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A BALLOON-BORNE EXPERIMENT TO INVESTIGATE THE MARTIAN MAGNETIC FIELD

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ABSTRACT

The Space Research Institute of the Austrian Academy, of Sciences (Graz, Austria) in cooperation with MPE (Berlin, Germany), GFZ Potsdam (Obs. Niemegk, Germany) IZMIRAN/IOFAN (Moscow, Russian) and IGPP/UCLA (Los Angeles, USA) is designing the magnetic field experiment MAGIBAL (MAGnetic field experiment aboard a martian BALloon) to investigate the magnetic field on the surface of Mars. The dual sensor fluxgate magnetometer is part of the MARS-98/ MARS-TOGETHER balloon payload. During a ten days period the balloon will float over a distance of about 2000 km at altitudes between 0 and 4 km. Due to the limited power and telemetry allocation the magnetometer can transmit only one vector per ten seconds and spectral information in the frequency range from 2 - 25 Hz. The dynamic range is ± 2000 nT. The main scientific objectives of the experiment are:

- Determination of the magnetism of the Martian rocks
- Investigation of the leakage of the solar wind induced magnetosphere using the correlation between orbiter and balloon observations
- Measurement of the magnetic field profile between the orbiter and the surface of Mars during the descent phase of the balloon.

Terrestrial test flights with a hot air balloon were performed in order to test the original MAGIBAL equipment under balloon flight conditions.

SCIENTIFIC OBJECTIVES

Introduction. Even after the 1989 PHOBOS-2 mission, it is still controversial whether Mars has an intrinsic magnetic field or interacts with the solar wind nonmagnetically /1, 2/. Using the combination of orbiter and surface magnetometers the following parts of the Martian magnetic field can be investigated:

- The main field with the source in the core mantle region (active dynamo?)
- The external field generated by the interaction of the solar wind with the upper atmosphere
- The magnetic field of the crustal anomalies
- The magnetic field of the 'telluric' currents induced by the external field.

Mission Scenario. After the injection of the MARS-98 probe into the Martian orbit a descent module including a balloon (fig. 1) will be released. During the descent phase the profile of the magnetic field will be measured. After landing the balloon (42 m high, 5500 m^3) will be inflated. The balloon moves during day time horizontally with the prevailing winds at an altitude of about 3 km. In the afternoon the gas cools and the balloon lands smoothly on its guiderope. At night the balloon drifts horizontally close to the surface. With an assumed target life time of ten days the balloon will travel about 2000 km at a day time altitude between 2 and 4 km.

Orbiter - Balloon Correlations. Recent calculations using both theoretical extrapolations of observations at low altitudes in the Venus ionosphere /3/ show that significant field strengths (up to 100nT) can exist below the Venus ionosphere when the solar wind dynamic pressure is high. Mars is expected to be in this magnetised state even more often than Venus. Thus we expect the intensity of the magnetic field in the ionosphere and on the surface of Mars to be highly correlated and both in turn to be strongly correlated with the solar wind dynamic pressure. The "leakage" of the solar wind induced magnetosphere into the atmosphere is important because this field will not diffuse into the core of Mars on short time scales. Hence, the distortion of the "leakage" field by induced currents in the interior can be used to deduce the size of the conducting core of Mars.

Expected Surface Magnetic Fields. The strength of the magnetic field on the surface of Mars will be determined by the iron content of Martian rocks together with the strength of external magnetic field to which these rocks were exposed. Our only previous experience other than on Earth which has a large present day internal field, is on the surface of the Moon. The surface rocks of the moon were magnetised to about 300nT at the maximum. While Mars could have more iron in its rocks than the moon a safety factor of 3 over the lunar case would seem to be prudent. Thus a 2000nT range is appropriate for MAGIBAL.

Comparisons with Lunar Exploration. Lunar magnetic exploration was used to deduce the ancient lunar paleofield and its evolution. We expect that Magibal will allow us to determine the magnetic field and magnetisation of several geologic units of differing age. The varying ages of these units will then allow a deduction of how the paleofield evolved with time. Conductivity sampling may be restricted on Magibal to the longest periods because of the properties of the ionosphere. On the moon the very weak ionosphere did not have any noticeable effect on the induced magnetic fields.

THE MAGIBAL EXPERIMENT

Experience of the team

The MAGIBAL experiment is based on the two triaxial flux-gate ring-core sensors and analogue electronics to be designed by MPE/Berlin (Germany) and IZMIRAN/IOFAN (USSR). The on board software is being developed by IWF (Austria) and MPE (Germany). Similar flux-gate sensors have been used successfully during the Phobos mission and will be used on the Orbiter during the MARS-96 mission too. A new design of the German sensor system with two ring-cores for three components figuring low mass and low power consumption was developed and successfully tested during the meeting of the MARS-94 magnetometer consortium in Garchy (France). The sensors from IZMIRAN is the result of many years'experience in the field of constructing magnetic measurement devices. The analogue hardware and software (experiment control and data compression) is based on developments for the magnetometers aboard Spacelab-1, Venera 13 /14, VEGA 1 /2 and the Phobos mission.

MAGIBAL structure

Sensors and electronics (Germany and Russia). One sensor system figuring low mass and power consumption was developed by the MPE/Berlin and Observatory Niemegk. The triaxial sensor system consist of two single ring-core sensors measuring the magnetic field in X- and Y-direction. The magnetic field in Z- direction is measured by a homogenised coil surrounding both single sensors. The second triad was developed by IZMIRAN/IOFAN Moscow/ Russia. The excitation and analogue electronics of both sensor systems are located at a common board. This board, 188mm * 126mm, consist of 1mm strong material and is fitted with special stabilising elements. The German part of the experiment hardware contains the sensor, the excitation and analogue electronics. The pulse generation electronics driving a high-symmetry excitation current consist of a crystal oscillator, a pre-timer and a 16-step programmable phase shifter for tuning of the x, y and z analogue channel. The limited space on the board required SMD components. Logic standard integrated circuits are substituted by a PLD component. The analogue electronics contains a phase-sensitive detector and an amplifier with 80 dB gain. The bandwidth is 50 Hz.

The linearity and the zero point of the system is stabilised through the field feed back. The limited power available for the magnetometer requires the on- and off-switching of the power supply. So, the analogue electronics has to reach stable working conditions within 200ms.

Software concept (IWF-GRAZ / Austria). Tasks of the software:
Experiment control for on/off (1 sec on, 9 sec off) and ADC (50 Hz, 6 Data channels, 2 housekeeping channels). Data Processing (IWF-GRAZ / Austria, MPE / Berlin) for calculation of the mean value for the 6 data channels, calculation of the standard deviation, data compression, compression of all mean values and selection and compression of the standard deviation and housekeeping values. Generation of the frame and relation of the data to time.

Measurement set-up and procedures. One sensor will be mounted at the outboard end of the 60 cm magnetometer boom of the gondola. The second sensor will be mounted on the same boom approximately 20 cm from the outboard end (mounted sensor positions on the balloon boom (fig. 1). Simultaneous measurements of both sensors give the opportunity to investigate the dynamic magnetic influence of the gondola on the sensors. The movement of the gondola can be used to calculate and then element its remanent magnetic field. As the power consumption and telemetry rate are limited, the magnetometer will be switched on every 10 sec for a working time of 1 sec with a sampling rate of 20 msec Two kinds of information are desired: Data on the Martian static magnetic field every 10 sec and information about the Martian field in the frequency range between 2 and 25 Hz.

Characteristic of the MAGIBAL experiment

Dual sensor fluxgate system		
Boom mounted	60cm, 40cm	
Dynamic range:	± 2000nT, ±200nT	
Resolution:	14 Bits	
Sampling:	50Hz, 6 channels (1sec. on, 9sec. off)	
Data processing:	Mean value +σ (data compression)	
Storage capacity:	32 k Byte(per day 2 links)	
Power :	max. 1W, average 0.1 W	
Mass budget:	Total	460g
Temperature range:	-100°	+60° (sensor)
	-50°	+60° (electronics)
Offset:	<5nT	
Noise:	20pT/√Hz	

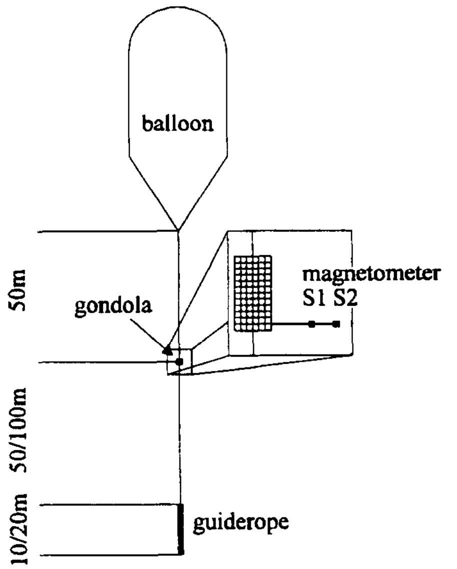

Figure 1: The MARS-98 balloon with the magnetic field experiment MAGIBAL

TERRESTRIAL TEST FLIGHTS

Scientific Objectives
Terrestrial test flights with a hot air balloon (fig. 2, 3) were performed in order to test the original MAGIBAL equipment under balloon flight conditions. The terrestrial magnetic field on the basket was measured during a flight time of about 3 hours. It was possible to simulate and investigate several magnetometer problems, which can appear during the real mission flight (gas balloon). In order to gain additional data we established two separate ground stations to make long time earth magnetic field measurements during the test flights. For data evaluation the combination of flight data and ground station data is very useful. The main scientific objectives of the balloon campaign were:

- Measurement of the earth magnetic field profile and variation on the hot-air balloon
- Test of the „Hedgecock method for zero-point determination" on the hot-air balloon
- Evaluation of the measured magnetic field Data
- Functionality tests of the different MAGIBAL equipment components
- Earth magnetic field measurements at different geographic positions and correlation with flight data

Experiment setup and campaign description

The experiment was flown aboard the gondola (1.74m*1.22m*1.15m) of a hot air balloon with a maximum payload capability of about 500kg. Test flight components mounted on the hot air balloon included a data logger, 3 magnetic field sensors mounted on a boom (gondola), which can be rotated, 1 magnetic field sensors mounted on a fixed boom (basket), inclination measurement equipment, 1 GPS (Global Positioning System) and a power supply (Battery). Two separate ground stations have been used ground station 1 was equipped with a data Logger (16 Bit), 1 Proton magnetometer, 1 Fluxgate magnetometer and a power supply. In ground station 2 (Krumpen) were a data Logger (16 Bit), 1 Proton magnetometer, 2 Fluxgate magnetometer and a power supply. A sketch of the hot air balloon payload is shown in Fig. 3 and a photo of the balloon during the flight is depicded in Fig. 2.

The terrestrial flights with a hot air balloon were performed between the September 25 and October, 1 1994. Due to of the bad weather situation there were many problems launching the hot air balloon with the mounted MAGIBAL equipment. We were able to launch three balloons. Only during the last flight no problems occurred with the test equipment. Therefore only the third flight data were used for calculations and evaluations. Plot see fig. 5.

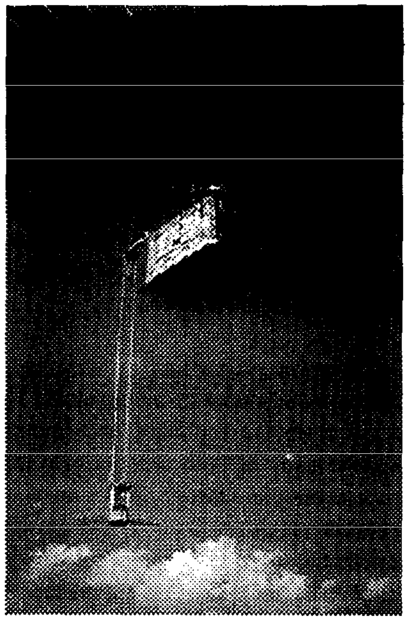

Figure 2: Photograph of the balloon gondola and the boom during the terrestrial test flight

TABLE 1 Test flight summary:

	Flight 1	Flight 2	Flight 3
Date:	29.09.1994	30.09.1994	01.10.1994
Pilot:	G.Kindermann	G.Kindermann	G.Kindermann
Passenger:	W. Koren	H. Feldhofer	K.H. Fornacon
	O. Hillenmaier	U. Auster	A. Zaroutzky
Take off	Admont,	Traboch,	Admont,
point (N,E):	47.35, 14.29	47.24, 14.60	47.35, 14.29
Take off time	14h 16min,	14h 28min,	9h 17min,
altitude:	600m	650m	600m
Landing	Admont,	Leoben,	Passail,
point (N,E):	47.36, 14.30	47.21, 15.05	47.16, 15.30
Landing time	15h 08min,	15h 45min,	11h 27min,
altitude:	600m	600m	600m
Flight time:	52min	1h 17min	2h 10min
Max. altitude:	2450m	3100m	3500m

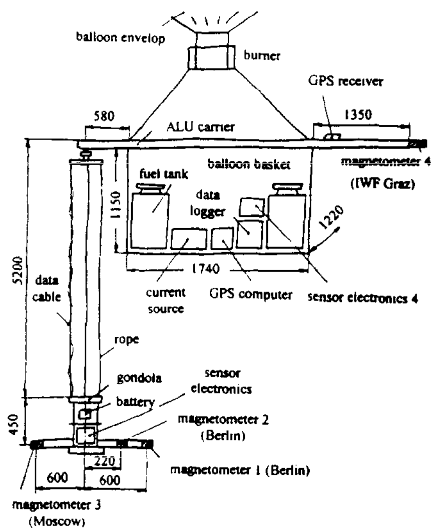

Figure 3: Sketch of the experimental setup on the basket of the balloon

Preliminary results

Four triaxial sensors have been flown aboard the balloon: 1 triad mounted on a fixed boom (magnetometer-4 in fig. 3) and 3 triads mounted on a boom which were able to be rotated (magnetometers 1-3 in fig. 3) along a vertical axis. The magnetic field was measured with a sampling frequency of 200Hz. A preliminary analysis of the magnetometer-4 data showed a variation of the total magnetic field in the order of 100nT, much higher than the variation caused by the magnetometer offsets (<10nT) or by natural variations (see the ground based measurements in fig. 4, upper panel). Most of these variations of B-total can be attributed to the non-orthogonality of the sensor triad. If one wants to measure the Martian surface magnetic field (<1000nT) with an accuracy of 1 nT the orthogonality, linearity and scale factor of the single sensors has to be known with an accuracy better than 0.1%. This requires a calibration of the non-orthogonality, linearity and scale factor as a function of the ambient temperature.

Fig. 5 shows the raw data of one triad mounted on the boom. The variations are caused by the movement of the gondola and the rotation of the gondola along a vertical axis.

<u>Future tasks.</u> Data correction using the preflight measured non-orthogonality of the sensor triads, inflight calculated zero levels points of the fluxgate components, inclination data to calculate horizontal field (H) and vertical field (Z), ground station data to reduce the earth field variation and GPS data to reduce the altitude gradient of the earth field. The aim is to get information about total field (F), H and Z with an accuracy of 20 nT (0.05%).

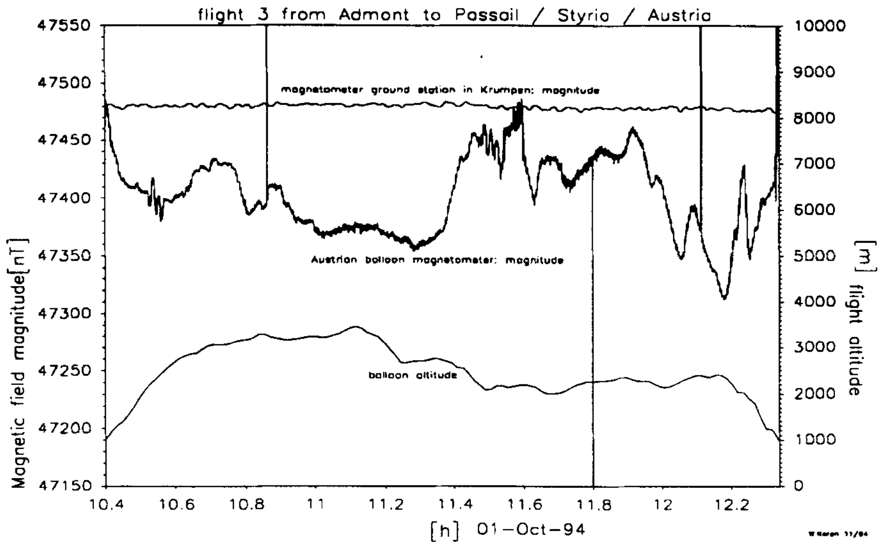

Figure 4: Altitudes (GPS), total intensity of the earth magnetic field measured aboard the balloon and at the ground

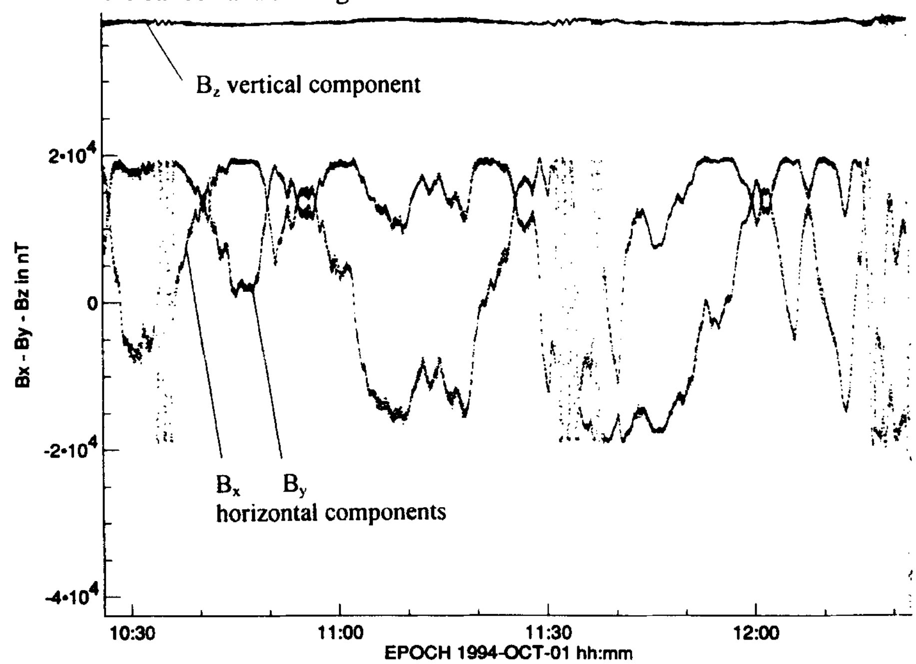

Figure 5: Magnetic field data (B_x, B_y, B_z) of the 3. balloon flight; sensor Berlin 1

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