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No.5 - SMART-1 is finding her way through the radiation storms!!

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Summary of overall status, current activities and planned activities

The spacecraft is now in its 78th orbit and has been flying for the last ten days in an intense radiation environment. This was caused by the recent, exceptional solar and geomagnetic activity. A series of intense solar flares occurred in the active sunspots regions 488 and 486 (see figure 1) and associated coronal mass ejections have generated extreme geomagnetic storms. Fortunately these active regions are expected to exit the solar disk in a couple of days, due to the Sun's rotation, and the number of observedsolar flares should significantly drop.

SMART-1, like many other spacecraft, has suffered in this harsh environment. The star tracker, the onboard computer and the electric propulsion system experienced major disturbances compared to normal operations. Despite this, we operated the spacecraft in electric propulsion mode and have now generated thrust for a total cumulated time of more than 380 hours and have consumed about 6 kg of Xenon fuel in the process.

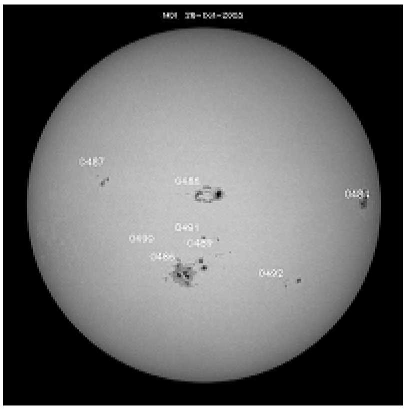

Figure 1: Distribution of the very active regions on the solar disc at the end of October

The electric propulsion engine performance, periodically monitored, as usual, by means of the telemetry data transmitted by the spacecraft and by radio-tracking by the ground stations, has stabilised with a small over-performance of about 1 to 1.5%. The main problem we are now facing is the occurrence, since launch, of eight autonomous shut-downs, or flame-outs, of the engine. The experts are still investigating the problems, but early analysis confirms, as anticipated in the last report, that all the flame-out events have occurred at the time of high incident radiation fluxes and mostly at perigee. This has led us to think that the energetic solar proton environment might affect the main electronic unit of the engine, the PPU. These ionising particles can create bit flips in the SRAM of the PPU, which are interpreted as sudden discharge current variations of the engine. The PPU then shuts down the engine autonomously. In order to ascertain this theory we are, over the coming week, going to perform some tests on the ground. In parallel the software maintenance team is preparing a modification to the S/W module controlling the electric propulsion performance - enabling the engine to be automatically restarted in these cases. This update will hopefully allow the continuous running of operations without human supervisions and ground contact.

The electric power degradation, due to the radiation environment, is about as expected. There was a sharp degradation at the beginning of the solar storms around 20 October 20, but more recently the degradation has softened up and we have now an average loss of less than 2 Watts per day. At this rate we still have good margin with respect to the end of life power predictions.

The communication, data handling and on-board software subsystems have been performing generally well. The increased radiation level, however, has caused, quite as expected, a few warm resets of the main computer and one switchover to the redundant computer. The spacecraft has reacted correctly to the events and nominal operations were recovered at the following ground contacts. The drawback, however, is that the planned operations are often disrupted.

The thermal subsystem continues to perform well and all the temperatures are as expected. The only item of concern is the slight increase of the star tracker optical head temperature during part of the orbit. This is a problem if it coincides with the use of the camera during periods of high radiation. The thermal engineers are looking into the possibilities to reduce the temperature of the star tracker optical heads.

The attitude control subsystem continues to work well in general. The star trackers have been working rather well, after the software modifications described in the last report. In the last period we only had two attitude drop-outs: one when one of the two star trackers was blinded by the Earth and the other when one star tracker had a relatively high temperature and was under heavy proton bombardment. There were no consequences, though, as the attitude control system is designed to cope with such situations. The main problem now is that the radiation dose received by the CCD of the camera heads is approaching what we were expecting by the end of the mission. In such a condition the star trackers can still provide good attitude data only if the temperature is relatively low (< 10 °C). It is desirable, therefore, to reduced the temperature of the star trackers as much as possible.

In the next few days we are planning to make some test observations with the AMIE camera. Possible targets are being presently analysed. More on the subject in the next report.

Orbital/Trajectory information

The effects of the electric propulsion low thrust continuously modify the SMART-1 orbit. ESOC specialists periodically compute these osculating orbital elements. These elements define the osculating orbit which would be travelled by the spacecraft if at that instant all perturbations, including EP thrust, would cease. So it is an image of the situation at that epoch. In reality the path travelled by the spacecraft is a continuous spiral leading from one orbit to another.
The most recent osculating elements are as follows:

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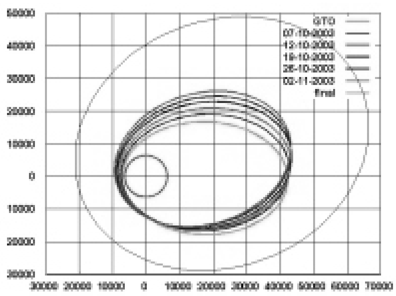
Elements WRT Earth (J2000)	
Pericentre Distance (km)	9068.636508
Apocentre Distance (km)	44581.017580
Semi Major Axis (km)	26824.830621
Eccentricity	0.661931
Inclination (deg)	6.906987
Asc. Node (deg)	158.793211
Arg. of Pericentre (deg)	197.751996
True Anomaly (deg)	179.939737
Osc. Orbital Period (h)	12.145460

The graphic shows the osculating orbits at launch, the GTO, and at different times are plotted. The large orbit, marked “final”, is the one what we expect to achieve at the end of the radiation belt escape in about one and half months.

From start, the electric propulsion system has managed to increase the semi-major axis of the orbit by 2195 km, increasing the perigee altitude from the original 656 km to 2690 km and the orbital period by more than 87 minutes, from the initial 10 hours 41 minutes to the present 12 hours 8 minutes.



SMART-1's osculating orbits

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