7. **KOMMANDOGABE**

Das Experiment wird im Flug durch 10 verschiedene Kommandos vom Boden aus kontrolliert und gesteuert.

(1) *Haupteinschaltkommando* mit folgender Wirkung:
   a) Vorgesehene Abtastrate (8 Vektoren/Umdrehung)
   b) AD-Wandler Nr. 2 ein
   c) Daten von E2 ein
   d) Kalibrierung aus
   e) Flipper aus

(2) *AD-Wandler Nr. 1 ein*
   (Einschalten eines redundanten Wandlers)

(3) *Daten von E3 ein*
   Im Falle eines Defektes der Sensoren kann das Signal des teiweise redundanten Magnetometers E3 übernommen werden

(4) *Empfindlichkeitskalibrierung ein*

(5) *Daten von E2 ein*

(6) *Flipper ein*

(7) *Doppelte Abtastrate*
   (falls die Spinrate des S/C unter eine bestimmte Grenze sinkt)

(8) *Halbe Abtastrate*
   (falls die Spinrate wesentlich größer ist als 1 Hz)

(9) *Normale Abtastrate*

(10) *AD-Wandler Nr. 2 ein*

The Rome-GSFC Magnetic Field Experiment for HELIOS A and B (E 3)

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The Rome-GSFC magnetic field experiment is a cooperative effort between the Laboratorio Plasma Spazio of CNR (formerly at the University of Rome) andGSFC. The experiment utilizes a tri-axial fluxgate (saturable inductor) magnetometer. The sensor unit is mounted on the end of a boom approximately four meters from the spacecraft spin axis. The three analog outputs of the magnetometer are converted into three 9 bit digital words. The experiment utilizes an automatic inflight range switch to select the optimum dynamic range out of 4 ranges. A nonmagnetic thermally oscillating actuator is used to re-orient the sensor unit by 90° to determine all three axes zero levels. The accuracy should be approximately $\pm$ 0.1 γ. The vector measurements are made at equal intervals in time ranging from 16 per second down to 1 per second depending on the telemetry bit rate.

Das Rome-GSFC Magnetometer-Experiment ist eine gemeinsame Arbeit des Laboratorio Plasma Spazio der CNR (früher Universität Rom) und dem Goddard Space Flight Center. Das Experiment verwendet ein Dreiachsen-Fluxgate-Induktions-Magnetometer. Der Sensor befindet sich an einem Boom ca. 4 m von der Spinachse entfernt. Die drei Analog-Ausgänge werden in drei 9 bit Digital-Worte umgewandelt. Das Experiment besitzt einen automatischen Wählschalter für die Auswahl des optimalen Meßbereiches unter den vier verschiedenen dynamischen Bereichen. Ein unmagnetischer Thermal-Oszillationsschalter wird verwendet, um den Sensorkopf um jeweils 90° zu drehen. Damit lassen sich die Nullwerte aller drei Achsen bestimmen. Die Meßgenauigkeit liegt bei $\pm$ 0,1 γ. Vektormessungen können mit einer Frequenz von 16 pro sek bis zu 1 pro sek gemacht werden, je nach der zur Verfügung stehenden Telemetrie-Bitrate.

1. INTRODUCTION

The Rome-GSFC magnetic field experiment is a cooperative effort between the "Laboratorio Plasma Spazio of CNR" (formerly at the University of Rome) and GSFC. The Laboratorio Plasma Spazio has the overall responsibility of design, fabrication, integration and data reduction. GSFC has the responsibility of fluxgate magnetometer, sensor package and thermal control of the sensor package.

The principal scientific objectives include studies of the following: 1. Quasi-stationary sector structure, its relation to the solar photospheric field, and its relation to the origin of streams and shocks. 2. Spatial variation of B compared to theories of the dynamics of shock waves, streams, and ambient wind. 3. Origin of filaments and discontinuities, and their physical properties; their evolution with distance from the sun, and/or heliographic latitude. 4. Frequency spectra (actually, measure wave-number spectra due to convection of the medium past the satellite); wave profiles; nature of the fluctuations and their origin, interactions, motions, and variations with distance. 5. Cosmic ray propagation and interaction with the magnetic field.

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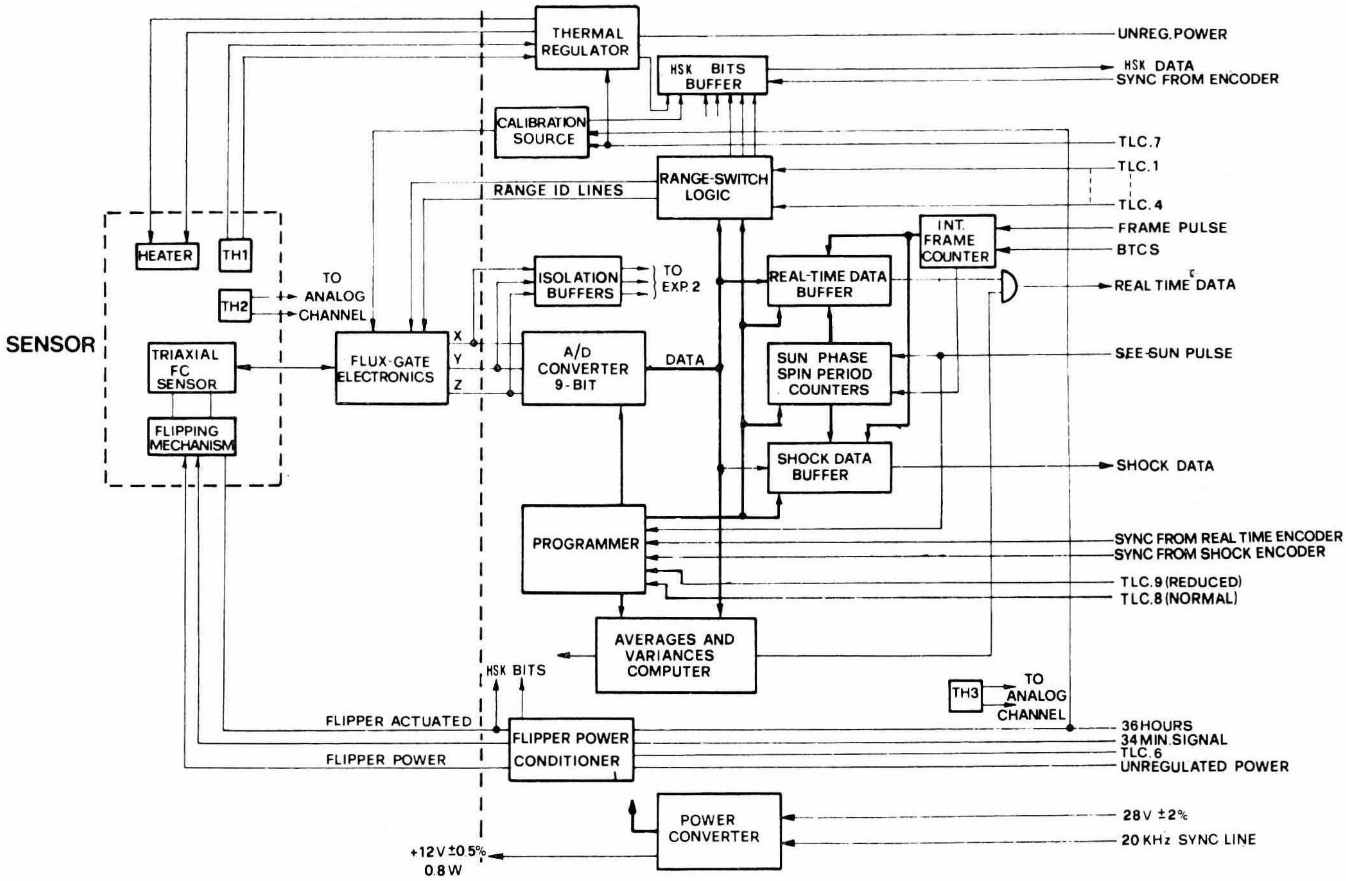

FIG. 1: **Rome-GSFC Magnetic Field Experiment Block Diagram**

The purpose of this report is to provide a brief description of the technical aspects of the experiment. The block diagram is shown in FIGURE 1.

2. FUNCTIONAL DESCRIPTION OF EXPERIMENT

2.1 Magnetic Noise

One of the limiting factors in measuring the magnetic field in space is the relative contribution of the magnetic field associated with the spacecraft. To minimize this source of magnetic noise, the sensor assembly is mounted on a boom approximately 4 meters from the spacecraft spin axis. The magnetic contamination generated by the spacecraft should be less than 0.2 γ.

2.2 Zero Level Drift

A major limitation of the fluxgate magnetic accuracy is the possibility of undetected zero level drifts. The zero level calibration is accomplished by physically reversing the sensing direction of the sensor by 180°. The three orthogonal sensors are mounted such that one is parallel to the spin axis and the other two are perpendicular to it; these two are reversed 180° by the rotation of the spacecraft. The sensor parallel to the spin axis can be calibrated by rotating the sensor assembly 90° about an axis perpendicular to the spin axis. Thus, the sensor parallel to the spin axis is rotated into a position that is perpendicular to the spin axis and one of the sensors that is perpendicular to the spin axis is rotated parallel to the spin axis. The sensor unit is rotated back and forth by a thermally oscillating actuator which is activated every 36 hours.

2.3 Performance Specifications

The magnetometer specifications are shown in TABLE I. The experiment incorporates an automatic inflight range with ground command capability to place the experiment in any fixed range.

The spacecraft provides 7.5 watts at 28 VDC ± 2 %; 3.5 watts are used for the experiment electronics and

TABLE I: **MAGNETIC FIELD EXPERIMENT SPECIFICATIONS**

Weight	
Electronics Assembly	3.75 kg
Boom Assembly	1 kg
Power	
Electronic	
Detail Mode	3.0 W
Average Mode	3.9 W
Thermal Control of Boom Assembly or Thermally Oscillating Actuator	4 W
Thermal Calibration	
Electronics	−20° C to +50° C
Sensor	−50° C to +50° C
Zero Drift	±1 %
Linearity	±1 %
Resolution (Sensitivity)	
Range 3	±0.03 γ
Range 2	±0.09 γ
Range 1	±0.28 γ
Range 0	±0.84 γ
Dynamic Range	
Range 3	± 16 γ
Range 2	± 48 γ
Range 1	±144 γ
Range 0	±432 γ

4 watts for the active thermal control or thermal oscillating actuator (flipper) power. A DC to DC power converter is included to provide the necessary voltages for the experiment. DC power is incorporated for the thermal control power and thermal oscillating actuator.

2.4 **The Magnetometer**

The experiment utilizes a tri-axial component Heliflux magnetometer developed and manufactured by the Schonstedt Instrument Company. All fluxgate magnetometers have in common a ferro-magnetic core (or cores) which is excited by a driving, or gating, magnetic field generated by current in a coil which contains the core. The magnetic flux induced in the core by the gating field is modified by an external magnetic field which generates even harmonics on the output winding depending on the magnitude of the external field.
The Heliflux sensor is a cross between a parallel and orthogonal gated core. When the AC current is applied to the primary winding, the magnetizing field has components both parallel and transverse to the core strips. The entire core is cyclically saturated by the gating field to minimize the remanent magnetization, or core memory. The secondary winding is wound around the core, perpendicular to the primary winding. Thus, the coupling between the gating field and core output is minimized by the physical orientation of the gating and output windings.

2.5 **The Thermally Oscillating Actuator**

The nonmagnetic, thermally actuated oscillating mechanism reorients the fluxgate magnetometer sensor unit in space to certify its zero level (see FIGURE 2).
The oscillating mechanism convects the rectilinear motion of the piston to the rotary motion via the rocking beam, and the associated gear train rotates the sensor.
An overcenter spring in conjunction with the rocking-beam provides a bistable feature; this spring is compressed as the rocking beams are rotated, thus it always forces the beam so that it is canted to one side or the other.

2.6 **Thermal Control**

The spacecraft is actively thermally controlled to keep the instrument shelf within -20° C to $+40^\circ$ C. The boom-mounted sensor package requires separate thermal control. GSFC has the thermal control responsibility of the sensor package. A special designed thermal canister with active thermal control is utilized. The canister is covered with several layers of super insulation with a δ radiation area looking into space along the spin axis. At one AU, electrical thermal power is applied to keep the temperature above -50° C. As the spacecraft goes in toward the sun, less power is used. At 0.25 AU, the sensor assembly is designed to keep the temperature below 50° C. Special thermal isolation between the boom and sensor package is required. The boom is to be thermally insulated to insure that the boom cable will not overheat. Power is shared with the flipper requirements.

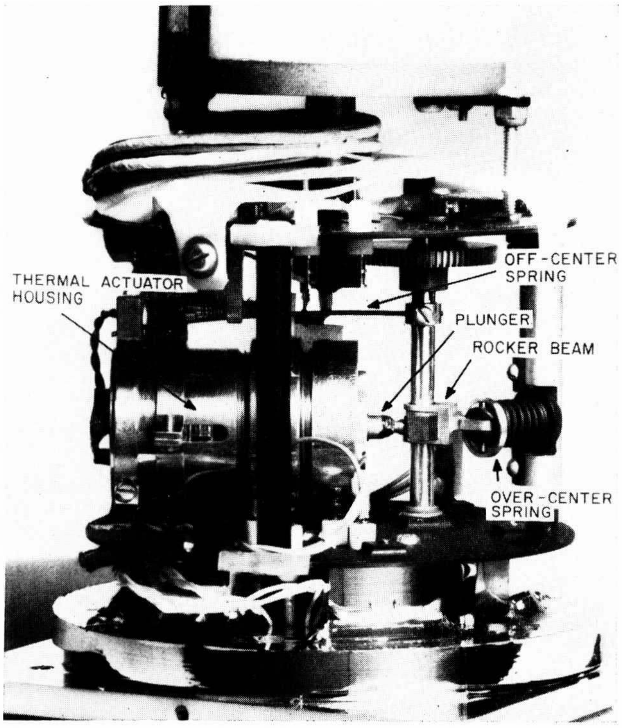

FIG. 2: **Thermally Oszillating Actuator.**

2.7 **Digital Data Handling Unit**

A dual slope integrating type A/D converter has been designed for this experiment; the 9-bit digitization of each component of the magnetic field is completed in approximately 1 m δ sec. The conversion is initiated at the end of a "Block Transfer signal", either from the "Science encoder" or the "Shock encoder", or from the "Sun pulse" if the experiment is in the Average Mode. If one conversion command occurs while the converter is busy, the command is stored and executed soon after the previous conversion is completed. The digital data are sent to the real-time buffer or to the shock buffer, as appropriate, or to the computer if required. Redundant systems have been implemented for the A/D converter and for the buffer registers, which can be substituted to the primary converter by the telecommand "processor back up"; the primary converter is selected at the experiment power turn-on.
The Digital Data Handling Unit operates in two different modes, namely Detailed Mode and Average Mode, depending upon the telemetry bit rate, and, for 128 bit/sec or less, two Telecommands C 055 (Normal Data Processing Mode) and C 322 (Reduced Data Processing Mode).
The Detailed Mode is used when the bit rate is higher or equal to 256 bit/sec. At least one magnetic field sample per satellite revolution is performed; each measurement is stored and transmitted without any data processing. In this case, each data block (32 bit) contains the measurement of the three magnetic field components X, Y, & Z, each with 9 bit accuracy; the remaining 5 bits are used to transmit auxiliary data, and are subcommutated.
The Average Mode is used when the bit rate is lower or equal to 128 bit/sec., it is selected automatically. In this mode of operation, the magnetic field is sampled one time per revolution at the occurrence of the see-sun pulse, and a number N of samples are processed by an onboard special purpose computer. This computes the averages of three components of the magnetic field:

$$\overline{X} = \frac{1}{N} \Sigma_i x_i; \overline{Y} = \frac{1}{N} \Sigma_i y_i; \overline{Z} = \frac{1}{N} \Sigma_i z_i$$

and the sum of the variances of the three components:

$$\sigma^2 = \frac{1}{N} \Sigma_i [(x_i - \overline{X})^2 + (y_i - \overline{Y})^2 + (z_i - \overline{Z})^2]$$

The number N of magnetic field samples processed corresponds to the number of spacecraft revolutions between two successive data read out, and can vary from 2 to 255. The averages $\overline{X}$, $\overline{Y}$, and $\overline{Z}$ are computed with 8 bit accuracy while σ^2, computed with 18 bits, is compressed in an 8-bit floating point number with a 4-bit fraction and a 4-bit exponent.
In a third mode, the "Shock Mode", "shock" data are read out from a special 32-bit buffer contained in the logic processor. The shock data are in the same format as in the Detailed Mode. As far as the shock data are concerned, the three components are sampled on command by the shock encoder, that is, at the end of each BTCS; therefore, the data are always ready for the next read out.

2.8 **Thermal Regulator and Flipper**

The temperature internal to the boom mounted package is controlled by an active thermal control system; DC power is applied to a heater element if the temperature drops below $+5^\circ$ C; the power is disconnected when the temperature increases above $+15^\circ$ C. The total power of 4 W required for the thermal control is provided by the essential 28 V line, which cannot be switched off for a period longer than 30 minutes.
The heater power is periodically applied to the flipper heater element, as determined by the 36 hour-signal provided by the spacecraft clock or by telecommand, for a period not longer than 17 minutes; during this time the heater power is disconnected. As soon as the flipper mechanism is activated, the power is connected back to the thermal control heater element.

2.9 **Telecommands**

The experiment uses the following 9 commands:

Telecommand N°	Code	Function
1	013	Range Mode 1
2	364	Range Mode 2
3	076	Range Mode 3
4	301	Range Execute and Thermal Heater Automatic
5	117	Processor Back-up
6	260	Flip
7	034	Calibrate and Thermal Heater turn-off
8	055	Normal data processing mode
9	322	Reduced data processing mode

Commands 1 to 4 actuate the range switch logic; command 5 inserts the redundant A/D converter and buffer registers; 6 actuates the flipping mechanism and command 7 the fluxgate magnetometer calibration; the last two commands permit bypass of the onboard computer independent of the telemetry bit-rate, in order to have a reduced operation at low bit rates even if the onboard computer fails.
Commands 4 and 7 are used, in addition to the previously mentioned functions, to set the thermal heater control system in the automatic on-off mode and to turn it off. At the experiment power turn-on the thermal heater control system is set in the automatic on-off mode.

2.10 **Sun Phase and Spin Period**

Two 10-bit counters and associated buffer registers are used to determine the phase of the sun pulse with respect to the telemetry frame and spin period.
The sun phase counter counts a 682 Hz clock from the end of the fourth BTCS in internal frame 0 (in format 5) or from the beginning of internal frame 1 (in the other formats) to the end of the next see-sun pulse; the spin rate counter counts the same clock between two successive see-sun pulses.
The information is sent to both the science encoder and the shock encoder.

3. **SUMMARY**

The Rome-GSFC magnetic field experiment is a co-operative effort between the "Laboratorio Plasma Spazio of CNR" (formerly at the University of Rome) and GSFC. The Laboratorio Plasma Spazio has the overall responsibility of the design, fabrication, integration and data reduction. GSFC has the responsibility of the fluxgate magnetometer and boom mounted package (flipper and thermal design and the sensor package).
The experiment utilizes a tri-axial fluxgate (saturable inductor) magnetometer. The sensor package is mounted on the end of a boom approximately 4 meters from the spacecraft center of spin axis. The instrument is designed to operate between 0.25 and 1 AU in which case the solar radiation vary from 1 to 16 solar constants. To insure proper operation of the magnetometer sensor and flipper a specially designed thermal canister with active thermal control is required. The three analog outputs of the magnetometer are convected into three 9 bit digital words (0-512). The experiment utilizes an automatic inflight range switch to select the optimum dynamic range. The 4 dynamic ranges and sensitivities available are as given in TABLE I. The accuracy of the experiment is limited by the spacecraft magnetic field and the zero drift of the sensors. A nonmagnetic thermally oscillating actuator is used to reorient the sensor unit by 90° to determine all three axes zero levels. The accuracy should be approximately $\pm$ 0.1γ.
The vector measurements are made at equal intervals in time ranging from 8 per second down to 1 per second depending on the telemetry bit rate (from 2048 bps to 256 bps) in the detailed mode. An average mode is utilized at lower telemetry bit rates.
The HELIOS spacecraft telemetry system is based on a one-half rate convolution encoder with a bit error rate of less than or equal to 10^{-5}. The spacecraft can operate in six formats, 8 modes of operation and 10 bit rates ranging from 2048 to 8 bps for realtime operation. The shock data is stored at 16 vector measurements per second.