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Summary report, ESTEC/Contract No. 16581/02/NL/LvH/bj - PROBA-1/SREM Data Processing

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List of Reference Documents

[1]	Proposal for PROBA-1/SREM data processing from July 19, 2002
[2]	Minutes of kick-off meeting from October 10, 2002
[3]	ESTEC/Contract No. 16581/02/NL/LvH/bj from October 29, 2002

Acronyms and Abbreviations

BIRA	Belgium Institute for Radio- and Astronomy	PROBA	PRoject for On-Board Autonomy
CDF	Common Data Format	SREM	Standard Radiation Environment Monitor
LEO	Low Earth Orbit	UTC	Universal Time Central

1 Introduction

The Standard Radiation Environment Monitor (SREM) is a particle detector, developed for space applications. It measures high energy electrons and protons with a fair angular and spectral resolution and provides the host spacecraft with radiation information.

On October 22, 2001 an SREM was launched aboard the Belgian satellite PROBA-1 into a Low Earth Orbit (LEO). During the commissioning phase, which lasted until the end of March 2002, SREM was successfully tested. Since then SREM is tried to be operated continuously .

In order to guarantee good data quality throughout the mission and make this data available for further studies of the Space Radiation Environment the raw data was processed, checked, and saved in a widely accepted data format.

ESTEC/Contract No. 16581/02/NL/LvH/bj - PROBA-1/SREM Data Processing contains the three work packages

WP 10, Preprocessing and checking

WP 20, Database

WP 30, Dissemination

The contract started on July 1, 2002 with a duration of twelve month and covers the processing of the data from the launch until June 30, 2003.

2 WP 10, Preprocessing and checking

2.1 Original raw data files

The SREM/PROBA1 raw data is available through a web-page at the address *194.78.233.110*. The access is protected by a username/password.

The data is contained in files with the following naming scheme:

From_dd_Mmm_yyyy_00_00_00_To_dd_Mmm_yyyy_00_00_00.SREM_P(.tar)

where dd specifies a day (one or two digits), Mmm specifies a month (first three letters of the month, first letter in capital letter), and yyyy specifies the year. Whereas files dating from before April 8, 2002 have the extra extension *.tar*, this extension is missing for the later files.

In a first step the raw data files (they are all tar-files) are downloaded. To those files where the extension *.tar* is missing it is appended to the filename. Then the files are compressed with gzip.

2.2 Extracted raw data files

The tar-files can contain eight different types of data files which have the same name as their parent file but are distinguished by their extensions (see table 1). The files are extracted and given new names according to the following convention

PROBA1SREM_*aaa*_yyyymmdd_yyyymmdd.*ext*

yyyymmdd specify the first and last day of data contained in the file, and *aaa* and *ext* are as shown in table 1.

Remarks:

- Only two periods with housekeeping data exist (20020408_20020418 and 20020707_20020717). Instead of downloading the housekeeping files, the register bank, which also contains the HK data, is periodically read out.
- Periodic reading of the register bank started on April 22, 2002.
- Until October 15, 2002 the raw data files cover periods of 10 days, since then every 5 days new raw data files are created.
- The PROBA1SREM_*aaa*_yyyymmdd_yyyymmdd.dat files are binary files and the PROBA1SREM_*aaa*_yyyymmdd_yyyymmdd.ts are ASCII files.

Table 1: Naming scheme of the eight different types of PROBA-1/SREM raw data files

extension of raw data files	*aaa*	*ext*	content
.688129.008.003.SREM_D or .008.003.SREM_D	acc	dat	accumulation data
.688129.008.003.SREM_I or .008.003.SREM_I	acc	ts	timing information for accumulation data
.688130.008.003.SREM_D	_hk	dat	housekeeping data
.688130.008.003.SREM_I	_hk	ts	timing information for housekeeping data
.688133.008.003.SREM_D or .008.003.SREM_D.reg	reg	dat	readings of the register bank
.688133.008.003.SREM_I or .008.003.SREM_I.reg	reg	ts	timing information for readings of the register bank
.688131.008.003.SREM_D	rep	dat	SREM report file with extra information on start of accumulation times
.688131.008.003.SREM_I	rep	ts	timing information for SREM report file

The files with extension *.ts* are timing information files and are ASCII files. The files with extension *.dat* are data files and contain the raw SREM data in binary format. For each entry in an SREM raw data file there exists a corresponding entry in a timing information file, specifying the stop time of accumulation or the HK or the register bank reading time in UTC.

Each entry in an SREM raw data file also contains a time stamp in spacecraft time. The conversion between spacecraft time t_{sc} and Julian days of UTC t_{UTC} is in good approximation given by the following equation:

$$\begin{aligned} t_{UTC} &= 9.09842 \cdot 10^4 + t_{sc}/8.639982 \cdot 10^4;\ t_{UTC} < 2002/11/14\text{T}12{:}00{:}00 \\ &= 9.13726 \cdot 10^4 + t_{sc}/8.639960 \cdot 10^4;\ t_{UTC} > 2002/11/14\text{T}12{:}00{:}00 \end{aligned} \quad (1)$$

2.2.1 PROBA1SREM_*aaa*_yyyymmdd_yyyymmdd.ts

The timing information files are ASCII files and contain three columns

1. Counter, represents number of entry (row).
2. Date in UTC with following format: yyyy-mm-ddThh:mm:ss.ssssss, with yyyy the year, mm the month, dd the day, hh the hour, mm the minutes, and ss.ssssss the seconds.
3. Integer number specifying type of information as shown in table. 2.

Table 2: Integer number specifying type of information in a timing information file.

aaa	type	content
acc	108	accumulation data
_hk	82	HK data
reg	268	registers
rep	35	report file

2.2.2 PROBA1SREM_acc_yyyymmdd_yyyymmdd.dat

The files PROBA1SREM_acc_yyyymmdd_yyyymmdd.dat are binary files. They consist of blocks of 108 bytes. One block contains the information of one science data accumulation. Blocks start with hex code *880A*. Position and length of the different items within each data block are as specified in table 3.

Table 3: Position of the science data items within a raw science data block

item	start position [number of bytes]	length
tstop	18	8
ID	40	4
LTstart	52	8
LTstop	60	8
TC1	68	8
S12	76	8
S13	84	8
S14	92	8
S15	100	8
TC2	108	8
S25	116	8
C1	124	8
C2	132	8
C3	140	8
C4	148	8
TC3	156	8
S32	164	8
S33	172	8
S34	180	8
PL1	188	8
PL2	196	8
PL3	204	8

Remarks:

- tstop is the stop accumulation time in units of spacecraft time.
- LTstart and LTstop are the start and stop accumulation times in SREM local time.
- For all items from LTstart to PL3 in table 3, which are 8 bytes long, the last four bytes are the most significant and the first four bytes the least significant.

2.2.3 PROBA1SREM_hk_yyyymmdd_yyyymmdd.dat

The files PROBA1SREM_hk_yyyymmdd_yyyymmdd.dat are binary files. They consist of blocks of 164 bytes. One block contains the information of one HK data acquisition. Blocks start with hex code *880A*. Position and length of the different items within each data block are as specified in table 4.

Table 4: Position of the HK data items within a raw HK data block.

item	start position [number of bytes]	length
tacq	18	8
fid	44	4
status	48	4
LTacq	52	8
T1raw	60	4
T2raw	64	4
T3raw	68	4
T4raw	72	4
T5raw	76	4
T6raw	80	4
T7raw	84	4
T8raw	88	4
T9raw	92	4
D1raw	96	4
D2raw	100	4
D3raw	104	4
D4raw	108	4
D5raw	112	4
D6raw	116	4
D7raw	120	4
AMint	124	4
Vcalref1	128	4
Vcalref2	132	4
Vcalref3	136	4
Vcalref4	140	4
Ccalref1	144	4
Ccalref2	148	4

Remarks:

- tacq is the time of acquisition in units of spacecraft time.
- LTacq is the time of acquisition in SREM local time.
- For LTacq the last four bytes are the most significant and the first four bytes the least significant.

2.2.4 PROBA1SREM_reg_yyyymmdd_yyyymmdd.dat

The files PROBA1SREM_reg_yyyymmdd_yyyymmdd.dat are binary files. They consist of blocks of 268 bytes. One block contains the information of one reading of the register bank. Blocks start with hex code *880A*. Position and length of the different items within each data block are as specified in table 5.

Remarks:

- treg is the time of the reading of the register bank in units of spacecraft time.
- LTreg is the time of the register bank reading in SREM local time.
- Except for treg, for all items in table 5, of 8 bytes length the last four bytes are the most significant and the first four bytes are the least significant.

Table 5: Position of the register bank items within a register bank data block.

item	start position [number of bytes]	length	item	start position [number of bytes]	length
treg	18	8	T6raw	292	4
status	40	4	T6proc	296	4
LTreg	44	8	T7raw	300	4
wfc	52	4	T7proc	304	4
cfc	56	4	T8raw	308	4
dtccr	60	4	T8proc	312	4
TC1	64	8	T9raw	316	4
S12	72	8	T9proc	320	4
S13	80	8	calref1raw	380	4
S14	88	8	calref2raw	384	4
S15	96	8	D1raw	388	4
TC2	104	8	D1proc	392	4
S25	112	8	D2raw	396	4
C1	120	8	D2proc	400	4
C2	128	8	D3raw	404	4
C3	136	8	D3proc	408	4
C4	144	8	D4raw	412	4
TC3	152	8	D4proc	416	4
S32	160	8	D5raw	420	4
S33	168	8	D5proc	424	4
S34	176	8	D6raw	428	4
PL1	184	8	D6proc	432	4
PL2	192	8	D7raw	436	4
PL3	200	8	D7proc	440	4
pacid	208	4	Agndraw	444	4
pahylev	212	8	Agndproc	448	4
paunlev	220	8	Vcalref1raw	452	4
eacid	228	4	Vcalref1proc	456	4
eahylev	232	8	Vcalref2raw	460	4
eaunlev	240	8	Vcalref2proc	464	4
aminterval	248	4	Vcalref3raw	468	4
T1raw	252	4	Vcalref3proc	472	4
T1proc	256	4	Vcalref4raw	476	4
T2raw	260	4	Vcalref4proc	480	4
T2proc	264	4	V6raw	484	4
T3raw	268	4	V6proc	488	4
T3proc	272	4	V5raw	492	4
T4raw	276	4	V5proc	496	4
T4proc	280	4	HVraw	500	4
T5raw	284	4	HVproc	504	4
T5proc	288	4			

2.3 Raw data checking

The raw data files are decoded according to the described file formats. In order to find corrupted data and select proper data for further processing several checks are performed on the raw data.

1. The number of entries in the timing files and the raw binary files is checked to be equal.
2. Accumulation times are checked to be positive.
3. Multiple occurrences of the same data point (same start/stop time) are eliminated. Multiple occurrences of the same data point happen frequently due to a download problem.
4. The start time of an accumulation is checked to be larger than the stop time of the previous accumulation. An overlap of 2 seconds is accepted.
5. The counter values are checked to have acceptable values. Therefore thresholds are set on the count ratios of selected pairs of counters.

3 WP 20, Database

After decoding and checking of the raw data files, auxiliary data is computed and the data is written to CDF-files. Three CDF-files per calendar day are created. They are listed in table 6. Two files with decoded data (decoded data files), and one file with further processed and auxiliary data (processed data files).

Table 6: Names and contents of the three different types of CDF-files

decoded data file name	content
SREMPROBA1_DACC_yyyymmdd.cdf	decoded science data
SREMPROBA1_DACQ_yyyymmdd.cdf	HK and/or register values
SREMPROBA1_PACC_yyyymmdd.cdf	processed science data and auxiliary data

A short description of the content of the CDF-files is given in tables 7 to 9. Further information can be found in the table headers in the files themselves.

3.1 SREMPROBA1_DACC_yyyymmdd.cdf

The files SREMPROBA1_DACC_yyyymmdd.cdf contain the decoded and filtered raw SREM science data.

Table 7: Items contained in the files SREMPROBA1_DACC_yyyymmdd.cdf

item	type	number of elements	description
EPOCH	CDF_EPOCH	1	time since 0 AD of center of accumulation interval in ms
label_SREMTIME	CDF_CHAR	2	labels for item SREMTIME, StartAcc/StopAcc
SREMTIME	CDF_DOUBLE	2	PROBA-1 time tags of start and stop accumulation times in units of 100 ms, is used to calculate accumulation time
label_COUNTERS	CDF_CHAR	18	labels for 18 SREM counters
COUNTERS	CDF_INT4	18	raw SREM counts

3.2 SREMPROBA1_DACQ_yyyymmdd.cdf

The files SREMPROBA1_DACQ_yyyymmdd.cdf contain the values of the register bank readings.

Table 8: Items contained in the files SREMPROBA1_DACQ_yyyymmdd.cdf

item	type	number of elements	description
EPOCH	CDF_EPOCH	1	time since 0 AD of register bank reading in ms
SREMTIME	CDF_DOUBLE	1	PROBA-1 time tag of readings of register values
STATWORD	CDF_INT4	1	SREM status word
label_TEMPERATURE	CDF_CHAR	9	labels for temperature sensors T_1 to T_9
TEMPERATURE	CDF_INT4	9	values of nine temperature sensors
label_RADFETDOSE	CDF_CHAR	7	labels for RadFETs D_1 to D_7
RADFETDOSE	CDF_INT4	7	values of seven RadFETs
label_VOLTAGE	CDF_CHAR	3	labels for 6V, 5V, and HV sensors
VOLTAGE	CDF_INT4	3	values of three voltage sensors, 6V and 5V are in units of mV and the HV in units of V

3.3 SREMPROBA1_PACC_yyyymmdd.cdf

The files SREMPROBA1_PACC_yyyymmdd.cdf contain the deadtime corrected SREM count rates and additional auxilliary data.

The orbit was computed with the NORAD elements which were periodically downloaded from http://celestrak.com/. The applied orbit generator is based on the spacetrack computer code which is available from http://celestrak.com/NORAD/documentation/spacetrk.zip

Magnetic field values were computed with the IRGF and Tsyganenko89 magnetic field models with Kp=0. The L-shell parameter was computed for locally mirroring particles in the model field. Magnetic field and L-shell were computed with routines of the UNILIB library from BIRA.

Table 9: Items contained in the files SREMPROBA1_PACC_yyyymmdd.cdf

item	type	number of elements	description
EPOCH	CDF_EPOCH	1	time since 0 AD of center of accumulation interval in ms
label_COUNTERS	CDF_CHAR	15	labels for fifteen dose counters
COUNTRATE	CDF_DOUBLE	15	deadtime corrected count rates
label_ORBIT	CDF_CHAR	3	labels for three cartesian components of spacecraft location
ORBIT	CDF_DOUBLE	3	three cartesian components of spacecraft location at time EPOCH in ECI system
label_MAGFIELD	CDF_CHAR	3	labels for three components of computed magnetic field
MAGFIELD	CDF_DOUBLE	3	three cartesian components of computed magnetic field at location of spacecraft at time EPOCH in ECI
LSHELL	CDF_DOUBLE	1	computed value of McIlwains L-shell parameter

3.4 Data examples

Figure 1 shows the SREM observation times per month since the launch of the mission. Observation times vary strongly from month to month but never reach 100 %. The off-periods are mainly due to spacecraft problems but have also been caused by failures of SREM. However, until now SREM was each time successfully restarted.

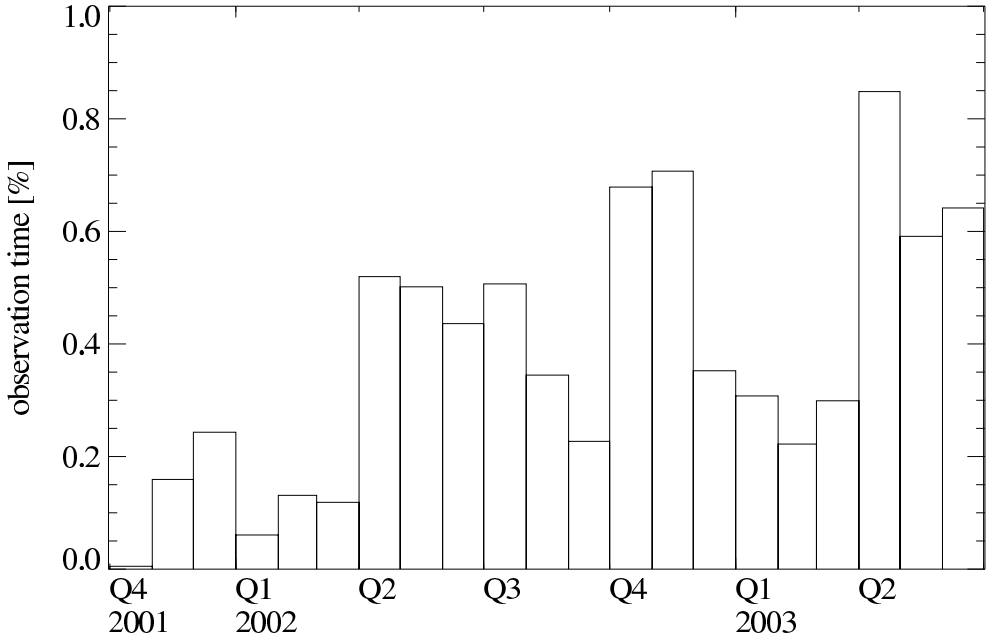

Figure 1: PROBA-1/SREM observation times as percentage available time per month. Off-times were mainly caused by spacecraft problems but also by some SREM failures.

Temperatures and voltages as shown in figure 2 indicate a proper functioning of the instrument throughout the mission so far. Figure 2 shows the average temperatures and voltages for each month which obviously changed only little over the more than one year period.

Figure 3 shows counter S14 count rates as function of geographic location. Counter S14 is mainly sensitive to protons with energies above 20 MeV and, as all counters, also counts cosmic rays. As expected, the highest rates are measured in the South Atlantic Anomaly, SAA. An enhanced background rate, caused by cosmic rays, is observed at high magnetic latitudes.

Figure 4 shows count rates in counters S14 and TC3 as function of magnetic field strength, B and L-shell parameter L for five consecutive passages through the inner and outer radiation belts at different magnetic latitudes. In both, inner and outer belt, the count rates depend on magnetic latitude - are smaller at high latitudes.

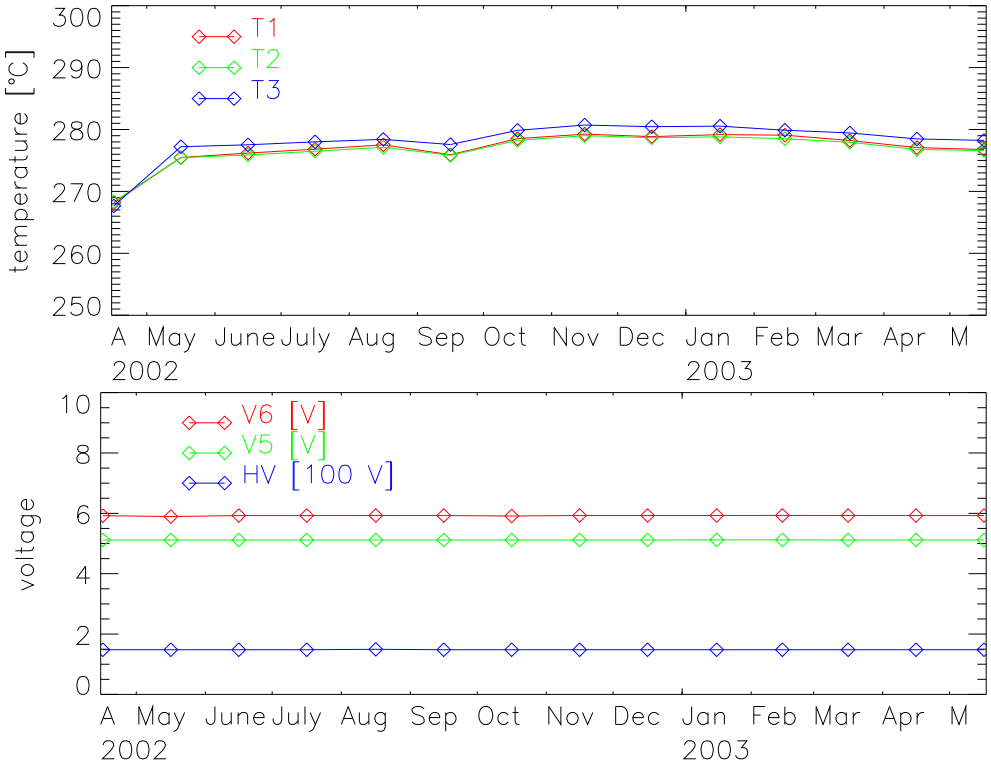

Figure 2: PROBA-1/SREM temperature and voltage average values per month. The values are very stable.

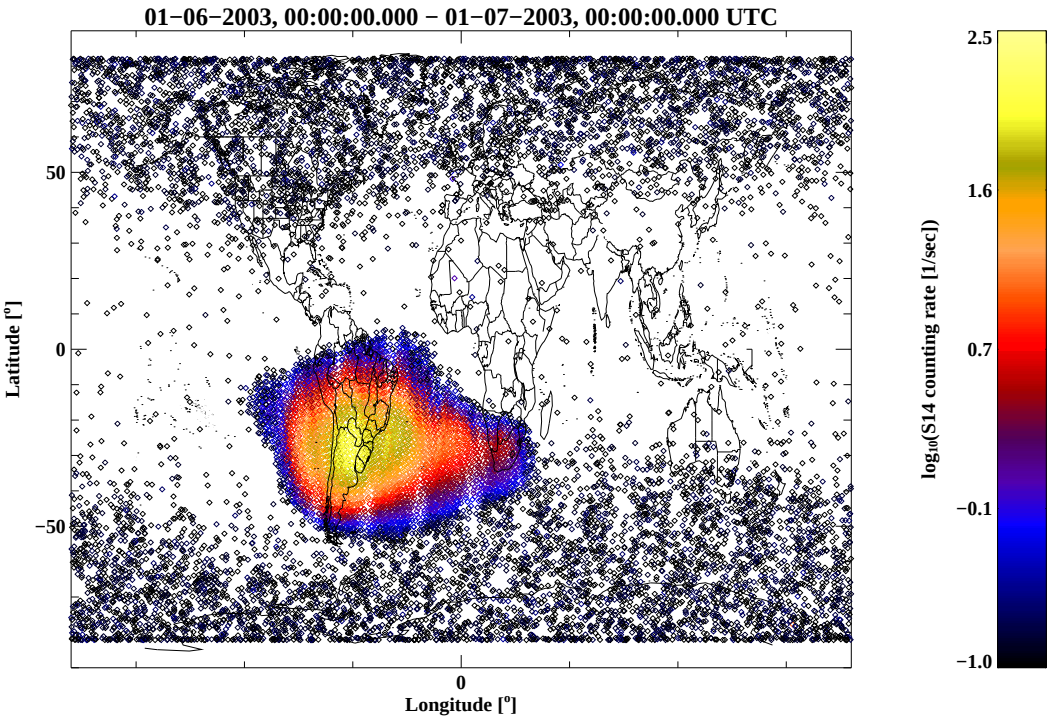

Figure 3: Counter S14 as function of geographic location during June 2003. The SAA is clearly visible. Cosmic rays penetrate at high magnetic latitudes to the spacecraft altitude.

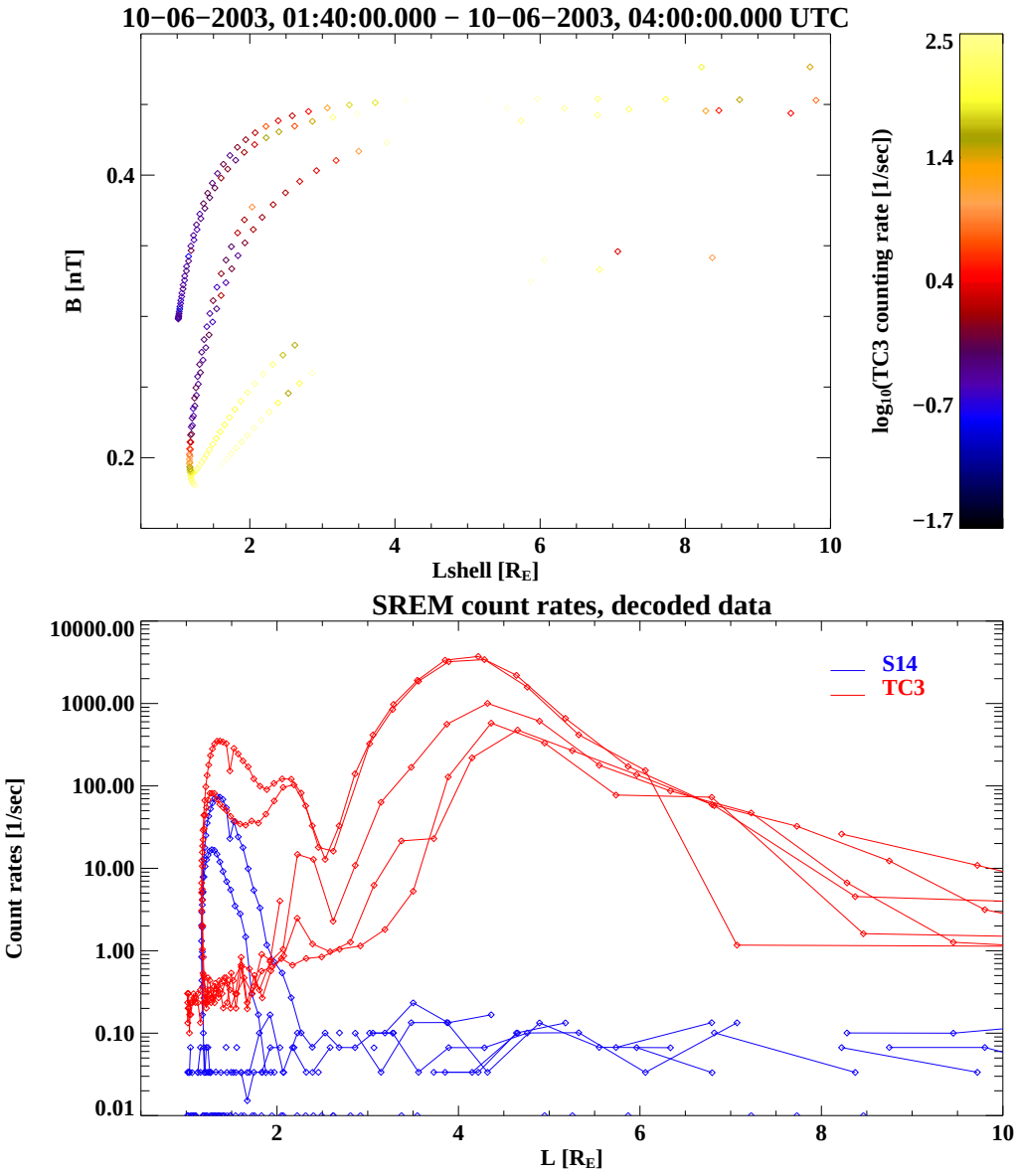

Figure 4: Counters S14 and TC3 as function of B and L for five consecutive orbits in June 2003. At a given L-shell the count rates are smallest at high magnetic latitudes.

4 WP 30, Dissemination

In order to disseminate the processed data the SREMPROBA1_PACC_yyyymmdd.cdf files are made available for public download on the web site http://srem.web.psi.ch/. In order to document changes in the radiation environment two summary plots for each month were created and displayed on the web site as well, one representing the proton environment at $3 < L < 7\ R_E$ (PROBA1__p_yyyymmdd_nnnn.gif using counter S15) and one for the electron/proton environment at $3 < L < 7\ R_E$ (PROBA1_ep_yyyymmdd_nnnn.gif using counter TC3). As an example summary plots for the period from April to July 2003 are shown in figure 5.

In addition to the data on the SREM web site, a CD was created (a copy is delivered to ESTEC) containing all available data from October 22, 2001 to June 30, 2003. The CD contains the following files and directory structure:

Table 10: Directory structure on PROBA-1/SREM CD.

README

PROBA1SREM_finalrep_03.ps

PROBA1SREM_finalrep_03.pdf

rawdata

PROBA1SREM_*aaa*_yyyymmdd_yyyymmdd.*ext*

orig

From_dd_Mmm_yyyy_00_00_00_To_dd_Mmm_yyyy_00_00_00.SREM_P.tar.gz

decdata

SREMPROBA1_DACC_yyyymmdd.cdf

SREMPROBA1_DACQ_yyyymmdd.cdf

prodata

SREMPROBA1_PACC_yyyymmdd.cdf

summary

PROBA1_ep_yyyymmdd_nnnn.gif

PROBA1__p_yyyymmdd_nnnn.gif

NORAD

SREMPROBA1_NORAD_yyyy.txt

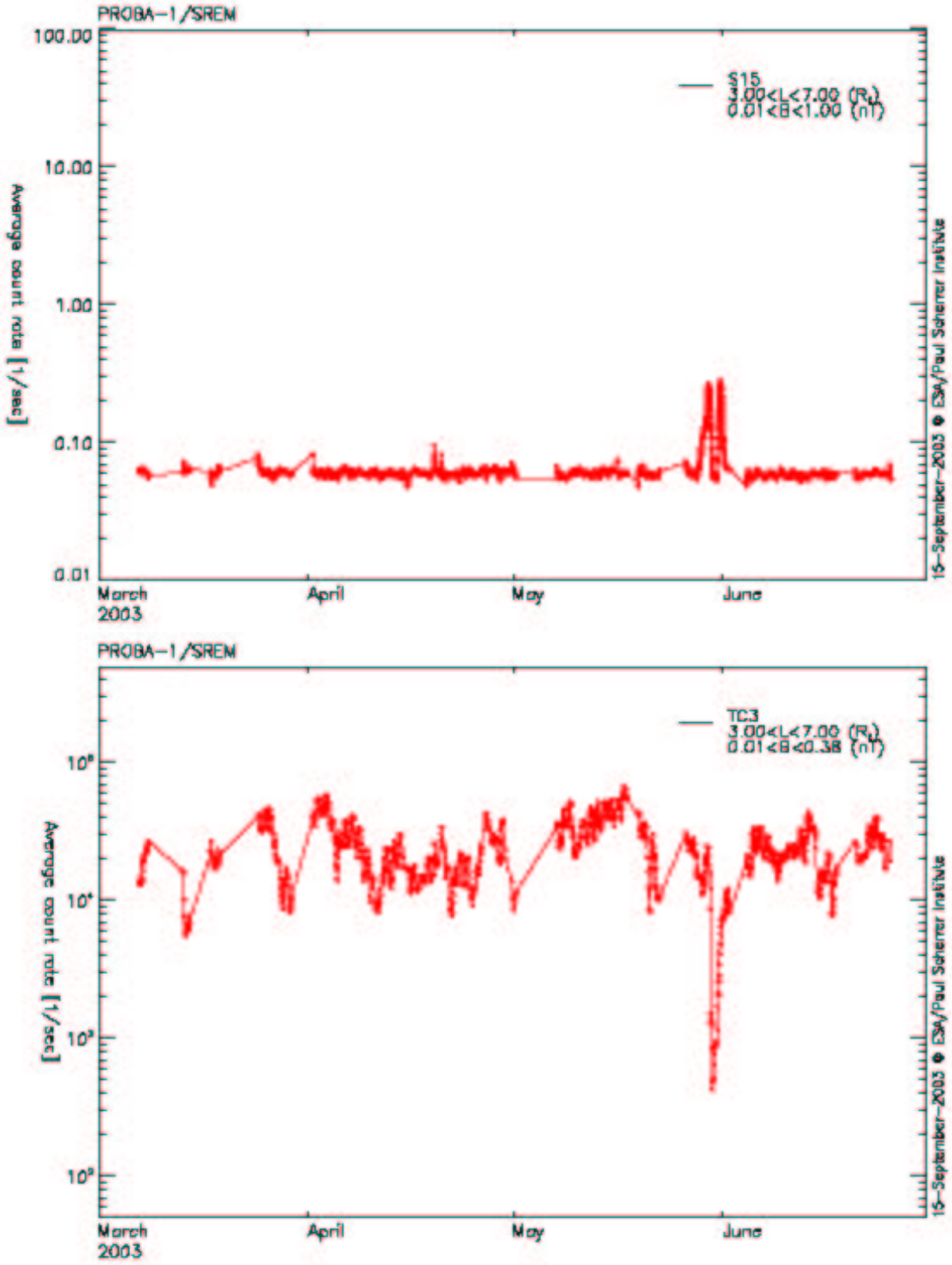

Figure 5: Summary plots for the period from March to July 2003. The two panels represent the temporal variations of the proton (upper panel) and electron/proton (lower panel) environment in the outer radiation belt.

5 Conclusion

Throughout the first twenty month of operation SREM was working fine. Only in few cases SREM crashed and had to be restarted. The restarts have been successfull so far. The instrument works very stable. Voltages are practically constant at their initial values and the noise levels are below the detection thresholds.

The data return is limited by the time the instrument is on. Mission constraints do not allow an uninterupted operation.

The developed procedures to decode and process the data yield good results as demonstrated with the examples shown in section 3.4. All data is available on a CD and in addition the processed data is also accessible at http://srem.web.psi.ch/.