PAUL BUEHLER

Rosetta/SREM commissioning

Issue	:	2.0
Date	:	November 11, 2004

Dr. Paul Bühler
Windbergstrasse 25
01189 Dresden
Germany

Contents

List of Reference Documents

[RO-ESC-IF-5003]	Rosetta/MARS EXPRESS Data Delivery Interface Document
[RO-MMT-IF-2011]	Rosetta/MARS EXPRESS Generic TM/TC Interface Control Document
[RO-ESC-PL-5000]	Rosetta Flight Operations Plan
[RO-SE-SURD]	SREM Rosetta Software Requirements Document
[RO-DSS-RS-1033]	SREM Experiment OBCP URD
[Hajdas et al, 2003.]	Radiation environment along INTEGRAL orbit measured with the IREM monitor, *Astron. Astrophys.* 411, L43-L47, 2003

Acronyms and Abbreviations

APID	Application Process ID
DDS	Data Disposition System
ESOC	European Space Operations Center
SREM	Standard Radiation Environment Monitor
SCET	Spacecraft Event Time
SCOS 2000	Spacecraft Operation System

1 Introduction

The commissioning of the Standard Radiation Environment Monitor (SREM) aboard Rosetta took place on May 12 and May 13, 2004 at ESOC in Darmstadt, Germany. Two passe of each approximately 6 hours were allocated for the operation of the instrument.

After successful completion of the tests it was decided to switch on SREM for continuous operation. It was realized then, that with the original OBCP a continuous operation of SREM would rapidly result in an overflow of the S1 packet store and that the OBCP needed to be modified. In the meantime the necessary modification were implemented and since October 21 SREM is continuously accumulating data.

The first part of this report summarizes the results from the SREM commissioning from May 2004. The second part briefly summarizes the actions taken to allow a continuous operation of SREM.

SREM was also switched on during the interference tests. In summary we note, that no signs of disturbing interference were seen in the SREM data.

2 Part I: SREM commissioning May 2004

2.1 Brief instrument description

SREM is a particle detector developed for space applications. It consists of two detector systems measuring the energy deposit of penetrating charged particles. Figure 1 shows a picture of SREM. The box measures $242 \times 122 \times 96$ *mm* and has a weight of approximately 2.7 *kg*. It contains the sensitive detectors and the analog and digital electronics. SREM was developed by the Paul Scherrer Institute, Switzerland and is manufactured for ESA by Contraves Space, Switzerland.

Figure 1: The Standard Radiation Environment Monitor, SREM.

There are two detector systems. One is a coincidence detector telescope (D1-D2) consisting of two solid state detectors. It is mostly sensitive to protons. The second is a single detector (D3) which measures electrons and protons. The detectors are covered with thin absorber shields. The thickness of the absorber defines the lower energy cut-off for particles to be detected. From the side and back the detectors are shielded with a layer of 4.2 *mm* Tantalum and 5 *mm* of Aluminum. Detector characteristics and absorber thicknesses are listed in table 1. The detectors are from EG&G Ortec and are 500 μm thick.

Table 1: Detector and absorber characteristics.

Detector	active areas $[mm^2]$	absorber [mm]	cut-off energy [MeV] electrons	protons
D1	70	0.5 Al + 0.7 Brass	1.3	20
D2	110	D1 + 0.7 Ta + 0.5 Al	2.0	40
D3	70	0.65 Al	0.5	10

SREM is run in a histograming mode. For a selectable time interval, the detections are binned into 15 scalers according to the registered energy deposit. The accumulated histograms are stored in the internal memory from where they are read out on request. There are 15 scalers. Their characteristics are listed in table 2. Scalers C1 to C4 are coincidence counters and measure particles which penetrate both detectors D1 and D2.

In addition the SREM on board Rosetta is equipped with a radiation sensitive Field Emission Transistor (radFET) which measure deposited doses.

Besides the scientific data SREM also delivers housekeeping (HK) data (temperatures, voltages) for health checking of the instrument.

Table 2: Characteristics of 15 SREM scalers

Scaler name	Detector	Discriminator levels [MeV]
TC1	D1	0.085
S12	D1	0.25
S13	D1	0.6
S14	D1	2.0
S15	D1	3.0
TC2	D2	0.085
S25	D2	9.0
C1	D1·D2	0.6, 2.0 (coincidence)
C2	D1·D2	0.6, 1.1-2.0 (coincidence)
C3	D1·D2	0.6, 0.6-1.1 (coincidence)
C4	D1·D2	0.085-0.6, 0.085-0.6 (coincidence)
TC3	D3	0.085
S32	D3	0.25
S33	D3	0.75
S34	D3	2.0

SREM has its own memory which is partly used for program execution and partly for storage of the accumulated data. The data part is split into 1024 accumulation files and 256 housekeeping files.

Aboard Rosetta SREM is operated with five Telecommand (TC) procedures (see table 3).

SE-FCP-001 is used to power up and switch on SREM.

SE-FCP-002 is used to switch off and power down SREM.

SE-FCP-003 is used to start data accumulation. On issue of this TC procedure SREM starts a sequence of accumulations and readouts of the radFET. Each accumulation is preceeded by a HK

Table 3: TC procedures for SREM aboard Rosetta [RO-ESC-PL-5000]

SE-FCP-001	SREM Switch ON
SE-FCP-002	SREM Switch OFF
SE-FCP-003	SREM Accumulation via OBCP
SE-FCP-004	SREM Hibernation Data Read via OBCP
SE-FCP-005	SREM Memory Dump via OBCP

parameter acquisition. Accumulation times and number of radFET readouts are parameters of the TC procedure. After each accumulation the data is read out from the memory and transfered to the on board memory of the satellite where it is kept ready for download to ground. The sequence of accumulations and readouts is stopped with an other issue of SE-FCP-003 and the parameter STOP set to true.

SE-FCP-004 can be used to read out several accumulation/HK files in the SREM memory. This TC procedure is however not used because in the current implementation of SE-FCP-003 each HK/accumulation file is directly transfered to the satellites on board memory.

SE-FCP-005 is used to read out parts of or the entire SREM memory.

2.2 Summary of scientific objectives

The purpose of SREM is to monitor the high energetic, ionizing particle environment aboard spacecrafts. These particles can penetrate several mm of shielding material and reach sensitive parts inside the spacecraft. The energy deposition into semiconductor devices can lead to slow degradation or failure of the device. Measurements of the particle environment allow to estimate absorbed doses which is helpful in anomaly analysis and for the planing of future missions. The objective of SREM aboard Rosetta is to provide a continuous, (nearly) uninterrupted measurement of the high energetic particles encountered by Rosetta and provide this information for mission analysis as well as for update of existing models. Currently there are two other SREMs in operation aboard he Belgium satellite PROBA-1 and ESA's gamma-ray mission Integral. Launches of additional SREMs are planed.

The particle environment along Rosetta's path is dominated by cosmic rays and solar particles. Both components are subjected to temporal variations. The cosmic background varies with solar cycle. During solar minimum, the shielding effect of the suns magnetic field against particles penetrating from deep space into the inner regions of the solar system is smaller than during solar maximum, leading to higher particle fluxes during solar minimum (a few %). In absence of solar events, the high energetic particle fluxes are relatively low. During solar events however, the high energetic proton fluxes can rise within a few hours by several magnitudes. Figure 2 shows data from the SREM which is operated aboard Integral [Hajdas et al, 2003]. The panel shows the count rates in counters C1, C2, and C3 as function of time. On October 28, 2003 around 11:30 UTC the count rates started to rapidly increase and reached an approximately 500-fold rate at 14:00.

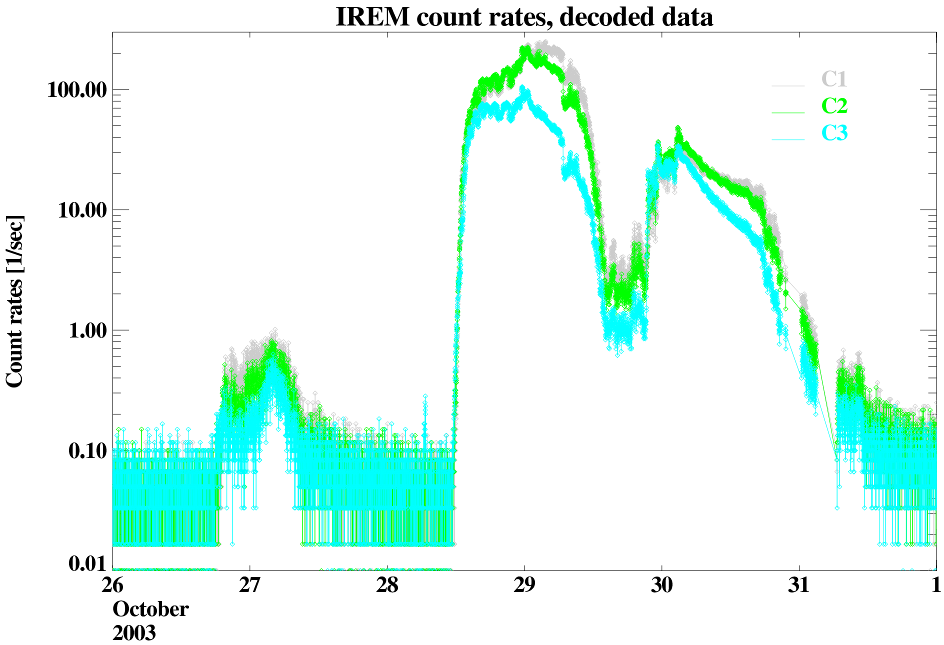

Figure 2: Solar proton event seen by the SREM aboard the Integral satellite.

3 Commissioning results

The ultimate goal of the commissioning of SREM was to switch on the instrument and to check its proper functioning. There were two passes allocated for the SREM tests - on May 12 (day 71) and May 13 (day 72). The test procedure is summarized in table 4.

During the first pass SREM was successfully powered up two times (one time on each redundant power line A and B). The current on the power lines was measured and was in the expected range. Figure 3 shows a screen shot from the Spacecraft Operation System (SCOS 2000). The left part shows the situation before upload of the SREM-Power-ON TC procedure. The parameter NPWDA11A is OFF (instrument not powered up) and NPWDA588 shows a negative current value (no current on power line A). The right part of the figure shows the situation after SREM was powered up. NPWDA11A is now ON and NPWDA588 shows a value of 0.08 A. After a warming-up period SREM was then commanded to accumulate data with an accumulation time of 90 seconds and to perform a radFET read out after every accumulation. On SCOS it was checked, that the accumulated data and radFET readouts were available and the status bits delivered by SREM were nominal. It was also verified that the data was available on the DDS. The measurements of two external temperature sensors (NTSA0022 and NTSA0085) were also monitored. It was noted, that these temperatures slightly but steadily increased (from 21^o to 23^o) without reaching a stable level until the end of the tests. After one hour the data accumulation was stopped and a memory dump was started. AT 01:43 SREM was switched off with TC procedure SE-FCP-002.

During the second pass SREM was switched on and after a warm-up period of 10 minutes data accumulation was started. Accumulation time was set to 300 seconds. After 2.5 hours the data accumulation was stopped and the instrument was powered down. All available information indicated that SREM has been working properly.

Table 4: SREM operations plan for commissioning.

		duration	start	stop
May 12/13,2004 (day 71)				
SREM Power ON	SE-FCP-001	00:30	22:00	22:30
SREM Power OFF	SE-FCP-002	00:30	22:30	23:00
SREM Power ON	SE-FCP-001	00:30	23:00	23:30
SREM Warming up	-	00:10	23:30	23:40
SREM Accumulation1	SE-FCP-003	01:50	23:40	01:30
FSK01480=0919<hex>, FSK01481=90, FSK01482=2, FSK01483=NO				
SREM Memory Dump	SE-FCP-005	01:00	01:30	02:30
FSK01490=4800<hex>, FSK01491=2047				
SREM Power OFF	SE-FCP-002	00:30	02:30	03:00
May 13/14,2004 (day 72)				
SREM Power ON	SE-FCP-001	00:10	21:30	21:40
SREM Warming up	-	00:10	21:40	21:50
SREM Accumulation1	SE-FCP-003	04:10	21:50	02:00
FSK01480=0881<hex>, FSK01481=300, FSK01482=1, FSK01483=NO				
SREM Power OFF	SE-FCP-002	00:10	02:00	02:10

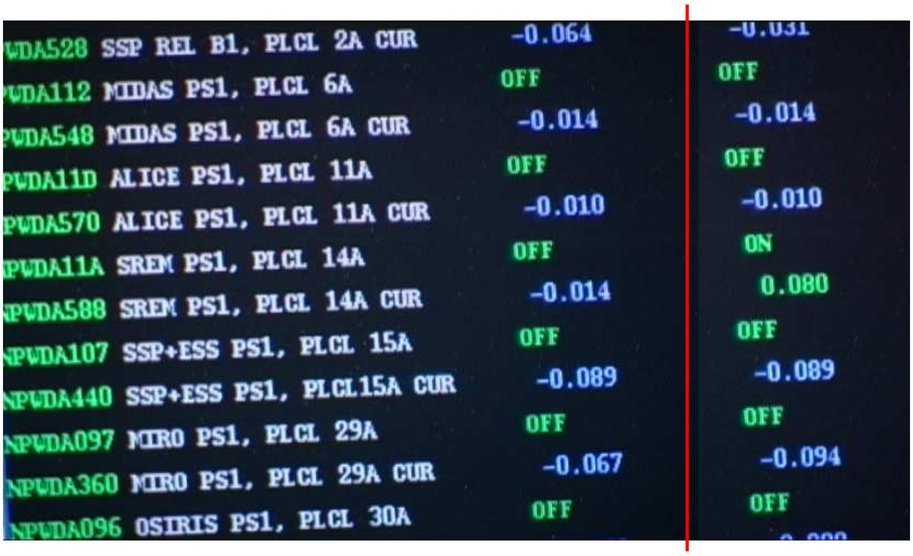

Figure 3: Screen shot of the SCOS before power up of SREM (left part) and after SREM was switched on (right part).

3.1 Experiment status at end of commissioning period

After completion of the tests the instrument was powered off.

3.2 Performance verification matrix (key parameters)

The parameters verified during commissioning are summarized in table 5. All available information indicates that SREM was working absolutely nominal. In figure 4 counting rates of selected SREM counters measured during the commissioning are compared with the rates observed by the SREM aboard Integral during the same period of time. The values are in good agreement. The differences in statistical variations reflect the different accumulation times of 90 seconds during the first pass of the commissioning, 300 seconds during the second pass, and 60 seconds aboard Integral.

Table 5: Verification of SREM performance during commissioning

SREM can be switched on	OK
current is nominal	OK
data accumulation can be started	OK
TC procedure parameters are correctly inherited by the instrument	OK
data accumulation can be stopped	OK
SREM can be switched off	OK
SREM memory dump works	OK
data is available on DDS	OK
HK data is nominal	OK
accumulation data is nominal	OK

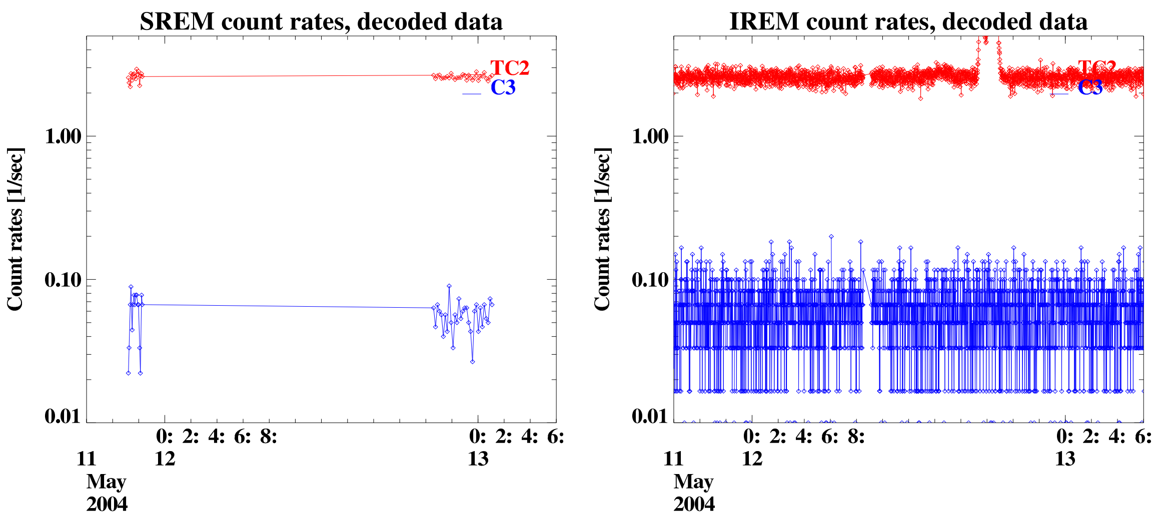

Figure 4: Comparison of Rosetta and IREM count rates.

3.3 Problem areas and anomaly reports

Two questions have arisen during the tests.

1. It was noted, that there is a time gap between two consecutive accumulations of 100 seconds (time between stop of accumulation and start of following accumulation) and 240 seconds in case a total dose reading is performed between the two accumulations. It was not clear where these gaps are created. SREM is able to start and stop accumulations without any time gaps.
2. During the test it was noted that the temperatures measured by the two external sensors NTSA0022 and NTSA0085 were slightly but steadily increasing during operation without reaching a stable value.

These two questions have been investigated in the meantime

1. The time gaps are introduced in the TC procedure SE-FCP-003. The observed durations of these gaps are consistent with the software code. Actually it is further investigated whether these time gaps can be reduced.
2. In an out-of-pass action SREM was switched on for 24 hours and the temperature sensors NTSA0022 and NTSA0085 were monitored. The result of this test is shown in figure 5. The lower panel shows, that approximately 6 hours after switch-on a stable temperature is reached. The maximum temperature of 28^o is well below the maximum acceptable temperature of 55^o.

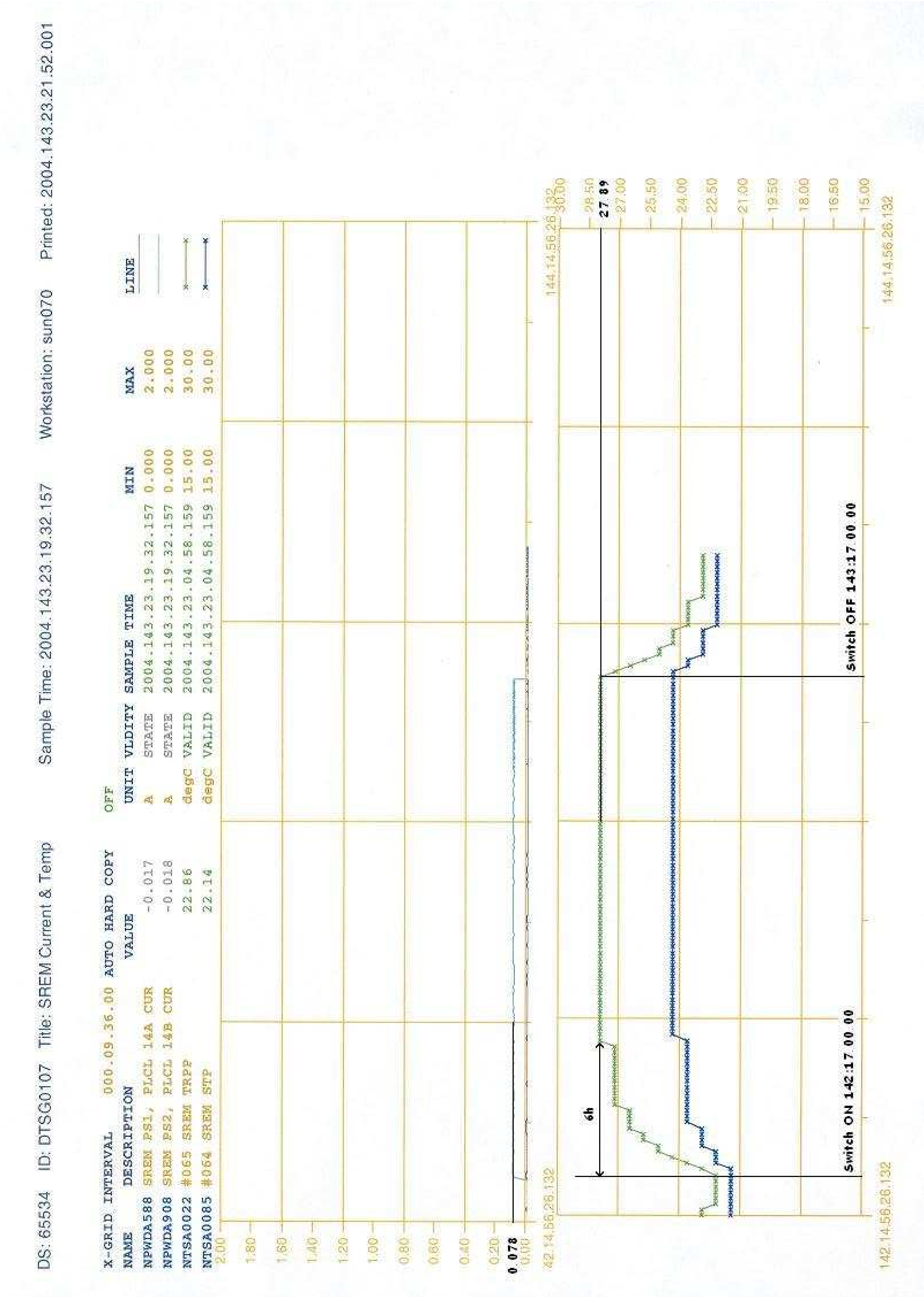

Figure 5: Out-of-pass test of SREM. The external temperature sensors NTSA0022 and NTSA0085 show that a stable temperature is reached after 6 hours of operation.

4 Conclusions and lessons learned

All TC procedures to operate SREM aboard Rosetta were successfully tested. No anomalies were observed. Since there are only five TC procedures with few parameters SREM is very simple to operate.

4.1 Recommendations for Comet Science operation (interaction with other experiments, spacecraft operation

Rosetta provides with its long journey to its final destination a unique platform for SREM to perform a continuous measurement of the radiation environment over an extended period of time. SREM should be continuously operated during the cruise phases to obtain a complete data set. SREM produces a relatively small amount of data. Table 6 shows a summary of the expected data rates as function of selected accumulation time and the number of radFET readings. At an accumulation time of e.g. 90 seconds and a radFET reading rate of 1 per 10 accumulations a data rate of 15 bits per second is produced. The data rates can be further reduced by choosing longer accumulation times (up to 2580 seconds is possible, resulting in data rates of below 2 bits per second). However, in view of the short time scales of the solar proton flux variations the accumulation times should not be longer than 300 seconds.

Table 6: SREM data rates in bits per second as function of the accumulation time T_{acc} and the number of accumulations per radFET readout (radFET rate).

radFET rate t_{acc}	1	2	5	10
60	13	15	17	18
90	12	13	15	15
120	11	12	13	13
180	10	10	11	11
300	8	8	8	8
2580	1.4	1.3	1.2	1.2

5 Part II: Continuous operation of SREM

After successful completion of the May 2004 SREM commissioning it was discussed, that SREM should be continuously operated. At the beginning of June SREM was switched on for continuous operation, but had to be stopped again after a few hours, because its operation was producing too many service 1 packets, which risked to overflow the S1 packet store.

In the following a brief summary of the actions taken since then to reactivate the continuous operation of SREM is given. The problem was solved by the ESOC team and since October 21 SREM is accumulating data again.

Figure 6 shows a summary plot of the data accumulated received on ground since October 21.

- At the beginning of June, OSIRIS requested a test with SREM, for which the instrument had to be switched on. In the evening of June 3 SREM was started to accumulate data, but had to be stopped again in the morning of June 4 because service 1 packets were generated autonomously by the system (about 30 packets every 10 minutes) and risked to overflow the S1 packet store. It was therefore decided to investigate the problem before keeping SREM continuously on.
- The analysis of the problem revealed, that the code of the OBCP was such, that it basically needed to be rewritten to be able to operate SREM continuously. Since manpower and EQM were booked at that moment for the upload of a new on-board software, the SREM OBCP development and testing was scheduled for August and the reactivation of SREM was scheduled for the beginning of September.
- In late August the new SREM OBCP was uploaded to the spacecraft and on August 26 SREM was tested with the new OBCP. A memory dump was performed which seemed to be successful.
- In the night of August 30 SREM was switched on again for continuous operation.
- However, the data received on ground was not as expected. Some counter values were out of limits and the counting rate histograms did not have the expected shape.
- Due to the running interference tests the analysis of the problem had to be postponed until October 6, when a test run was performed with the EQM and the new OBCP. The conclusions of the test was, that the new SREM OBCP had some timing problems, i.e. some commands were sent too early with respect to the previous one.
- Until October 15 further test were performed which confirmed the timing problem. The OBCP was modified and successfully tested. with the EQM
- In the following the modified OBCP was uploaded to the spacecraft and in the night of October 21, SREM was switched on again with the new OBCP.
- The data received since then looks good!

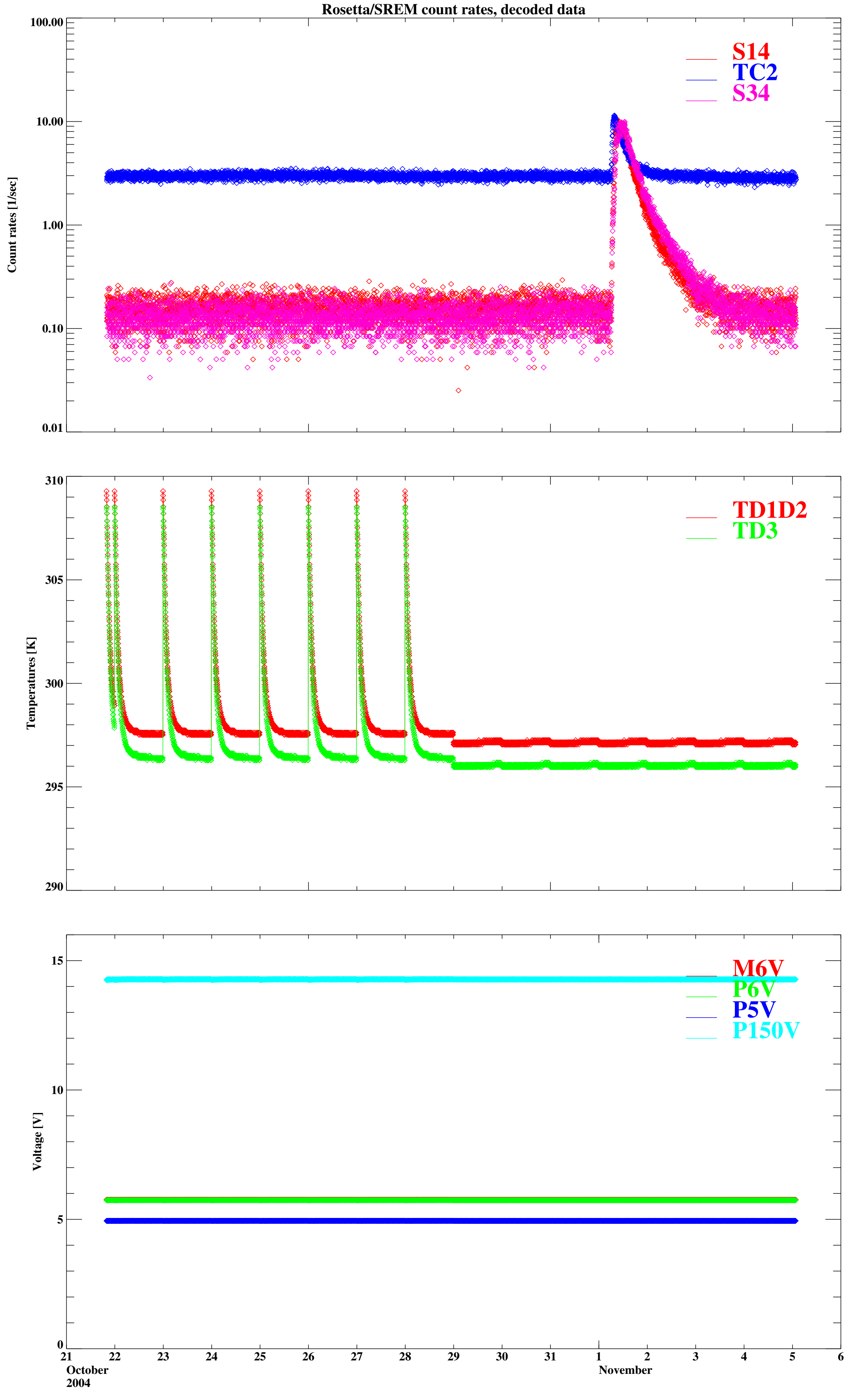

Figure 6: SREM/Rosetta summary plot from October 21 to November 6. The upper panel shows count rates of three SREM counters. The enhancement on November 1 is due to solar protons. The middle panel shows the two detector head temperatures. In the lower panel the SREM voltages are plotted, which are very stable and at nominal level.