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TÜNDE-M APPARATUS OF THE SPF UNIT OF THE VEGA PROGRAM

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ABSTRACT

The TÜNDE-M apparatus is designed to determine the spatial distribution and energy spectrum of ions originating from Halley's comet and to measure the time profiles of electrons and ions of the solar cosmic radiation. TÜNDE-M consists of two charged particle telescopes each of which is built of two semiconductor detectors and an anticoincidence scintillation counter. A deflecting magnet is applied to each telescope to avoid contamination from electrons with energies lower than 500 keV. The signal processing systems of the telescopes, including multichannel analysers and power supply units, operate independently. The digital part is controlled by a microprocessor which performs data acquisition, reduction and transfer of data, as well as periodically checking the operation of the instrument. Threefold redundancy and majority logic are applied to increase reliability at critical places.

1. SCIENTIFIC COALS

The main purpose of the TÜNDE-M (VEGA) apparatus is to detect ions accelerated in the vicinity of Halley's comet, to measure their energy and to determine their flux at different points of the environment of the comet.

Neutral molecules emanating from the nucleus of the comet get ionized by the ultraviolet radiation of the sun or in direct charge exchange collisions with solar wind particles. The cometary ions produced in this way can then be accelerated by moving magnetic fields of the solar wind, by the bow-shock produced as a result of interaction between cometary plasma and the solar wind, or by magnetic processes taking place in the tail of the comet (e.g. magnetic reconnection). Theoretical considerations suggest that cometary ions may be accelerated by solar wind magnetic fields up to velocities exceeding that of the solar wind by a factor of two. (Just for illustration: the kinetic energy of a CO_2^+ ion with a velocity of 800 km s^{-1} is about 160 keV.) TÜNDE-M will measure fluxes of cometary ions with energies between 20 and 640 keV, with energy resolutions of 10 keV (from 20 to 160 keV), 20 keV (from 160 to 400 keV), and 40 keV (from 400 to 640 keV).

In order to gain information on the angular distribution of the accelerated ions, two independent detector systems (telescopes) are used. As a result of the acceleration in the solar wind, the direction of the maximum flux of fast ions is approximately perpendicular to the magnetic field and fluctuates roughly around the plane of the ecliptic. Therefore one of the detector systems is placed in a position to point in the direction of the expected maximum of the accelerated particles (i.e. in the plane of the ecliptic, approximately perpendicular to the magnetic field lines), and the other is aligned in a direction at an angle of 35^{o} to this, also in the plane of the ecliptic. The second telescope points in a direction roughly opposite the velocity of the space probe.

TÜNDE-M will operate continuously from the launch throughout the fifteen months' space voyage to the rendezvous with the comet. The purpose of this is to collect reliable data on the ionic background in interplanetary space in the 20-650 keV region.

This background may vary as a function of solar activity, thus some parameters indicating the level of solar activity relevant to the measured ionic fluxes must also be measured simultaneously. For this purpose we have chosen ionic and electronic particle fluxes of energies higher than 3 MeV/N, and 0.5-0.75 MeV (electrons), respectively, which will also be measured continuously from launch. Other particle detectors on board the spacecraft (PLAZMAG-2, ING, etc.) too may benefit from the continuous in situ recording of fast charged particle fluxes coming from the sun, and a good approximation of the total radiation dose received by the spacecraft during the voyage may also be derived from these data. In addition to this, continuous detection of high energy ionic and electronic fluxes will result in observing SPEs (solar particle events) occurring during the fifteen months between launch (December 1984) and encounter (March 1986). These data together with data obtained simultaneously on board other spacecraft and/or satellites will yield a good opportunity to study the propagation of flare particles in interplanetary space, together with dynamic interactions of ions and interplanetary magnetic fields.

2. GENERAL DESCRIPTION OF THE APPARATUS

TÜNDE-M consists of the following parts (see *Fig. 1*): Telescopes (T1, T2), analogue signal processing units (APU1, APU2), digital signal processing unit (DAPS), and power supply unit (PSU). Mechanically, the instrument including the telescopes constitutes a single unit.

Main technical data:

external dimensions:	150 mm x 165 mm x 150 mm
mass:	2.2 kg
consumption:	5 W
energy range of ions:	20 keV to 640 keV*

*The spectrum of ions below 20 keV is measured by PLAZMAG which is the second part of the SPF unit.

energy range of fast solar particles:	
electrons:	0.50 MeV to 0.75 MeV
protons:	3.2 MeV to 4.5 MeV
protons:	4.5 MeV to 13 MeV
$Z \geqq 2$ nuclei:	3.2 MeV/N to 13 MeV/N
nuclei (incl. protons):	>13 MeV/N integral flux
geometric factor of each telescope:	$\approx 0.8\ cm^2\ sr$
data format:	floating point, 11 bits + parity
speed of data transfer:	3072 bit/s or 65536 bit/s
angle between the telescopes:	35^o

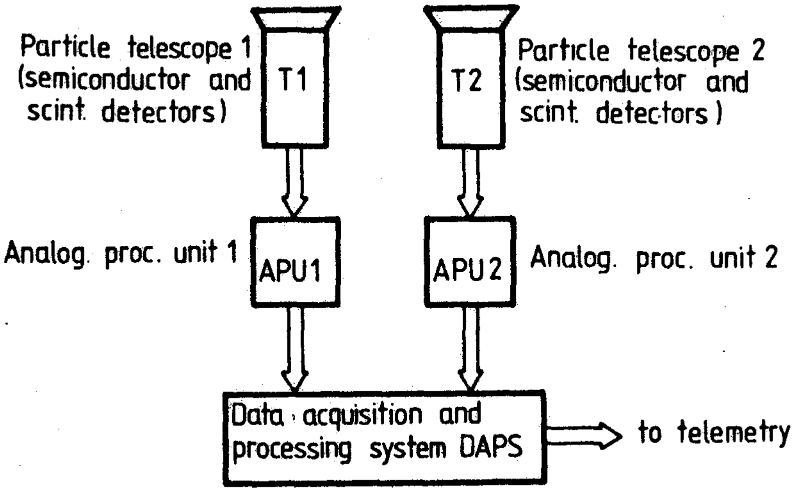
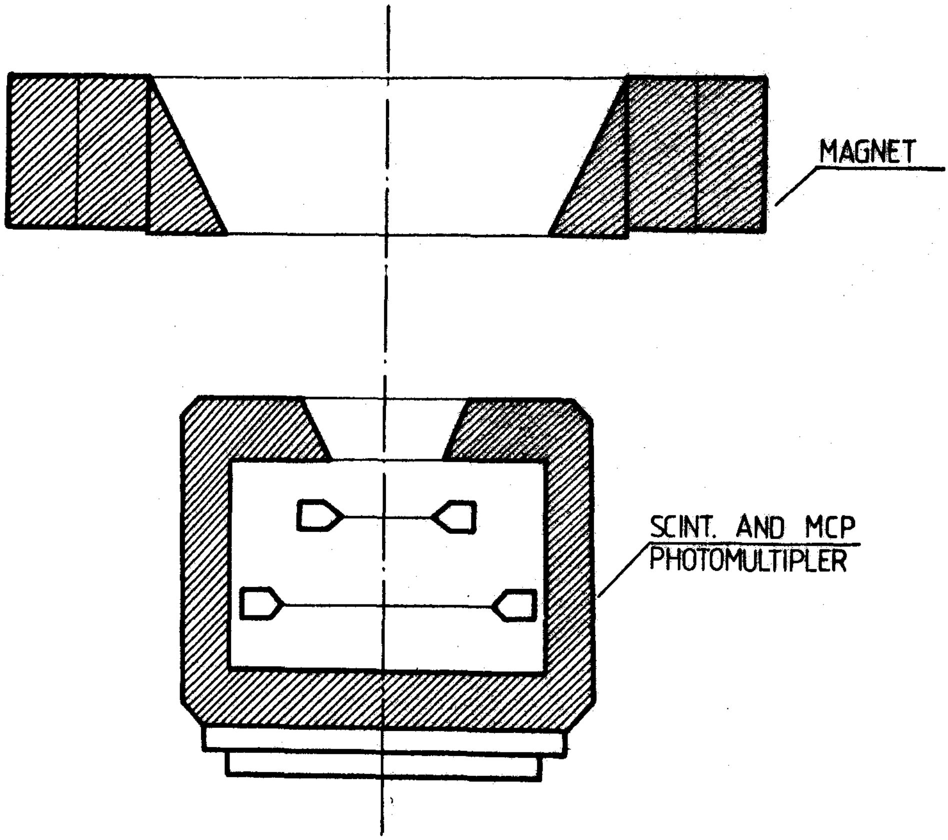


Fig. 1. Scheme of TÜNDE-M

2. THE TELESCOPES AND THE ANALOGUE SYSTEM

Telescopes T1 and T2 are of identical geometric construction, consisting of semiconductor detectors A and E and anticoincidence scintillation detector MCP (*Fig. 2*). In the case of low energy (20-640 keV) ion detection only detector A supplies signals. To distinguish electrons, protons, and heavier nuclei, detectors A,B from a ΔE/E system. The geometric factor of the telescopes is approximately 0.8 cm^2 sr. The purpose of the magnet is to prevent electrons with energies lower than 0.5 MeV from reaching the detector system.



DETECTORS	DIA	THICKNESS
UPPER	8	0.10
LOWER	16	1.0

Fig. 2. Scheme of a particle telescope in TÜNDE-M

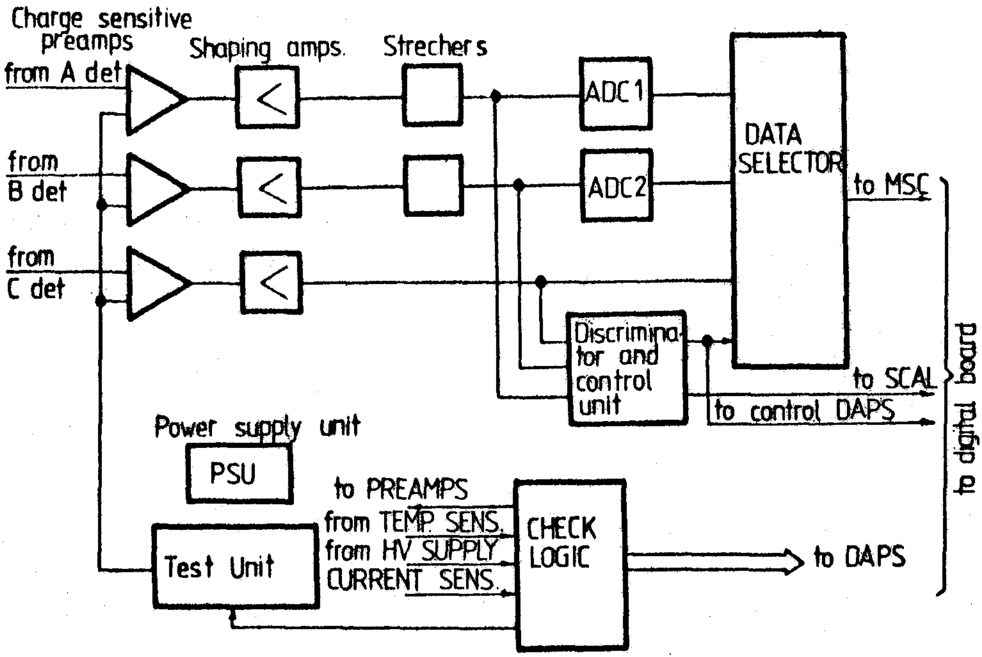


Fig. 3. Block diagram of an analogue processing unit (APU) in TÜNDE-M

The block diagram of the analogue signal processing unit is shown in *Fig. 3*. The detector signal is coupled to the inputs of the 6 bit fast ADC, of the amplitude discriminator and of the control unit through the charge sensitive preamplifier, the main amplifier (furnished with pole-zero cancellation, active quasi-Gaussian signal shaping and baseline restoration) and the stretcher. The signal of the discriminators are the input signals of the 8 channel 32 bit SCAL scaler (4 inputs for each telescope), the control unit determines the mode of operation of the analyser ($A\overline{BC}$, $AB\overline{C}$, ABC). In the case of energy measurement the data selector receives information from ADC1; in the case of particle identification it receives information from both ADCs. Additionally, the data selector reduces the received information to 6 bits in accordance with the required energy levels and resolution by means of a ROM.

4. DIGITAL ELECTRONICS

The digital electronics performs counting and analysis of the events. It transmits the collected data to the telemetry system of the space probe in floating point format. It communicates with the board system of the probe (*Fig. 4*).

The control and check functions as well as the processing of the measurement data and the signals from the board system are performed by a microprocessor. The digitized information from each telescope is recorded in 64 channels (MSC); pulses are counted in 4 channels (SCAL); every channel is of 32 bits.

The MCS is built from a byte (8 bits) organized memory. Every channel is formed from 4 memory bytes. The 6 bit code from the analogue unit defines the channel where the event is to be recorded. The first byte of the channel is read, incremented by one, and rewritten into the same location. If overflow occurred, the same is done with the next byte. This operation can be repeated up to byte 4 of the actual channel. The counting losses are minimized by a buffer memory (FIFO), capable of storing 16 events. The SCAL unit consists of 4 32 bit scalers. It collects data first of all to check the correct operation of the detectors.

Both counter systems record the events autonomously. At the end of the integration time the microprocessor stops the counting, reads the data, sets the initial values, and restarts the measurement cycle. The dead time between two measurements is the same for every channel, and it is constant in each mode of operation.

Additional tasks of the microprocessor:

- Since, during flight, the volume of information which can be transmitted to the telemetry changes from time to time the resolution of the spectrum and the integration time of the measurement must be modified.

- The functional units of the instrument are checked every day, the results of this must be transmitted to Earth.

- The necessary modifications of the operation must be performed by commands transmitted from Earth.

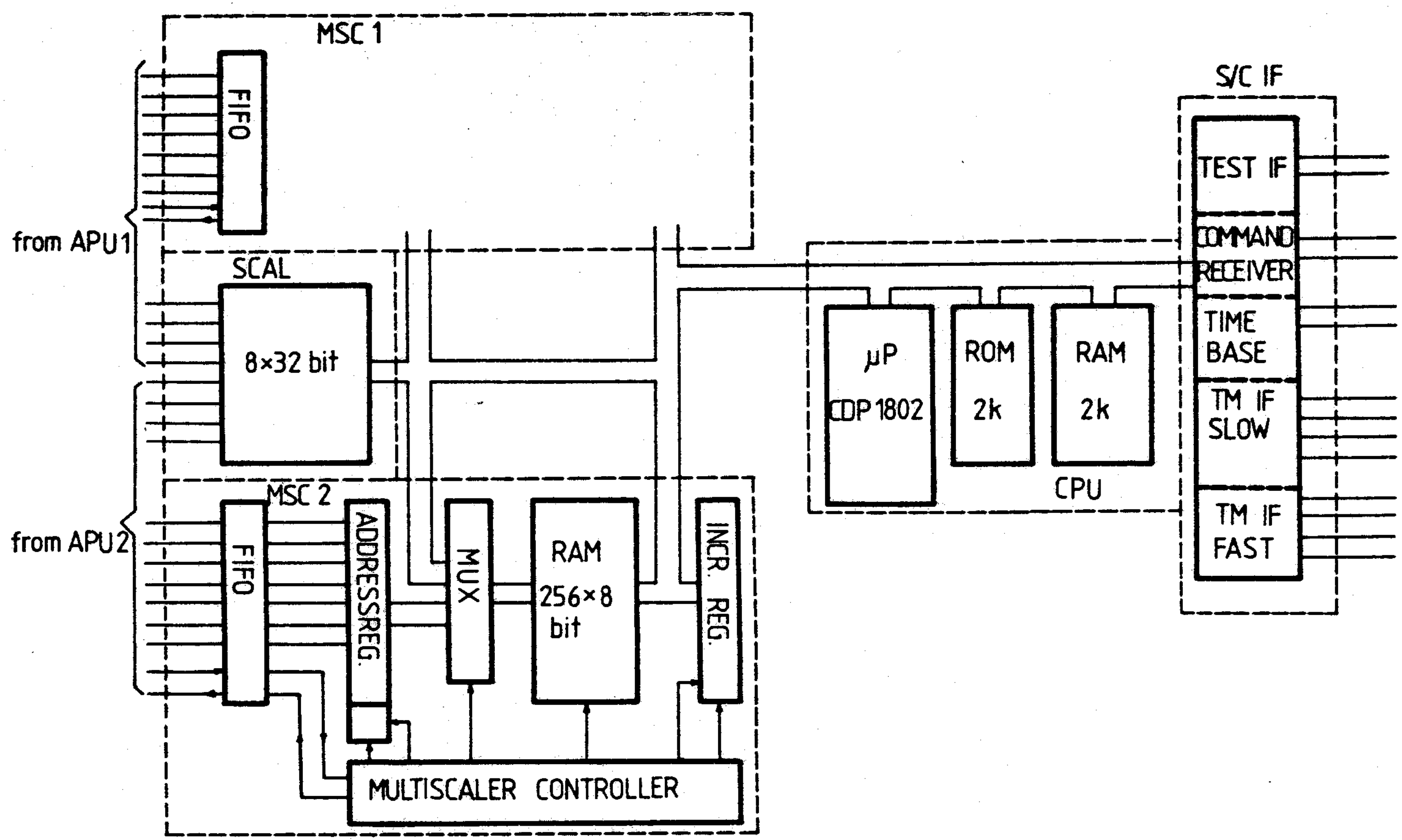


Fig. 4. Block diagram of the digital signal processing unit (DAPS) in TÜNDE-M

- The data read from the counter units must be transformed from 32 bit fixed point format into 11 bit + parity floating point format for better utilization of the telemetry capacity.

- For telemetry transmission the information must be organized into blocks, supplied with an identifying code and transferred to the telemetry interface.

- The technological data (temperatures, supply voltages, etc.) supplied by the analogue unit must be transferred to the digital telemetry along with the measurement data.

For these purposes a microprocessor of high reliability and low consumption is required. The type CDP 1802 of RCA was chosen which has worked well under space conditions. The operating programme is in a ROM of 2k; for data processing 2k RAM is available.

The instrument communicates with the board system of the probe via the S/CIF module. The measurement data are sent to two independent TM channels of 3072 bit/s and 64 kbit/s data transfer speed, respectively. This module receives commands from the Earth and timing signals from the board of the probe as well.

The requirements of reliability towards the instrument operating in deep space for 440 days are high. According to a preliminary analysis the memories are the critical parts of the instrument from the point of view of data transfer. Threefold redundancy was built both into the MSC module and the memory of the microprocessor, with majority logic ensuring the correction of data errors. Reliability is also enhanced by processing the signals of the telescopes independently, in parallel channels up to the microprocessor. Thus, if occasional failure occurs in one channel, the other - correctly operating - channel can deliver useful information.

5. OUTLINE OF THE COOPERATION BETWEEN THE PARTICIPATING INSTITUTIONS

The instrument has been built in international cooperation coordinated by the Central Research Institute for Physics (CRIP), Budapest. The scientific goals and the main parameters were defined jointly by experts of CRIP (Budapest), of the Space Research Institute (SRI), Moscow, and of the Nuclear Research Institute (NRI) of Moscow State University. Technical development of the instrument has taken place at CRIP (Budapest), at the Max-Planck-Institute (MPAE), Lindau, and at the Space Science Department (SSD) of ESTEC, Noordwijk. The power supplies have been developed at the Technical University, Budapest. Experts of SRI (Moscow), NRI (Moscow), CRIP (Budapest), and of MPAE (Lindau) have taken part in the calibration. The experts of SRI (Moscow) are responsible for the final checks to be performed in the Soviet Union. CRIP (Budapest), SRI (Moscow), NRI (Moscow), MPAE (Lindau) and SSD-ESTEC will participate in the data processing and the subsequent scientific analysis.