 | 42 | 62 | 58 | 72 | 62 | 80 | 60 |
| | AZ7 | 0 | 0 | 1 | 5 | 9 | 11 | 18 | 21 | 27 | 36 | 27 | 40 | 52 | 42 | 44 | 34 |
| | AZ8 | 0 | 0 | 0 | 5 | 4 | 8 | 9 | 13 | 19 | 17 | 30 | 19 | 29 | 26 | 28 | 32 |

I1A/3 MAX AT: EN9 EL5 AZ8

| | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EN7 | | | | | EN8 | | | | | EN9 | | |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| AZ8 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 6 | 1 | 0 | 4 | 13 | 115 (4) | 21 | 0 |
| AZ9 | 0 | 1 | 2 | 0 | 0 | 3 | 13 | 19 | 3 | 0 | 1 | 34 | 216 | 36 | 2 |
| AZ10 | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 6 | 1 | 0 | 4 | 18 | 16 | 1 | 0 |
| | | | EN10 | | | | | EN11 | | | | | EN12 | | |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 1 | 7 | 144 | 24 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ9 | 2 | 32 | 464 (4) | 100 | 0 | 2 | 3 | 10 | 3 | 0 | 0 | 0 | 0 | 2 | 0 |
| AZ10 | 0 | 10 | 26 | 5 | 0 | 1 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | EN13 | | | | | EN14 | | | | | EN15 | | |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 10 | 3 | 0 | 0 | 0 | 4 | 0 | 0 |
| AZ10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 2

$r = 0{,}954$ AU

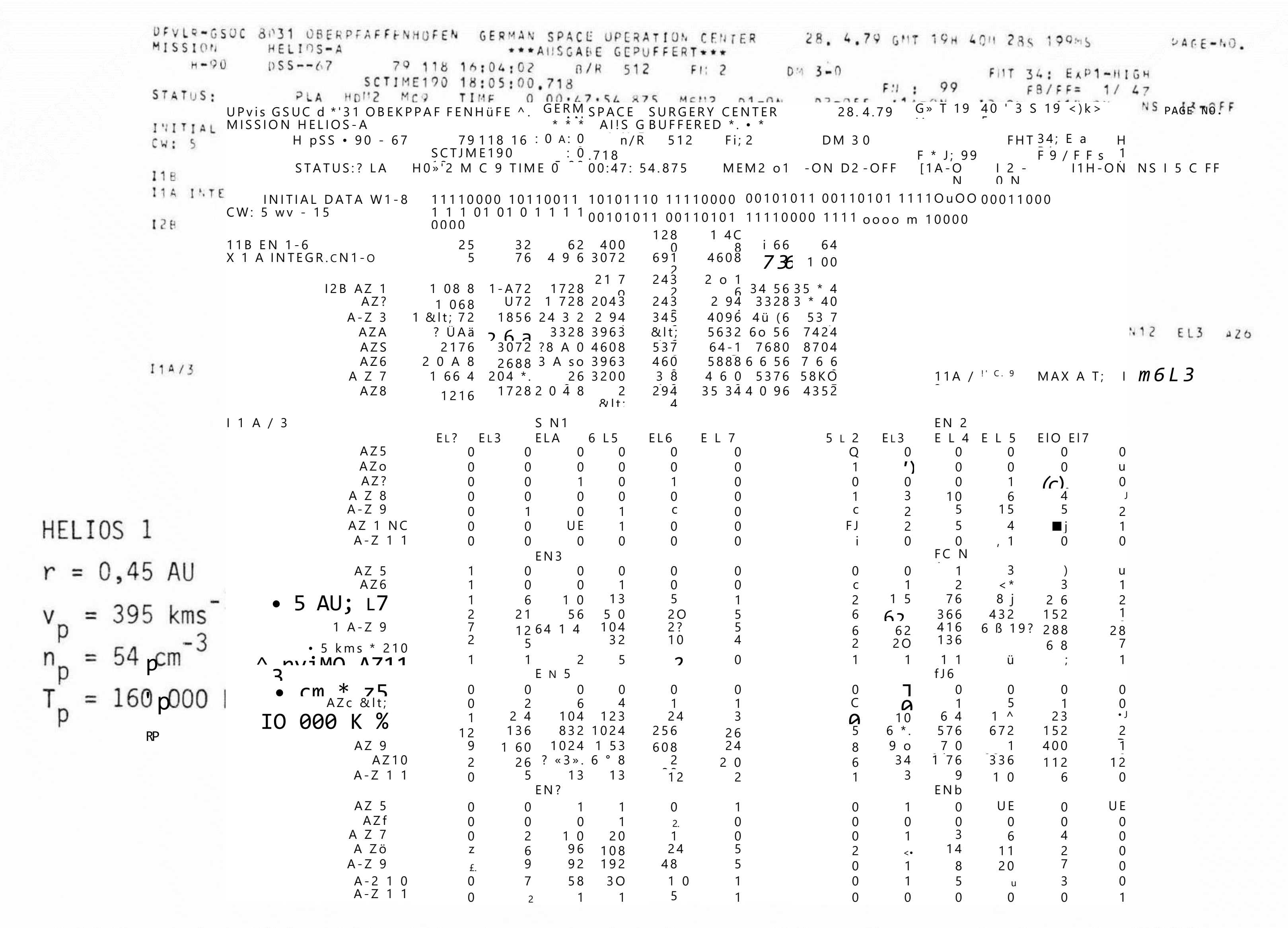
$v_p = 312\ \mathrm{kms}^{-1}$

$n_p = 6{,}5\ \mathrm{cm}^{-3}$

$T_p = 22\ 000$ K

Figure 54: "Normal" slow solar wind, away from the Sun.
(1) The photo-peak in the A-programme of I2.
(2) The NZR by I1b varies only to ± 1 count (in HELIOS 2).
(3) The integral NZR by I1a lies at approx.2-3 counts.
(4) The maximum of the distribution has jumped from EN9/EL5/AZ8 to EN10/EL5/AZ9.
The stirring that often comes from the alternate channel shift.

Ausgabe gepuffert = buffered output


DFVLR-GSOC 8031 OBERPFAFFENHOFEN GERMAN SPACE OPERATION CENTER 28. 4.79 GMT 19H 40M 28S 199MS PAGE-NO.
MISSION HELIOS-A ***AUSGABE GEPUFFERT***
H-90 DSS--67 79 118 16:04:02 B/R 512 FM 2 DM 3-0 FMT 34: EXP1-HIGH
SCTIME190 18:05:00,718 FM : 99 FB/FF= 1/ 47
STATUS: PLA HDM2 MC9 TIME 0 00:47:54.875
INITIAL DATA W1-8
CW: 5
I1B
I1A INTE
I2B
I1A/3

HELIOS 1

$r = 0,45$ AU

$v_p = 395$ $kms^{-1}$

$n_p = 54$ $cm^{-3}$

$T_p = 160\,000$ K

Figure 55: "Normal" slow solar wind, close to the Sun.
Sample HDM2-block small block length (p.89), where the EL8 data be omitted.Still, the distribution of Proton is captured well.



Ausgabe gepuffert = buffered output

DFVLR-GSUC 8031 OBERPFAFFENHOFEN GERMAN SPACE OPERATION CENTER 14.11.79 GMT 5H 27M 44S 423MS PAGE-NO. 20
MISSION HELIOS-B ***AUSGABE GEPUFFERT***
H-91 DSS--44 79 317 08:18:08 B/R 128 FM 2 DM 2-0 FMT 34: EXP1-NOR
SCTIME 38 16:48:46.908 FN : 261 FB/FF* 0/ 3
STATUS: PLA NDM TIME 0 00:21:57.437 MEM2 D1-ON D2-OFF I1A-ON I2-ON I1B-ON NS I3-OFF PEHEL

INITIAL DATA W1-8 11110000 01010010 01010111 11110000 00000000 01010111 11110000 00001110
CW: 5 W9-15 11101001 11110000 00000000 01010111 11110000 11110000 11110000

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | (1) 176 | 116 | 60 | 42 | 40 | 32 | 29 | 29 | 28 | 28 | 27 | 28 | 27 | 27 | 27 | 27 |
| | EN17-32 | 27 | 27 | 27 | 27 | 26 | 25 | 26 | 26 | 26 | 26 | 27 | 25 | 26 | 26 | 25 | 25 |
| I1A INTEGR. | EN1-16 | (1) 832 | 448 | 152 | 62 | 44 | 10 | 10 | 2 | 5 | 1 | 3 | 0 | 1 | 3 | 1 | 0 |
| | EN17-32 | 3 | 2 | 0 | 3 | 7 | 5 | 3 | 2 | 4 | 4 | 1 | 4 | 1 | 5 | 2 | 1 |
| I2A | AZ1 | 0 | 112 | 512 | 992 | 2816 | 432 | 640 | 864 | 1024 | 1280 | 1664 | 1984 | 2304 | 2944 | 3328 | 3712 |
| | AZ2 | 0 | 112 | 432 | 1088 | 3200 | 704 | 608 | 800 | 1024 | 1344 | 1664 | 2048 | 2432 | 2816 | 3456 | 3712 |
| | AZ3 | 0 | 192 | 736 | 1216 | 3840 | 3584 | 672 | 832 | 1088 | 1408 | 1728 | 2048 | 2304 | 3072 | 3456 | 3968 |
| | AZ4 | 0 | 3584 | 5888 | 4608 | 4352 | 3840 | 1024 | 1024 | 1216 | 1600 | 1920 | 2432 | 2816 | 3328 | 3840 | 4096 |
| | AZ5 | 0 | 2944 | 4352 | 3712 | 3456 | 3200 | 864 | 992 | 1216 | 1536 | 1984 | 2304 | 2688 | 3200 | 3584 | 3968 |
| | AZ6 | 0 | 304 | 736 | 1280 | 4864 | 1344 | 672 | 864 | 1088 | 1536 | 1920 | 2176 | 2560 | 3072 | 3584 | 3840 |
| | AZ7 | 0 | 136 | 544 | 2432 | 4352 | 1856 | 640 | 864 | 1088 | 1344 | 1792 | 2048 | 2432 | 2944 | 3456 | 3840 |
| | AZ8 | 0 | 136 | 496 | 928 | 1856 | 1536 | 640 | 896 | 1088 | 1344 | 1664 | 1984 | 2304 | 2816 | 3200 | 3584 |

I1A/3 MAX AT: EN1 EL5 AZ8

| | EN1 EL3 | EL4 | EL5 | EL6 | EL7 | EN2 EL3 | EL4 | EL5 | EL6 | EL7 | EN3 EL3 | EL4 | EL5 | EL6 | EL7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AZ6 | 1 | 8 | 18 | 12 | 17 | 0 | 2 | 4 | 9 | 5 | 0 | 1 | 1 | 2 | 0 |
| AZ7 | 3 | 28 | 68 | 72 | 54 | 3 | 15 | 32 | 44 | 24 | 1 | 3 | 8 | 13 | 6 |
| AZ8 | 9 | 46 | 112 | 112 | 64 | 5 | 27 | 44 | 76 | 42 | 3 | 8 | 21 | 27 | 8 |
| AZ9 | 4 | 17 | 42 | 64 | 38 | 2 | 11 | 27 | 28 | 14 | 1 | 3 | 21 | 12 | 5 |
| AZ10 | 0 | 1 | 7 | 8 | 4 | 0 | 2 | 3 | 4 | 2 | 0 | 1 | 1 | 1 | 1 |
| | EN4 | | | | | EN5 | | | | | EN6 | | | | |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 1 | 4 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| AZ8 | 0 | 5 | 5 | 5 | 3 | 0 | 5 | 7 | 4 | 1 | 1 | 0 | 1 | 1 | 1 |
| AZ9 | 3 | 4 | 8 | 0 | 3 | 0 | 4 | 5 | 3 | 0 | 0 | 2 | 0 | 2 | 0 |
| AZ10 | 1 | 1 | 5 | 3 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EN7 | | | | | EN8 | | | | | EN9 | | | | |
| AZ6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ10 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |

HELIOS 2

$r = 0{,}308$ AU

$v < 170$ kms$^{-1}$

Figure 56: The slowest so far solar wind.

(1) Here $v_p$ has become so low, that even the maximum of the distribution is still below EN1. $v_p$ is likely much less than 170 kms$^{-1}$ amount.This phase lasts several hours.

Ausgabe gepuffert = buffered output

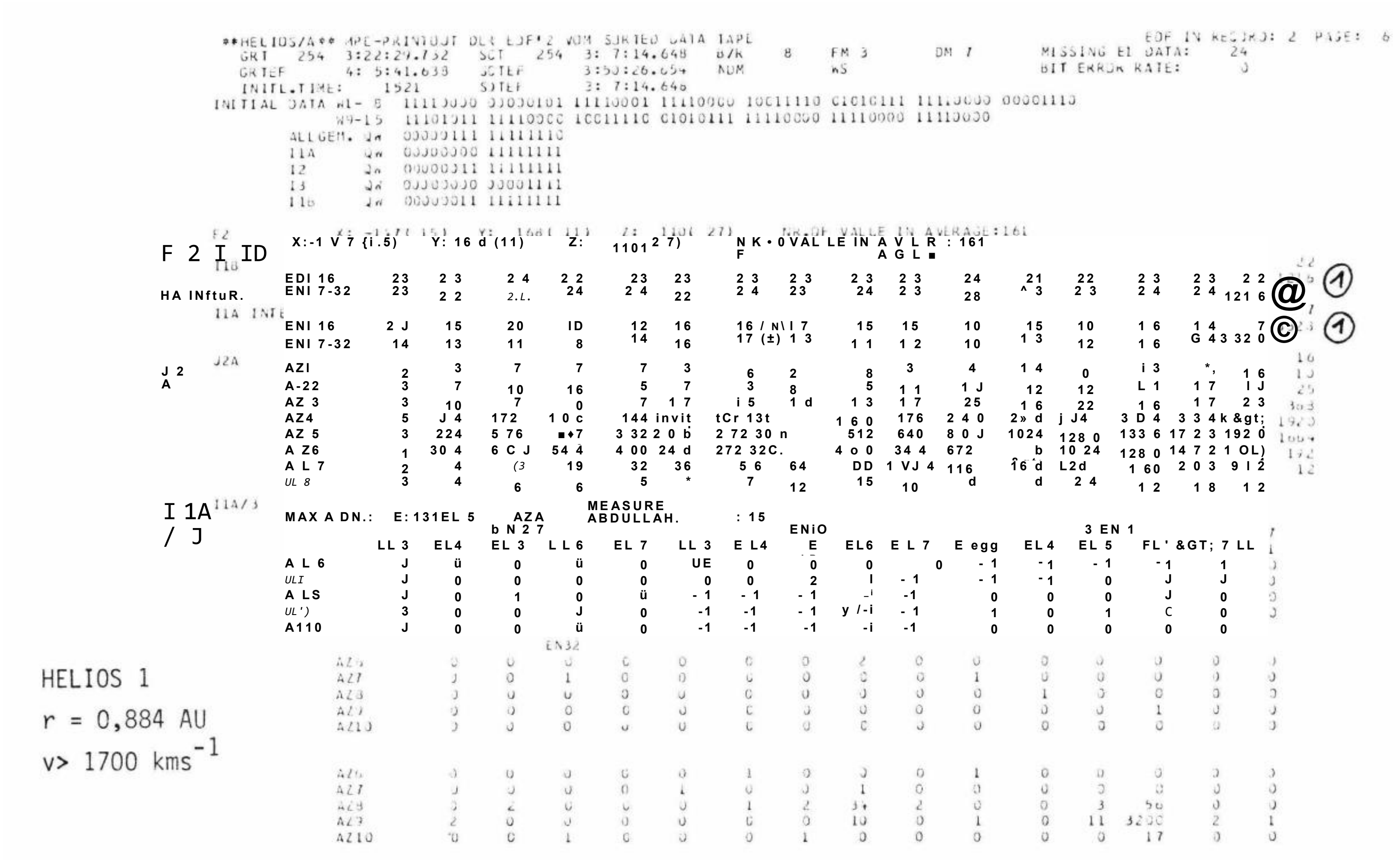



Figure 57: Extremely faster solar wind.

(1) After a strong shock $v_p$ has grown so much, that our range is no longer sufficient. For several hours, the distribution had disappeared completely, i.e.$v_p$ was larger than 1700 $kms^{-1}$.This happened only once.

(2) The high values of the NZR stemming from high energy, presumably electrons, particles generated by a flare.

(3) Here is missing a data frame.The illegible values are marked with-1.According to the tab. 11 on p. 84 a data frame at FM3 comprises 24 words.The absence of two bits in the quality Word indicates the absence of this framework and the decoding problem.In this case, only the affected 3D data would be excluded from evaluation.

```
DFVLR-GSOC 8031 OBERPFAFFENHOFEN  GERMAN SPACE OPERATION CENTER      4. 1.78 GMT 23H 26M 57S 601MS        PAGE-NO.   25
MISSION   HELIOS-A                 ***AUSGABE  BUFFERED **
   DSS 11            78A 20:19:00       8/R 512FW 3                DM 7-1                 PMT34  : Exp 1-ONLY
                 SCTIME 27 09:39:05,.   8A3               *READOUT *.           FTJ j        F = 8/FF  1/3
STATES:           PIA NDM TIME 001      : 03: 37.250   HEM 2 01 0N  D2 0FF   I1    ON 12     UN  I1 B-O   ws  I3-UFF

 INITIAL DATA W1 FE   11110000 11101110 10010100   11110000  10010000   01011001 11110000  00001000
CH:                W9-1 5    11101010 11110000 10010000   01011001  1 1 1 10000  1 1 1 1 0000 1 1 1 1 0000

  11 8        N1-1E6       18 20   32   15   15   19   21   AA   38   21   30   32   32   30   23   15
              EN17-32      28A-32  A0   38   20   28   152  36   28   34   3A   36   21   25   i7   18

I1A INTEGR.   ENI-1NC       20     5    A    1    1    1    2    3    2    1    0    3    0    2    2
              EM 7-3 2     5 61440) 3   3    1    A    3         3    1    A    2    1    1    A    0

  128         AZ1      . •' ö ~ \ 26   26   26   25   10    9    6         A    2    A    0    0    1    1
              A 2 2      / 0 ' AA      30   32   36   18   11    7    5    3    1    2    0    2    1    0
              A-Z 3        0 26        28   29   24    5    A    3    0    0    0    1    0    0    0    0
              AZA       v J 00 / 92    6 A  76   38   20    8    3    1    0    0    0    0    0    0    0
              AZ5       2 36 2 A 8    22 A  160  152  8 A   A0   21   6    5    2    1    1    1    0    0
              AZA        192-200      200  168  12A   96   5A   27   8    7    5    2    1    1    0    0
              AZ7          96 72       76   58   38   17    7    1    0    1    0    0    0    0    1    0
              AZ 8         3A 36       20   20   10    3    A    1    0    0    0    0    0    0    0    0

I1A/4          MAX AT   : EN17 EL5   AZ1 0
                                     EM 5                    E\16                                   ENI7
                       EL3 ELA    EL5    EL6 EL7    EL   EL    EL5   EL6   EL7    EL3   ELA    EL5   EL6   pL7
              AZ8      0 0               0     0     0      0    u    0     0     0      0     0      0     O     0
              A-Z 9    0 0               0     0     0      0    0    1     0     0      0     0      0     0     0
              A-Z 1 0  n 0               0     0     0      0    0    0     0     0      0     1      2     0     0
              A-Z 1 1  0 0               0     1     0      0    0    0     0     0      0     n      0     0     I)
              A-Z 1 2  n 0               0     0     0      0    0    0     0     0      0     0      0     0     0
                                         EN18                           EN19                      EN20
              AZF                        0     0     0      0    0    0     0     0      0     0      0     0     0
              AZQ      0 0 0 0           0     0     0      0    0    0     0     0      0     0      ü     n     0
              A-Z 1 0  0 1             61AA    @ 2   0      0    0    1     0     0      0     0      0     0     0
              A-Z 1 1  0 1               6     0     0      0    0    0     0     0      0     0      0     0     ü
              A-Z 1 2  0 0               0     0     0      0    0    0     0     0      0     0      0     1     .1
                                        EN 21                           EN22                      EN23
              AZ8      1 0               0     0     0      0    0    0     0     0      0     0      0     0     0
              AZ9      0 0               0     0     0      0    0    0     0     0      0     0      0     n     0
              A-Z 1 C. 0 0               0     0     0      0    0'   0     0     0      0     0      1     0     0
              AZ1 1    O O               0     0     0      0    0    0     0     0      0     0      0     0     0
              A-Z 1 2  0 0               0     0     0      0    0    0     0     0      0     0      0     0     o
```

HELIOS 1

$r = 0{,}952$ AU

$v_p$ 600 $\mathrm{km\,s^{-1}}$

$n_p$ 5

$T_p$ 10 000 K

Figure 58: Extreme cold solar wind.
(1) The entire distribution of Proton is in a single 3D-measuring channel.
(2) The extremely cold $\alpha$ particles fall at I1a through the grate.

```
DFVLR-GSOC 8031 OBERPFAFFENHOFEN  GERMAN SPACE OPERATION CENTER      4. 1.78 GMT 20H 21M  5S 994MS        PAGE-NO.    35
MISSION      HELIOS-B                   ***AUSGABE GEPUFFERT***
    H-91     DSS- 67        78   4 17:46:13     B/R 2048      FM 3        DM 7-1                  FMT 34: EXP1-NUR
                      SCTIME717 14:57:11.468                        +READOUT+         FN : 252          FB/FF=  4/  3
STATUS:          PLA  NDM  TIME   0 00:02:11.187  MEM2  D1-ON    D2-OFF  I1A-ON   I2-ON   I1B-ON   WS  I3-OFF          PEHEL

INITIAL DATA     W1-8    11110000 00001000 00110011 11110000 10010001 01100110 11110000 00001110
CW: 5            W9-15   11101001 11110000 10010001 01100110 11110000 11110000 11110000
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 24 | 23 | 24 | 24 | 23 | 24 | 24 | 24 | 24 | 24 | 23 | 23 | 23 | 24 | 24 | 23 |
| | EN17-32 | 23 | 32 | 88 (1) | 24 | 25 | 24 | 48 (2) | 25 | 25 | 24 | 25 | 24 | 25 | 25 | 25 | 23 |
| I1A INTEGR. | EN1-16 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | EN17-32 | 4 | 42 (1) | 3 | 1 | 2 | 0 | 4 (2) | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 2 | 0 |
| I2A | AZ1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 2 | 7 | 7 | 5 | 8 | 9 | 16 | 14 |
| | AZ2 | 0 | 0 | 0 | 2 | 2 | 1 | 3 | 2 | 1 | 5 | 2 | 4 | 3 | 7 | 3 | 4 |
| | AZ3 | 0 | 0 | 1 | 1 | 2 | 3 | 7 | 9 | 5 | 5 | 6 | 5 | 9 | 6 | 10 | 10 |
| | AZ4 | 0 | 128 | 208 | 176 | 112 | 64 | 80 | 54 | 64 | 60 | 50 | 52 | 38 | 46 | 25 | 26 |
| | AZ5 | 0 | 224 | 336 | 256 | 160 | 116 | 76 | 108 | 104 | 120 | 104 | 112 | 112 | 104 | 76 | 80 |
| | AZ6 | 0 | 232 | 416 | 320 | 176 | 84 | 64 | 68 | 58 | 50 | 72 | 50 | 68 | 60 | 64 | 76 |
| | AZ7 | 0 | 2 | 7 | 5 | 6 | 7 | 11 | 22 | 15 | 23 | 25 | 22 | 27 | 36 | 52 | 44 |
| | AZ8 | 0 | 0 | 3 | 5 | 3 | 6 | 6 | 6 | 6 | 10 | 9 | 11 | 19 | 18 | 20 | 29 |

I1A/3 MAX AT: EN18 EL6 AZ7

| | | | EN16 | | | | | EN17 | | | | | EN18 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 |
| AZ5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 14 | 21 | 1 |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | EN19 | | | | | EN20 | | | | | EN21 | | |
| AZ5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | | EN22 | | | | | EN23 | | | | | EN24 | | |
| AZ5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 2

$r = 0{,}98$ AU

$v_p \approx 600\ \mathrm{kms}^{-1}$

Figure 59: Extreme cold solar wind, not be evaluated.

(1) These 42 counts represent only a fraction of the real proton distribution.Even I1b, which is approx. five times less sensitive, counts already (88-24) = 64 counts.The proton distribution is apparently so narrow that most protons have fallen through the grate at I1a.

(2) Also I1a does not see the $\alpha$-particles.

DFVLR-GSOC 8031 OBERPFAFFENHOFEN GERMAN SPACE OPERATION CENTER 19.12.78 GMT 12H 12M 43S 283MS PAGE-NO. 3
MISSION HELIOS-A ***AUSGABE GEPUFFERT***
H-90 DSS- 44 78 353 09:16:23 B/R 512 FM 1 DM 2-0 FMT 34: EXP1-NOR
SCTIME 60-11:17:51.468 FN : 162 FB/FF= 0/ 13
STATUS: PLA NOM TIME 0 00:37:10.062 MEM1 D1-ON D2-OFF I1A-ON I2-ON I1B-ON WS I3-OFF

INITIAL DATA W1-8 11110000 10001011 01100001 11110000 10001000 01101010 11110000 10001000
CW: 5 W9-15 11101010 11110000 10001000 01101010 11110000 11110000 11110000

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 21 | 24 | 24 | 26 | 22 | 27 | 21 | 25 | 22 | 24 | 26 (2) | 19 | 21 | 28 | 20 | 26 |
| | EN17-32 | 25 | 26 | 21 | 22 | 24 | 22 | 19 | 18 | 23 | 28 | 22 | 19 | 27 | 26 | 28 | 23 |
| I1A INTEGR. | EN1-16 | 0 | 1 | 0 | 5 | 2 | 4 | 1 | 6 | 10 | 13 (1) | 10 | 9 | 4 | 10 | 4 | 8 |
| | EN17-32 | 6 | 7 | 4 | 4 | 2 | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 2 | 1 | 3 |
| I2B | AZ1 | 0 | 108 | 184 | 336 | 640 | 736 | 224 | 48 | 168 | 6 | 7 | 2 | 1 | 0 | 0 | 0 |
| | AZ2 | 2 | 88 | 76 | 96 | 96 | 64 | 44 | 19 | 10 | 6 | 5 | 0 | 1 | 1 | 0 | 0 |
| | AZ3 | 2 | 96 | 64 | 36 | 36 | 22 | 5 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | AZ4 | 480 | 176 | 184 | 116 | 96 | 68 | 36 | 20 | 13 | 3 | 3 | 3 | 0 | 0 | 0 | 0 |
| | AZ5 | 116 | 248 | 336 | 608 | 896 | 1216 | 1344 | 1344 | 1088 | 736 | 544 | 288 | 92 | 27 | 6 | 2 |
| | AZ6 | 108 | 152 | 152 | 136 | 92 | 52 | 21 | 11 | 7 | 5 | 3 | 2 | 0 | 0 | 1 | 0 |
| | AZ7 | 112 | 128 | 96 | 60 | 58 | 42 | 15 | 7 | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | AZ8 | 104 | 128 | 136 | 200 | 232 | 240 | 124 | 42 | 12 | 17 | 4 | 0 | 0 | 0 | 0 | 0 |

I1A/3 MAX AT: EN9 EL6 AZ11

| | EN7 | | | | | EN8 | | | | | EN9 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| AZ10 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EN10 | | | | | EN11 | | | | | EN12 | | | | |
| AZ9 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ10 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ11 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| AZ13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EN13 | | | | | EN14 | | | | | EN15 | | | | |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| AZ10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| AZ11 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

MIN DQ=4

HELIOS 1

$r = 0{,}771$ AU

$n < 0{,}1\ cm^{-3}$

Figure 60: A "hole" in the solar wind.

(1) Since 1977 we see occasionally Plasmas with extremely low densities, to less than 0.1 $cm^{-3}$.This manifests itself in the conspicuously low count rates, which reach up to the lower level of the significance level.

(2) The distribution in the noise of the NZR has sunk at I1b.

```
**HELIOS/A** MPE-PRINTOUT DER EDF'2 VOM SORTED DATA TAPE                                         EDF IN RECORD: 2  PAGE: 22
   GRT    150 12:20:13.387    SCT    150 12:14:15.687    B/R  512     FM 1        DM 2       MISSING E1 DATA:       0
   CRTEF      12:20:53.890    SCTEF      12:14:56.187    NDM          WS                     BIT ERRCK RATE:        0
   INITL.TIME:    14701       SDTEF      12:14:16.405
INITIAL DATA W1- 8   11110000 00111001 01101101 11110000 10001100 01011000 11110000 00001111
             W9-15   01111010 11110000 10001100 01011000 11110000 11110000 11110000
        ALLGEM. QW   00000111 11111110
        I1A     QW   00000000 00001111
        I2      QW   00000011 11111100
        I3      QW   00000011 11111111
        I1B     QW   00000011 11111111

E2            X:  -33(198)    Y:    50( 93)    Z: -349(124)       NR.OF VALUE IN AVERAGE:160

I1B           EN1 -16      7     12     18     20     12      8     18     17     25     23     36     30     52     96    320  1984
              EN17-32  10752  29696  27648   6656    960   4864  21504   4096    256    128     60     18      7      3      9      0

I1A INTEGR.   EN1 -16      0      3      0      1      0      0      1      0     10     25    208   2176   6656   4352    464      1
              EN17-32   1920     11   6656    208      4    152      6      6      6      3      7      6      7     10      7      2

J2B           AZ1          1  36864  43008  47104  45056  38912  23552   9216  14848   1024    640    480    256    168     80     64
              AZ2       7936  38912  45056  49152  49152  43008  27648  11264   3968   1088    672    448    288    152    100     58
              AZ3       1344  47104  53248  55296  55296  53248  43008  21504   6144   1472    800    576    320    184    116     72
              AZ4      36864  55296  55296  55296  55296  55296  55296  40960  12288   2688   1088    736    416    224    124     64
              AZ5      51200  55296  55296  55296  52248  55296  55296  49152  17408   4096   1536    704    480    256    128    100
              AZ6      47104  55296  55296  55296  55296  55296  55296  45056  15360   3200   1280    736    432    240    124     80
              AZ7      38912  49152  53248  55296  55296  55296  49152  26624   7936   1664    928    576    368    184    112     52
              AZ8      31744  40960  49152  51200  51200  47104  32768  13312   3456   1152    672    416    272    160     76     64

I1A/3            MAX ADR:  EN13  EL5    AZ9       MASS CHNL.NR.:  16
                                 EN11                                   EN12                                   EN13
                     EL3    EL4    EL5    EL6    EL7      EL3    EL4    EL5    EL6    EL7      EL3    EL4    EL5    EL6    EL7
              AZ7      5     13     11      5      3       26    108    124     27     10       60    272    368    144     14
              AZ8     13     30     28     14      1       84    336    400    168     30      272   1088   1280    544     32
              AZ9      5     17     13     10      3       50    256    272    152     16      208    736    992    400     36
              AZ10     1      8      3      3      1        4     36     48     22      8       22    112    152     64      4
              AZ11     2      0      0      1      1        1      4      2      3      0        2      6      6      3      1

                                 EN14                                   EN15                                   EN16
              AZ7     21    192    192     88      9        7     11     31      8      1        0      0      0      0      0
              AZ8    108    672    560    352     30       13     42     84     30      3        0      0      0      0      0
              AZ9     88    512    736    288     16       12     46     80     36      5        0      0      0      0      0
              AZ10     9     64    104     26      5        3      6     15      4      1        0      0      0      0      0
              AZ11     1      1      7      3      1        1      0      3      1      1        0      0      0      0      0

                                 EN17                                   EN18                                   EN19
              AZ7      2     14     26      1      0        0      0      0      1      0       84    320    336    116      8
              AZ8     19    576    736     26      2        0      1      2      0      0      288   1152   1344    544     46
              AZ9      6    176    320     32      3        0      2      0      1      0      152    736   1024    368     34
              AZ10     1      2      6      2      1        1      0      0      0      0       21     88    128     42      9
              AZ11     0      0      0      0      0        0      0      1      0      0        1      5      8      4      2
```

HELIOS 1

$r = 0{,}31$ AU

$v_p = 574\ \mathrm{kms}^{-1}$

$n_p > 1500\ \mathrm{cm}^{-3}$

$T_p = 210\ 000$ K

$\frac{n_\alpha}{n_p} > 10\ \%$

Figure 61: Extreme plasma density
After a shock the density rose to a record of over 1500 $cm^{-3}$.
(1) Such counting rates in I1b and I3 are ten times larger than the 'normal' counting rates in perihelion.The low sensitivity of I3 here proved to be a great advantage.
(2) The count rates from I2 approach the possible maximum of 63 488, but never exceed it.

```
DFVLR-GSOC 8031 OBERPFAFFENHOFEN  GERMAN SPACE OPERATION CENTER      23. 5.80 GMT 21H 22M 37S  42MS        PAGE-NO.    33
MISSION      HELIUS-A                   ***AUSGABE GEPUFFERT***
   H-90     DSS--67        80 144 08:02:29    B/R  512     FM 1        DM 3-0                   FMT 34: EXP1-NUR
                        SCTIME102 12:53:08.218                                     FN :  72      FB/FF=  0/  1
STATUS:          PLA  NDM  TIME   0 00:59:54.125  MEM1  D1-ON    D2-OFF  I1A-OFF  I2-ON    I1B-ON   NS  I3-ON

INITIAL DATA     W1-8    11110000 11100000 10100010 11110000 00000111 01101000 11110000 10001111
CW: 5            W9-15   01111010 11110000 00000111 01101000 11110000 11110000 11110000
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 18 | 23 | 22 | 23 | 22 | 24 | 40 | 80 | 232 | 640 | 1024 | 800 | 136 | 68 | 96 | 152 |
| | EN17-32 | 136 | 62 | 44 | 44 | 32 | 27 | 29 | 21 | 17 | 28 | 25 | 19 | 19 | 23 | 24 | 21 |
| I1A INTEGR. | EN1-16 | 0 | 0 | 1 | 2 | 5 | 36 | 120 | 256 (1) | 124 | 9 | 20 (2) | 9 | 3 | 0 | 0 | 2 |
| | EN17-32 | (3) 11 | 1 | 256 | 8 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| I2B | AZ1 | 0 | 7936 | 11776 | 15360 | 17408 | 17408 | 12800 | 5888 | 8192 | 512 | 192 | 58 | 18 | 4 | 3 | 0 |
| | AZ2 | 144 | 7936 | 11776 | 14848 | 16384 | 15360 | 11264 | 5376 | 2432 | 672 | 184 | 68 | 28 | 8 | 4 | 0 |
| | AZ3 | 152 | 8192 | 12288 | 15872 | 17408 | 15360 | 9728 | 4096 | 1344 | 496 | 216 | 34 | 42 | 13 | 2 | 0 |
| | AZ4 | 4608 | 9728 | 14336 | 17408 | 20480 | 21504 | 18432 | 9728 | 3072 | 640 | 216 | 68 | 32 | 8 | 5 | 0 |
| | AZ5 | 6144 | 9728 | 13824 | 18432 | 22528 | 27648 | 30720 | 32768 | 34816 | 30720 | 25600 | 12800 | 5120 | 2304 | 304 (4) | 12 |
| | AZ6 | 6400 | 9216 | 13824 | 18432 | 21504 | 23552 | 20480 | 13824 | 6656 | 1792 | 256 | 100 | 32 | 6 | 2 | 1 |
| | AZ7 | 5888 | 9216 | 13824 | 17408 | 20480 | 18432 | 12288 | 5376 | 1536 | 496 | 208 | 96 | 29 | 9 | 0 | 2 |
| | AZ8 | 5120 | 8192 | 12288 | 15872 | 17408 | 16384 | 12288 | 5632 | 2048 | 672 | 248 | 100 | 32 | 6 | 1 | 0 |

I1A/3 MAX AT: EN8 EL6 AZ9

| | EN6 | | | | | EN7 | | | | | EN8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 | EL4 | EL5 | EL6 | EL7 | EL8 |
| AZ7 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ8 | 0 | 2 | 0 | 2 | 2 | 0 | 10 | 8 | 3 | 0 | 1 | 19 | 8 | 1 | 1 |
| AZ9 | 2 | 2 | 2 | 5 | 0 | 2 | 20 | 26 | 8 | 1 | 12 | 68 | 50 | 11 | 0 |
| AZ10 | 1 | 3 | 3 | 0 | 1 | 4 | 8 | 11 | 5 | 0 | 4 | 40 | 32 | 6 | 0 |
| AZ11 | 0 | 2 | 2 | 0 | 0 | 3 | 2 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 0 |
| | EN9 | | | | | EN10 | | | | | EN11 | | | | |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| AZ8 | 1 | 3 | 5 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 |
| AZ9 | 5 | 36 | 29 | 5 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 11 | 1 | 0 | 0 |
| AZ10 | 2 | 14 | 17 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| AZ11 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EN12 | | | | | EN13 | | | | | EN14 | | | | |
| AZ7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ8 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}333$ AU

$v_p = 340\ \mathrm{kms}^{-1}$

$n_p = 82\ \mathrm{cm}^{-3}$

$T_p = 180\ 000$ K

Figure 62: A measurement with I3 instead of 11a.

(1) Here the significantly reduced count rate stands out, in comparison to I1b.
(2) In a measurement with I1b alone, this secondary maximum would be been interpreted as $\alpha$-particle. I3 but also sees this peak in the proton cycle and proves that this is a second proton component.
(3) These are the real $\alpha$-particles (comp.Tab.7 on p. 61).
(4) A strong beam in the electron distribution.

```
DFVLR-GSOC 8031 UBERPFAFFENHOFEN   GERMAN SPACE OPERATION CENTER      1. 1.79 GMT  8H 40M  0S 567MS        PAGE-NO.    12
MISSION     HELIOS-A                  ***AUSGABE GEPUFFERT***
   H-90     DSS- 44       . 79   1 08:12:50    B/R  512     FN 1        DM 3-0                  FMT 34: EXP1-NOR
                      SCTIME 73 10:14:03.468                                   . FN :  18         FB/FF=  0/ 33
STATUS:         PLA  NDM  TIME    0 00:56:33.687  MEH2  D1-ON    D2-OFF  I1A-ON    I2-ON    I1B-ON   NS  I3-OFF

INITIAL DATA    W1-8   11110000 11010100 00011011 11110000 00001100 01001010 11110000 00001000
CW: 5           W9-15  11101010 11110000 00001100 01001010 11110000 11110000 11110000
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 19 | 15 | 19 | 22 | 21 | 19 | 21 | 20 | 25 | 22 | 22 | 63 | 160 | 128 | 72 | 32 |
| | EN17-32 | 27 | 25 | 27 | 26 | 21 | 23 | 26 | 22 | 25 | 27 | 28 | 15 | 19 | 22 | 27 | 26 |
| I1A INTEGR. | EN1-16 | 3 | 5 | 1 | 0 | 2 | 3 | 1 | 0 | 3 | 9 | 84 | 400 | 640 | 320 | 128 | 26 |
| | EN17-32 | 15 | 32 | 13 | 12 | 10 | 15 | 17 | 13 | 17 | 5 | 3 | 4 | 3 | 1 | 3 | 3 |
| I2B | AZ1 | 0 | 168 | 64 | 60 | 40 | 27 | 29 | 32 | 27 | 15 | 9 | 11 | 3 | 0 | 0 | 0 |
| | AZ2 | 1 | 124 | 44 | 44 | 34 | 22 | 25 | 12 | 13 | 25 | 19 | 8 | 7 | 1 | 1 | 0 |
| | AZ3 | 0 | 272 | 240 | 84 | 36 | 23 | 30 | 6 | 31 | 15 | 18 | 7 | 6 | 4 | 0 | 1 |
| | AZ4 | 384 | 496 | 608 | 544 | 144 | 46 | 14 | 68 | 34 | 38 | 22 | 15 | 3 | 3 | 2 | 1 |
| | AZ5 | 576 | 736 | 800 | 736 | 544 | 144 | 168 | 60 | 60 | 42 | 25 | 12 | 3 | 3 | 4 | 2 |
| | AZ6 | 800 | 768 | 992 | 832 | 480 | 216 | 160 | 23 | 40 | 108 | 19 | 8 | 7 | 3 | 2 | 1 |
| | AZ7 | 544 | 480 | 400 | 320 | 58 | 58 | 12 | 26 | 34 | 15 | 17 | 13 | 5 | 1 | 1 | 0 |
| | AZ8 | 384 | 224 | 192 | 68 | 36 | 12 | 40 | 36 | 32 | 27 | 15 | 4 | 7 | 1 | 3 | 0 |

I1A/3 MAX AT: EN13 EL4 AZ11

| | | | EN11 | | | | | EN12 | | | | | EN13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL2 | EL3 | EL4 | EL5 | EL6 | EL2 | EL3 | EL4 | EL5 | EL6 | EL2 | EL3 | EL4 | EL5 | EL6 |
| AZ9 | 0 | 0 | 16 | 8 | 0 | 1 | 38 | 76 | 10 | 0 | 7 | 152 | 44 | 11 | 3 |
| AZ10 | 0 | 2 | 25 | 23 | 0 | 2 | 80 | 116 | 10 | 0 | 18 | 232 | 96 | 16 | 1 |
| AZ11 | 0 | 0 | 1 | 7 | 0 | 1 | 17 | 71 | 3 | 4 | 2 | 50 | 11 | 1 | 0 |
| AZ12 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 1 | 0 |
| AZ13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | EN14 | | | | | EN15 | | | | | EN16 | | |
| AZ9 | 0 | 6 | 12 | 12 | 4 | 0 | 0 | 8 | 17 | 2 | 0 | 1 | 1 | 1 | 0 |
| AZ10 | 7 | 31 | 76 | 48 | 3 | 1 | 4 | 20 | 40 | 2 | 0 | 2 | 3 | 2 | 0 |
| AZ11 | 4 | 56 | 32 | 18 | 0 | 0 | 1 | 10 | 11 | 2 | 0 | 1 | 6 | 2 | 0 |
| AZ12 | 1 | 5 | 2 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 1 |
| AZ13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | EN17 | | | | | EN18 | | | | | EN19 | | |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 1 |
| AZ10 | 0 | 0 | 5 | 3 | 0 | 0 | 3 | 1 | 2 | 1 | 0 | 0 | 2 | 0 | 1 |
| AZ11 | 0 | 0 | 3 | 2 | 1 | 0 | 2 | 6 | 7 | 2 | 0 | 0 | 2 | 0 | 2 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| AZ13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}866$ AU

$v_p = 435\ \mathrm{kms}^{-1}$

$n_p = 5{,}9\ \mathrm{cm}^{-3}$

$T_p = 123\ 000$ K

Figure 63: Quiet solar wind immediately before a shock, just before picture 64.

```
DFVLR-GSOC 8031 OBERPFAFFENHOFEN   GERMAN SPACE OPERATION CENTER        1. 1.79 GMT  8H 40M  53  60MS          PAGE-NO.    13
MISSION      HELIOS-A                  ***AUSGABE GEPUFFERT***
   H-90     DSS- 44      79   1 08:13:30   B/R  512    FF 1        DM 3-0                          FMT 34: EXP1-NOR
                     SCTIME 73 10:14:43.968                                            FN :  36        FB/FF=  9/ 33
STATUS:          PLA  NOM  TIME   0 00:57:14.687  DEM1  D1-ON   D2-OFF  I1A-ON   I2-ON   I1B-ON   WS  I3-OFF

INITIAL DATA     W1-8    11110000 11010110 10101011 11110000 10001100 00111001 11110000 10001000
CW: 5            W9-15   11101010 11110000 10001100 00111001 11110000 11110000 11110000
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 17 | 17 | 19 | 21 | 12 | 23 | 13 | 21 | 20 | 18 | 13 | 27 | 36 | 76 | 128 | 192 |
| | EN17-32 | 272 | 232 | 240 | 120 | 68 | 56 | 42 | 52 | 36 | 28 | 22 | 29 | 24 | 26 | 29 | 26 |
| I1A INTEGR. | EN1-16 | 2 | 0 | 1 | 4 | 2 | 0 | 2 | 1 | 2 | 3 | 7 | 15 | 116 | 352 | 576 | 832 |
| | EN17-32 | 1280 | 800 | 768 | 304 | 152 | 96 | 88 | 54 | 26 | 10 | 6 | 2 | 7 | 3 | 3 | 3 |
| I2 | AZ1 | 0 | 432 | 640 | 384 | 224 | 112 | 60 | 46 | 64 | 16 | 17 | 3 | 5 | 4 | 2 | 1 |
| | AZ2 | 1 | 336 | 448 | 304 | 320 | 168 | 64 | 42 | 36 | 21 | 13 | 5 | 4 | 3 | 2 | 0 |
| | AZ3 | 5 | 768 | 600 | 832 | 704 | 216 | 112 | 64 | 44 | 27 | 13 | 5 | 8 | 1 | 1 | 0 |
| | AZ4 | 1024 | 1664 | 2304 | 2304 | 1600 | 512 | 216 | 128 | 72 | 58 | 20 | 12 | 6 | 2 | 1 | 0 |
| | AZ5 | 1024 | 1984 | 2944 | 3584 | 3200 | 1536 | 544 | 192 | 80 | 52 | 30 | 9 | 7 | 0 | 1 | 0 |
| | AZ6 | 1024 | 1408 | 2432 | 2560 | 1984 | 1408 | 464 | 160 | 64 | 46 | 24 | 16 | 9 | 1 | 2 | 0 |
| | AZ7 | 1216 | 1152 | 1728 | 1728 | 1728 | 400 | 152 | 88 | 58 | 34 | 22 | 12 | 1 | 5 | 2 | 0 |
| | AZ8 | 864 | 1216 | 1216 | 832 | 512 | 104 | 58 | 52 | 46 | 40 | 18 | 9 | 2 | 1 | 0 | 0 |

(1) (2)

I1A/3   MAX AT:  EN13  EL3  AZ10

| | EN11 | | | | | EN12 | | | | | EN13 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL1 | EL2 | EL3 | EL4 | EL5 | EL1 | EL2 | EL3 | EL4 | EL5 | EL1 | EL2 | EL3 | EL4 | EL5 |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| AZ9 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 7 | 2 |
| AZ10 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 8 | 12 | 18 |
| AZ11 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 10 | 12 | 10 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 2 |
| | EN14 | | | | | EN15 | | | | | EN16 | | | | |
| AZ8 | 0 | 3 | 3 | 7 | 4 | 7 | 6 | 10 | 13 | 10 | 1 | 3 | 2 | 6 | 6 |
| AZ9 | 0 | 3 | 9 | 10 | 5 | 4 | 8 | 10 | 14 | 9 | 2 | 5 | 10 | 17 | 16 |
| AZ10 | 1 | 12 | 19 | 25 | 13 | 5 | 7 | 18 | 15 | 15 | 3 | 9 | 20 | 32 | 26 |
| AZ11 | 2 | 12 | 38 | 38 | 28 | 3 | 21 | 46 | 44 | 46 | 0 | 8 | 25 | 32 | 50 |
| AZ12 | 0 | 2 | 2 | 23 | 17 | 3 | 12 | 32 | 46 | 38 | 1 | 14 | 40 | 56 | 38 |
| | EN17 | | | | | EN18 | | | | | EN19 | | | | |
| AZ8 | 0 | 5 | 5 | 6 | 8 | 0 | 4 | 7 | 5 | 13 | 2 | 1 | 7 | 7 | 15 |
| AZ9 | 1 | 6 | 15 | 36 | 22 | 2 | 5 | 29 | 54 | 27 | 1 | 4 | 11 | 31 | 29 |
| AZ10 | 4 | 7 | 15 | 46 | 44 | 2 | 3 | 21 | 34 | 34 | 4 | 8 | 32 | 42 | 40 |
| AZ11 | 2 | 9 | 48 | 76 | 88 | 2 | 14 | 18 | 36 | 36 | 0 | 12 | 32 | 46 | 54 |
| AZ12 | 2 | 13 | 96 | 138 | 120 | 2 | 4 | 8 | 18 | 64 | 0 | 5 | 9 | 34 | 40 |

(1)

HELIOS 1

$r = 0{,}866$ AU

$v_p = 560\ \mathrm{kms}^{-1}$

$n_p = 14{,}7\ \mathrm{cm}^{-3}$

$T_p = 570\ 000$ K

Figure 64: First spectrum after the shock, only 40 seconds after image 63 recorded.
(1) The maximum is now moved after EN17 (previously at EN13). The location of the 3D-Measurement range depends however on the old maximum so that poorly fits the new distribution.
(2) The electron flows are here four times larger than before.

```
DFVLR-GSOC 8031 OBERPFAFFENHOFEN  GERMAN SPACE OPERATION CENTER     21. 2.79 GMT 15H  0M  8S 159MS        PAGE-NO.    10
MISSION       HELIOS-A                  ***AUSGABE GEPUFFERT***
   H-90       DSS- 62        79  52 13:43:23    B/R  128     FM 2        DM 3-0                 FMT 34: EXP1-NOR
                      SCTIME124 15:42:13.968                                          FN :  18       FB/FF=  1/  5
STATUS:       PLA  NDM  TIME    0 00:27:47,562  MEM1  D1-ON   D2-OFF  I1A-ON   I2-ON    I1B-ON   WS  I3-OFF

INITIAL DATA  W1-8    11110000 01101000 00111001 11110000 10001111 01011001 11110000 10001000
CW: 5         W9-15   11101010 11110000 10001111 01011001 11110000 11110000 11110000
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 22 | 18 | 10 | 19 | 12 | 22 | 21 | 20 | 14 | 20 | 17 | 11 | 13 | 13 | 38 | 128 |
| | EN17-32 | 136 | 58 | 50 | 29 | 17 | 20 | 19 | 11 | 31 | 18 | 18 | 18 | 21 | 27 | 32 | 10 |
| I1A INTEGR. | EN1-16 | 2 | 3 | 2 | 0 | 0 | 3 | 1 | 1 | 0 | 3 | 4 | 3 | 4 | 11 | 184 | 672 |
| | EN17-32 | 304 | 100 | 64 | 27 | 10 | 7 | 6 | 5 | 1 | 2 | 1 | 1 | 0 | 1 | 2 | 1 |
| I2B | AZ1 | 0 | 288 | 320 | 352 | 184 | 56 | 19 | 11 | 17 | 3 | 0 | 2 | 1 | 1 | 1 | 0 |
| | AZ2 | 0 | 176 | 152 | 152 | 104 | 42 | 22 | 10 | 5 | 4 | 1 | 0 | 0 | 0 | 0 | 0 |
| | AZ3 | 0 | 184 | 160 | 96 | 50 | 13 | 7 | 8 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | 0 |
| | AZ4 | 320 | 544 | 608 | 480 | 288 | 100 | 31 | 20 | 12 | 7 | 2 | 1 | 0 | 0 | 0 | 0 |
| | AZ5 | 544 | 736 | 992 | 1152 | 1472 | 2176 | 2816 | 3072 | 2432 | 1920 | 1088 | 496 | 208 | 76 | 32 | 14 |
| | AZ6 | 544 | 768 | 864 | 704 | 384 | 168 | 44 | 20 | 12 | 12 | 4 | 4 | 1 | 1 | 0 | 0 |
| | AZ7 | 384 | 496 | 416 | 256 | 136 | 64 | 21 | 15 | 4 | 10 | 3 | 3 | 0 | 0 | 0 | 0 |
| | AZ8 | 304 | 368 | 384 | 336 | 248 | 100 | 23 | 17 | 5 | 6 | 2 | 1 | 0 | 0 | 0 | 0 |

I1A/3 MAX AT: EN16 EL5 AZ10

| | EN14 | | | | | EN15 | | | | | EN16 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 |
| AZ8 | 0 | 1 | 0 | 0 | 0 | 0 | 10 | 11 | 4 | 0 | 2 | 15 | 23 | 16 | 2 |
| AZ9 | 0 | 1 | 2 | 4 | 0 | 6 | 38 | 30 | 19 | 2 | 21 | 84 | 128 | 48 | 6 |
| AZ10 | 0 | 0 | 0 | 1 | 0 | 3 | 13 | 29 | 10 | 1 | 13 | 80 | 112 | 38 | 5 |
| AZ11 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 19 | 26 | 11 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | EN17 | | | | | EN18 | | | | | EN19 | | | | |
| AZ8 | 4 | 3 | 12 | 5 | 1 | 1 | 2 | 9 | 1 | 0 | 1 | 7 | 6 | 3 | 0 |
| AZ9 | 5 | 22 | 19 | 8 | 1 | 2 | 11 | 21 | 6 | 1 | 1 | 11 | 13 | 7 | 0 |
| AZ10 | 8 | 58 | 56 | 24 | 4 | 1 | 10 | 17 | 4 | 0 | 1 | 5 | 6 | 1 | 0 |
| AZ11 | 5 | 18 | 44 | 11 | 0 | 0 | 3 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | EN20 | | | | | EN21 | | | | | EN22 | | | | |
| AZ8 | 2 | 1 | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 2 | 5 | 3 | 2 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| AZ10 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| AZ11 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}97$ AU

$v_p = 525\ \mathrm{kms}^{-1}$

$n_p = 3{,}9\ \mathrm{cm}^{-3}$

$T_p = 180\,000$ K

Figure 65: Extreme beam in the electron distribution.

(1) In AZ5 greatly appear inflated count rates, a note on a focused component in the electron distribution.This "beam" was discovered with our instrument.

(2) The selected count rates are not valid (p.117).

(3) The NZR by I1b varies with HELIOS 1 typical to $\pm$ 5 counts.

HELIOS-SSIC ... GERMAN SPACE OPERATION CENTER 16.2.76 GMT 3H 32' 22.67695 PAGE-NO. 4

EXP1-NOR ... FF/FFF= 0/ 5

STATUS: ... I1=ON WS I3=OFF

INITIAL DATA 1-8 11110000 01011110 01001101 11110000 10010001 01011000 11110000 10001000

CH: 5 9-15 11101010 11110000 10010001 01011000 11110000 11110000 11110000

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 21 | 23 | 21 | 19 | 20 | 29 | 20 | 16 | 19 | 20 | 19 | 28 | 20 | 28 | 22 | 28 |
| | EN17-32 | 62 | 152 | 136 | 66 | 31 | 28 | 22 | 20 | 20 | 23 | 18 | 24 | 24 | 18 | 32 | 36 |
| I1A INTEGR. | EN1-16 | 5 | 1 | 6 | 1 | 0 | 1 | 3 | 1 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 32 |
| | EN17-32 | 336 | 544 | 368 | 92 | 21 | 8 | 11 | 4 | 4 | 3 | 3 | 1 | 2 | 2 | 1 | 1 |
| I2F | A21 | 0 | 368 | 432 | 448 | 432 | 240 | 104 | 68 | 96 | 29 | 22 | 36 | 4 | 9 | 7 | 6 |
| | A22 | 1 | 352 | 432 | 464 | 368 | 184 | 92 | 50 | 23 | 23 | 16 | 14 | 7 | 8 | 12 | 6 |
| | A23 | 5 | 416 | 608 | 672 | 640 | 400 | 169 | 52 | 32 | 25 | 5 | 3 | 2 | 10 | 10 | 2 |
| | A24 | 304 | 704 | 1008 | 1408 | 1472 | 1216 | 608 | 208 | 124 | 60 | 48 | 32 | 25 | 14 | 14 | 15 |
| | A25 | 544 | 864 | 1280 | 1356 | 2048 | 1728 | 992 | 384 | 168 | 104 | 60 | 40 | 31 | 13 | 15 | 8 |
| | A26 | 480 | 704 | 1088 | 1472 | 1600 | 1280 | 640 | 216 | 68 | 40 | 31 | 24 | 23 | 11 | 13 | 5 |
| | A27 | 336 | 576 | 832 | 960 | 896 | 576 | 232 | 64 | 32 | 20 | 13 | 12 | 18 | 7 | 5 | 6 |
| | A28 | 352 | 496 | 704 | 640 | 496 | 304 | 160 | 62 | 34 | 25 | 23 | 14 | 16 | 7 | 4 | 11 |

(1)

I1A/3 MAX AT: EN18 EL5 A29

| | EN16 | | | | | EN17 | | | | | EN18 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 |
| A27 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 40 | 56 | 16 | 0 | 13 | 72 | 42 | 7 |
| A28 | 0 | 0 | 3 | 11 | 3 | 0 | 0 | 46 | 80 | 23 | 0 | 17 | 124 | 84 | 20 |
| A29 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 5 | 27 | 17 | 0 | 0 | 50 | 80 | 19 |
| A210 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 11 | 0 |
| A211 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | EN19 | | | | | EN20 | | | | | EN21 | | | | |
| A27 | 0 | 8 | 13 | 16 | 5 | 0 | 3 | 6 | 2 | 1 | 0 | 2 | 1 | 1 | 1 |
| A28 | 0 | 38 | 44 | 34 | 13 | 0 | 4 | 17 | 10 | 2 | 0 | 0 | 2 | 0 | 1 |
| A29 | 1 | 11 | 68 | 42 | 7 | 0 | 6 | 4 | 11 | 4 | 0 | 2 | 2 | 2 | 0 |
| A210 | 0 | 0 | 12 | 21 | 5 | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| A211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | EN22 | | | | | EN23 | | | | | EN24 | | | | |
| A27 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| A28 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| A29 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| A210 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| A211 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}944$ AU

$v_p = 585\ \mathrm{kms}^{-1}$

$n_p = 4{,}8\ \mathrm{cm}^{-3}$

$T_p = 150\ 000$ K

Figure 66: High-energy electrons.

(1) after strong flares on the Sun, I2 count rates increased in the upper energy-channels occasionally observed for some time.This seems to be the low-energy end of the spectrum of flare generated solar electrons.Such electrons cause type III radio bursts.Here we would have liked an extension of range to higher energies.

```
**HELICS/A** MPE-PRINTOUT DER EDF'2 VOM SORTED DATA TAPE                                  EDF IN RECORD: 1   PAGE: 29
   GRT     29 10:39:13.356   SCT     29 10:34: 7.572   B/R  512    FM 1        DM 3        MISSING E1 DATA:      0
   GRTEF      10:39:13.356   SCTEF      10:34: 7.572   NDM         NS                      BIT ERROR RATE:       0
   INITL.TIME:   12731       SDTEF      10:33:27.790
INITIAL DATA W1- 8  11110000 00110001 10111011 11110000 00001110 01011001 11110000 10001000
             W9-15  11101010 11110000 00001110 01011001 11110000 11110000 11110000
        ALLCEM. QW  C0000111 11111110
        I1A     QW  C0000011 11111111
        I2      QW  C0000011 11111100
        I3      QW  CCCCCCCC 00001111
        I1B     QW  C0000011 11111111

E2             X:   83( 13)   Y:   111( 11)   Z:  256(  2)     NR.OF VALUE IN AVERAGE:163
```

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1 -16 | 14 | 17 | 30 | 20 | 20 | 22 | 20 | 14 | 24 | 22 | 17 | 27 | 24 | 32 | 3584 | 128 |
| | EN17-32 | 28 | 34 | 20 | 224 | 15 | 26 | 20 | 21 | 50 1 | 25 | 28 | 27 | 24 | 26 | 28 | 24 |
| I1A INTEGR. | EN1 -16 | 2 | 3 | 0 | 0 | 2 | 5 | 2 | 1 | 0 | 2 | 2 | 3 | 5 | 1024 | 8704 | 40 |
| | EN17-32 | 7 | 1 | 38 | 6 | 5 | 5 | 5 | 64 1 | 3 | 3 | 0 | 3 | 0 | 2 | 1 | 0 |
| J28 | AZ1 | 0 | 56 | 50 | 46 | 32 | 44 | 20 | 28 | 38 | 19 | 13 | 6 | 2 | 0 | 0 | 0 |
| | AZ2 | 2 | 38 | 64 | 44 | 46 | 34 | 40 | 28 | 34 | 11 | 12 | 6 | 1 | 1 | 0 | 0 |
| | AZ3 | 0 | 144 | 112 | 84 | 46 | 44 | 52 | 40 | 40 | 31 | 9 | 3 | 2 | 0 | 0 | 0 |
| | AZ4 | 416 | 464 | 416 | 216 | 104 | 88 | 84 | 62 | 44 | 24 | 11 | 5 | 3 | 1 | 0 | 0 |
| | AZ5 | 1024 | 1024 | 800 | 464 | 232 | 144 | 88 | 76 | 46 | 28 | 15 | 8 | 3 | 0 | 0 | 0 |
| | AZ6 | 768 | 836 | 640 | 448 | 200 | 128 | 104 | 80 | 68 | 42 | 19 | 6 | 1 | 3 | 1 | 1 |
| | AZ7 | 400 | 336 | 256 | 184 | 108 | 62 | 68 | 58 | 31 | 25 | 15 | 6 | 2 | 1 | 0 | 1 |
| | AZ8 | 136 | 136 | 116 | 84 | 48 | 52 | 60 | 46 | 15 | 30 | 10 | 7 | 1 | 0 | 1 | 0 |

I1A/3     MAX ACR:  EN15  EL5  AZ10     MASS CHNL.NR.:  9

| | EN13 EL3 | EL4 | EL5 | EL6 | EL7 | EN14 EL3 | EL4 | EL5 | EL6 | EL7 | EN15 EL3 | EL4 | EL5 | EL6 | EL7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 38 | 3 | 0 | 4 | 8 | 34 | 2 | 0 |
| AZ10 | 0 | 0 | 0 | 0 | 1 | 1 | 58 | 928 | 11 | 4 | 4 | 1280 | 7936 | 18 | 3 |
| AZ11 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 2 | 6 | 1 | 2 | 16 | 208 | 0 | 2 |
| AZ12 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | **EN16** | | | | | **EN17** | | | | | **EN18** | | | | |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ10 | 3 | 7 | 11 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ11 | 4 | 2 | 5 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | **EN19** | | | | | **EN20** | | | | | **EN21** | | | | |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| AZ10 | 3 | 0 | 34 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}95$ AU

$v_p = 475\ \mathrm{kms}^{-1}$

$n_p = 15\ \mathrm{cm}^{-3}$

$T_p = 17\,000$ K

Figure 67: Discovery of singly ionized Helium

(1) this unusual third peak could be attributed to singly ionized helium.The distribution of protons and $\alpha$-particles are extremely narrow, i.e."cold".It's "Piston gas" in the wake of an interplanetary shock wave.

DFVLR-GSOC 8031 OBERPFAFFENHOFEN GERMAN SPACE OPERATION CENTER 2, 4,80 GMT 7H 5M 57S 980MS PAGE-NO. 25
MISSION HELIOS-A ***AUSGABE GEPUFFERT***
H-90 DSS--67 80 92 13:43:00 B/R 128 FM 2 DM 1-0 FMT 34; EXP1-NOR
SCTIME 50 18:29:06.468 FN : 99 FB/FF= 0/ 2
STATUS: PLA NDM TIME 0 01:02:32.500 MEM1 D1-ON D2-OFF I1A-ON I2-ON I1B-ON WS I3-OFF

INITIAL DATA W1-8 11110000 11101010 10001000 11110000 10001011 01011001 11110000 10001000
CW: 5 W9-15 11101010 11110000 10001011 01011001 11110000 11110000 11110000

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I1B | EN1-16 | 19 | 19 | 26 | 7 | 10 | 22 | 30 | 22 | 6 | 18 | 15 | 512 | 1984 | 128 | 15 | 7 |
| | EN17-32 | 168 | 58 | 30 | 12 | 21 | 14 | 11 | 27 | 31 | 26 | 26 | 22 | 30 | 11 | 34 | 9 |
| I1A INTEGR. | EN1-16 | 1 | 4 | 1 | 1 | 1 | 2 | 0 | 0 | 2 | 5 | 192 | 5376 | 3712 | 31 | 5 | 7 |
| | EN17-32 | 1024 | 10 | 8 | 4 | 6 | 1 | 1 | 1 | 3 | 0 | 2 | 1 | 0 | 0 | 3 | 0 |
| I2B | AZ1 | 0 | 2 | 2 | 3 | 3 | 4 | 2 | 11 | 9 | 6 | 2 | 4 | 1 | 2 | 1 | 1 |
| | AZ2 | 0 | 0 | 2 | 5 | 4 | 6 | 5 | 7 | 7 | 1 | 6 | 4 | 3 | 2 | 3 | 2 |
| | AZ3 | 0 | 2 | 3 | 7 | 6 | 8 | 8 | 9 | 8 | 3 | 4 | 3 | 1 | 2 | 0 | 2 |
| | AZ4 | 2 | 2 | 7 | 3 | 2 | 17 | 9 | 10 | 12 | 7 | 9 | 3 | 3 | 2 | 0 | 0 |
| | AZ5 | 4 | 4 | 4 | 8 | 7 | 9 | 11 | 14 | 11 | 12 | 10 | 4 | 1 | 1 | 1 | 0 |
| | AZ6 | 4 | 3 | 5 | 0 | 11 | 11 | 21 | 11 | 10 | 11 | 9 | 1 | 2 | 2 | 1 | 0 |
| | AZ7 | 5 | 2 | 5 | 6 | 12 | 11 | 3 | 9 | 10 | 9 | 6 | 1 | 3 | 3 | 0 | 0 |
| | AZ8 | 3 | 2 | 5 | 3 | 10 | 4 | 9 | 10 | 6 | 5 | 0 | 2 | 1 | 1 | 1 | 1 |

(1)

I1A/3 MAX AT: EN12 EL5 AZ10

| | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 | EL3 | EL4 | EL5 | EL6 | EL7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EN10 | | | | | EN11 | | | | | EN12 | | |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 12 | 0 | 0 |
| AZ9 | 0 | 1 | 1 | 0 | 0 | 0 | 9 | 108 | 10 | 0 | 0 | 160 | 2432 | 184 | 1 |
| AZ10 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 52 | 6 | 0 | 1 | 100 | 2432 | 248 | 0 |
| AZ11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 6 | 2 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | | EN13 | | | | | EN14 | | | | | EN15 | | |
| AZ8 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 48 | 1152 | 54 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| AZ10 | 0 | 64 | 2176 | 208 | 0 | 0 | 4 | 17 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| AZ11 | 0 | 0 | 12 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | EN16 | | | | | EN17 | | | | | EN18 | | |
| AZ8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ9 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 432 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| AZ10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 576 | 0 | 0 | 0 | 0 | 6 | 0 | 1 |
| AZ11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

HELIOS 1

$r = 0{,}869$ AU

$v_p = 381\ \mathrm{kms}^{-1}$

$n_p = 42\ \mathrm{cm}^{-3}$

$T_p = 20\ 000$ K

Figure 68: The electron-less solar wind.
This strange phenomenon occurred during the whole mission only once for several hours, after 5 1/4 years!
(1) it seems as if the main part of the electron distribution, which is usually seen is gone.At the same time, the Proton distribution is absolutely normal.Could be the probe have so highly negatively charged, that the plasma electrons are shielded?We have so far no explanation.

# FINAL WORD

With the completion of this report, the hardware-phase of the plasma experiment takes its final conclusion.Not only, because he was so long overdue, it is located the famous "Annex A" to the contract between the MPE and MBB in worthy succession to a similar work. which was however right at the beginning of the project, namely.Why this time thus came and a lot more about the fate of the project now running thirteen years, is described in further forward detail .This report comes late, simply because he had to be stopped because of the constantly bubbling abundance always again aside new exciting results.This wealth of data will occupy us for many years; us - soon also some who can apply their knowledge about the instruments of this report include.On the other hand is not to be forgotten: the instruments still to run and provide data unchanged quality, but now from a very different phase of the solar cycle, as we they had at the start.

This unexpectedly rich blessing of the data can be regarded as special success of ambitious, elaborate and often laborious project.So many individuals, companies and organizations have contributed to its success, that it is difficult for us to see any, if we want to go because here again, expressing our gratitude to all of them.

The HELIOS project was a joint undertaking of the Federal Republic of Germany and the United States.We don't want to miss, to thank particularly the German taxpayers that have applied over 450 million DM for HELIOS, about13 million directly for our experiment.Under permit WRS 10/7 we got this money from the Federal Ministry for research and technology, funded at the time even our data analysis.For this we thank in particular the German program scientist Dr Otterbein and the program manager Mr. Käsmeier.

The German part of the project was led by Dr Ants Kutzer and his representative Dr Unz (in the DFVLR-BPT, the former GfW), the American Gil Ousley (NASA - Goddard Space Flight Center).We emphasize especially the good, even if a tough struggle often regulating cooperation with the members of the project team, who dealt directly with the experiments: Dr. Kasten, Dr. Wodsak, Dr. Dodeck, Dr. Kempe and H. Galle and of course our direct partners, Dr. Stampfl.

We are particularly pleased that this group - and they may also project management - it became gradually clear how passionate we were fighting for the success of the mission and our experiments; that alone was the reason that we measured in not always the number one priority works on paper...Here we thank also the project scientists, the gentlemen Porsche, Meredith and Trainor for their tireless efforts, to bring the interests of experimenters and project teams under one hat.

Our instruments have been developed to flight readiness and also manufactured by the company MBB, the sub-contracting of the company Lewicki, Zeiss and awarded Dornier System.The project manager Dr. Brauer together with his representative, H. Wagner and to H. Jochimsen was responsible for design and manufacturing of mechanics.The gentlemen Stiller, Friedrich and Nogai and their colleagues developed the complicated electronics.The skill, the extreme care and also the unusual personal commitment of this MBB team it is, that our instruments are today still with to the most modern, there is and that they work up today still error free.We also thank the MBB-HELIOS team, especially in the gentlemen Grün, Schuran and Ziegler for understanding, we always found them.The NASA crew at KSC provided two trouble-free startup of the first, by the mission control at the JPL orGSOC continue then were controlled.Still, we say thanks to H. Heftman at the JPL for his constant help in the fight to ground stations, as well as also Prof. Hachenberg and his colleagues at the MPI for radio astronomy for the possibility to use the 100 m radio telescope in Effelsberg for HELIOS data reception.

The DFVLR team in the GSOC - for many years headed by H. Panitz - sought from the outset very carefully to mission control, headed the HELI0S-2-start even on their own.Later, only H. led sweeping the HELIOS mission, then H. Hiendlmayer.He and his colleagues

have become true virtuoso in the optimum benefits of all options, in particular of the on-board storage system when it comes to bypass Station gaps.We thank also H. Wiegand, H. Piotrowski and wife Dusl and their colleagues for their careful work in the definition and production of our data tapes.

At MPE the experiment lasted more than ten years by Professor Lüst and Prof. Pinkau was been promoted continuously. H. Pellkofer, the first project managers, the gentlemen Ludwig, Müller, Kaiser, Fischer, still miss Kusser and Miss Wantosch and finally H. Mühlhäuser wore the brunt during development, testing, and calibration for many years. H. Antrack, H. Kipp and Miss Lipp concerned the treatment of the data tapes at MPE or run even today.

Our most gracious thanks to all these people and the many, that names should be mentioned here actually still.

The author and editor of this report, Rainer Schwenn, would not fail to thank their previous reports and other documents he could work here personally even when all those ("Annex A", "Final report", etc.), and - last not least - when Mrs. Spilker, who brought the slow-growing manuscript with amazing patience to the print-ready.

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LIST THE ABBREVIATIONS

| | |
|---|---|
| AG | Contracting Authority |
| AHK | analog house-keeping data |
| AT | Contractor |
| BM | bitrate mode |
| BMFT | Federal Ministry for research and technology |
| BPS | Bits per second |
| BPT | Area for project funds in the DFVLR |
| BSP | bit shift pulse |
| BTC | block transfer clock pulse |
| CEM | channel electron multiplier ("Channeltron") |
| CMD | Telemetry command |
| CP | Amendment |
| DFVLR | German research – and Laboratory of air - and space travel e.V. |
| DHK | Digital house-keeping data |
| DM | distribution mode |
| E1 | Experiment 1 |
| E1A | Box containing I1a, I1b, and electronics |
| E1B | Box containing I2 and electronics |
| E1C | Box containing I3 and electronics |
| E1D | Box that contains digital electronics |
| EDF | experiment data frame |
| EM | Engineering model 1 |
| F1 | flight unit for HELIOS-1 |
| F2 | Flight unit for HELIOS 2 |
| FM | format (telemetry format) |
| GB | large block length |
| GfW | Society for space research in the DFVLR |
| GMT | Greenwich mean time |
| HAN | Prime contractor (MBB) |
| HDM | high data mode |
| HP | Hewlett Packard |
| HTS | HELIOS test set |

| | |
|---|---|
| HV | High-voltage |
| I1a | 3D-Ion instrument with CEMs |
| I1b | 1D-Ion instrument with electrometer |
| I2 | 2D-Electron instrument |
| I3 | 3D-Ion instrument with CEMs, dynamic mass spectrometer |
| IABG | Industrial operating company in Ottobrunn |
| IST | integrated system test |
| JPL | Jet Propulsion Laboratory |
| KB | small block length |
| KSC | Kennedy Space Center, Florida, USA |
| KV | No shift (KV ≡ NS) |
| MBB | Messerschmitt-Bölkow-Blohm in Ottobrunn |
| MV | with shift (MV ≡ WS) |
| NDM | normal data mode |
| NS | without shift |
| NZR | Zero count rate |
| P | Prototype |
| PHA | Pulse height analysis |
| S/C | Spacecraft |
| UHV | Ultra high vacuum |
| UT | Universal time |
| UV | Ultraviolet (UV) |
| WS | with shift |
| WTC | Word transfer clock pulse |