On-orbit Power Fluctuations of ADEOS-II

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ABSTRACT

Since ADEOS-II was launched, JAXA has analyzed on-orbit telemetry routinely in order to verify design and to find any sign of anomaly or degradation. One of the findings is generation power fluctuation of solar array paddle. We have investigated mechanisms of the power fluctuation and reached a scenario, space debris impact on solar cell. The impact might cause short circuit in solar array paddle and drop generation current. To confirm the scenario, we carried out hypervelocity impact tests to the solar array blankets. The investigation and test result are reported in this paper.

1. INTRODUCTION

Advanced Earth Observing Satellite –II (ADEOS-II) is Japanese earth observation satellite succeeding ADEOS. ADEOS-II has observed global earth observation data regarding water and carbon cycle. It was launched into polar low earth orbit by H-IIA launch vehicle on 14 December 2002 from Tanegashima Space Center.

ADEOS-II has recorded all telemetry on the onboard memory and downlinked with higher rate during visibilities of ground stations. JAXA has analyzed on-orbit telemetry after launch routinely in order to verify design and to find any sign of anomaly or degradation. Solar array generation power has been monitored to find long term degradation. Telemetry data was averaged and plotted to evaluate the trend. The plot indicated power fluctuation on March 20th. We have investigated mechanism of the power fluctuation. Some scenarios have been investigated, most possible one was space debris impact on solar cell. To confirm the scenario, we carried out hypervelocity impact test.

ADEOS-II stopped operation on 24 October 2003. Most possible cause is discharge on power line harness [1]. Relation between power fluctuations and fatal anomaly has been investigated, however, no evidence existed.

2. POWER SYSTEM

ADEOS-II has a flexible type Solar Array Paddle of 3 m x 24 m. It includes 64 array circuits. Each array circuit generates 100 W and totally over 6 kW. Generated power goes through Power harness, Paddle Drive Mechanism (PDM), Shunt circuits and Power Control Unit (PCU). Shunt circuits, controlled by PCU, dissipates surplus power and regulates bus voltage.

Power system consists of 2 units, called side-1 and 2, each unit has 32 array circuits and shunt circuits. Current telemetry can be monitored at PCU and Shunt. Generation power is calculated by summation of PCU current and shunt current. Block diagram of Power system is illustrated in Figure 1.

3. ANOMALY

We found first 100 W power fluctuation on March 20_{th} 2002. The long term plots from December 2002 to October 2003 for Solar Array generation current are illustrated in Figure 2 and 3 for side 1 and 2 respectively. To identify the power fluctuation occurring timing, current data measured 1, 30 and 58 minutes after end of eclipse were plotted. 58 minutes after end of eclipse corresponds to just before start of next eclipse. Bus voltage is almost 50 V therefore 100 W in power corresponds to 2 A in current.

10 power fluctuations on 7 solar array circuits were found for mission life of 10 months. All power fluctuations were 100 W steps and occurred in Side-1 or 2 independently. Some power drops returned to previous states during the sunlit or some days after the drop.

4. ANALYSIS

4.1 CATEGORY 1

Difference between Shunt circuit side-1 and 2 was plotted in Figure 4. 2 A offset was found on July 5th and

August 24th. Latter continued only 1 day and returned to nominal state on August 25th. No change in generation power was found even if the Shunt current fluctuated.

Shunt circuit is controlled by detected bus voltage automatically. Therefore Shunt-1 and 2 should operate simultaneously. In nominal, the difference between Shunt-1 and 2 current becomes zero. Assuming short circuit between power hot lines, the phenomena can be explainable. If an array circuit transmits 4 A, generation current, defined as PCU input current + Shunt current, didn't change. However, when a shunt circuit dissipated 4 A, 2 A difference between shunt 1 and 2 appeared. Additionally, temperature drop was found in PDM, therefore short circuit must occur on Solar Array Paddle or Power harness.

4.2 CATEGORY 2

From the start of sunlit, generation power is lower by 100 W and the situation continued during whole sunlit. This was found on March 20th and April 29th. The generation current plot for 3 orbits on April 29th is illustrated in Figure 5. The power drop can be seen in the side 2 at just beginning of second orbit. The power is still low in third orbit. This is independent from shunt operation. A short circuit between Hot and Return lines or an open circuit of Blocking Diode is suspected. Considering the power drop occurred on March 20th returned to nominal state on May 9th, the possibility of a permanent failure of Blocking Diode is low.

4.3 CATEGORY 3

From the start of sunlit, generation power is lower by 100 W. However the power drop returns during the sunlit. This is found on April 14th, July 17th, and July 19th. Generation current and Shunt current are plotted in Figure 6. Middle is telemetry plot of generation current. It isn't easy to find a fluctuation in the plot due to noise, so schematic figure is shown in upper. Power returned at curtain shunt current level. This is found in each orbit. Assuming a short circuit between hot and return line with small resistance, current doesn't flow to PCU but goes to Shunt when a shunt circuit turns on.

4.4 CONSIDERATION

All categories can be explained by a scenario that "Short circuit between Solar Array Cell and Cupper harness (hot or return)". ADEOS-II has a flexible type Solar Array Paddle. Hubble Space Telescope also has flexible paddles. The paddles were retrieved and many space debris impact holes were found [2]. HST had experienced a power drop however the cause wasn't identified.

The possibility of space debris impact to ADEOS-II Solar Array Paddle was simulated by MASTER [3]. It indicated that space debris or micro meteorloids of 100 micron or smaller in diameter could hit at the rate of 12 /m2/year.

5. HYPERVELOCITY IMPACT TEST

Short circuit between Solar Array Cell and Cupper harness could occur by space debris impact. To verify the scenario, we performed hypervelocity impact test using ADEOS-II Solar Array Blanket at ISAS/JAXA. Sectional view of blanket is illustrated in Figure 7. Cupper harnesses are sandwiched by thin polyimide sheets. Cells adhere on the polyimide sheet. A particle might penetrate from bottom of the blanket and meke a short circuit between a cell and a cupper harness.

Soda-lime glass of 74 – 88 micrometer in diameter was selected for projectile. At 4 km/s, projectiles penetrated Cupper harness and cracked cover glass (Figure 8). No short circuit was found in the test, however possibility couldn't be denied in the different conditions in velocity and incident angle.

For the contrast, the test using ADEOS-type blanket was performed. ADEOS, launched in 1998, has Ag-teflon sheet at bottom of the blanket. This might make difficult to penetrate for space debris. The impact tests were conducted at the same condition as ADEOS-II, no projectiles penetrated Cupper harness at the condition (Figure 9). ADEOS operated 10 months on-orbit, no power fluctuation was observed. Ag-teflon might protect Solar Array Paddle from impact of space debris.

6. CONCLUSION

Cause investigation of ADEOS-II on-orbit power fluctuation was carried out. Hypervelocity impact test showed that space debris impact on Solar Array Blanket had a possibility of power fluctuations for flexible type paddle with sandwiched cupper harness of ADEOS-II.

REFERENCES

[1]H. Maejima, et Al, "Investigation of Power System Failure of a LEO Satellite", AIAA #21IECEC, 16-19 Aug 2004
[2]L. Gerlach, "HST-Solar Array 1 in-Flight Power Generation Anomalies", HST Solar Array Workshop, 30-31 May 1995
[3]P. Wegener, et Al, "Upgrade of the ESA MASTER Space Debris and Meteoroid Environment Model", Final Report of EOSC/TOS-GA contract 14710/00/D/H

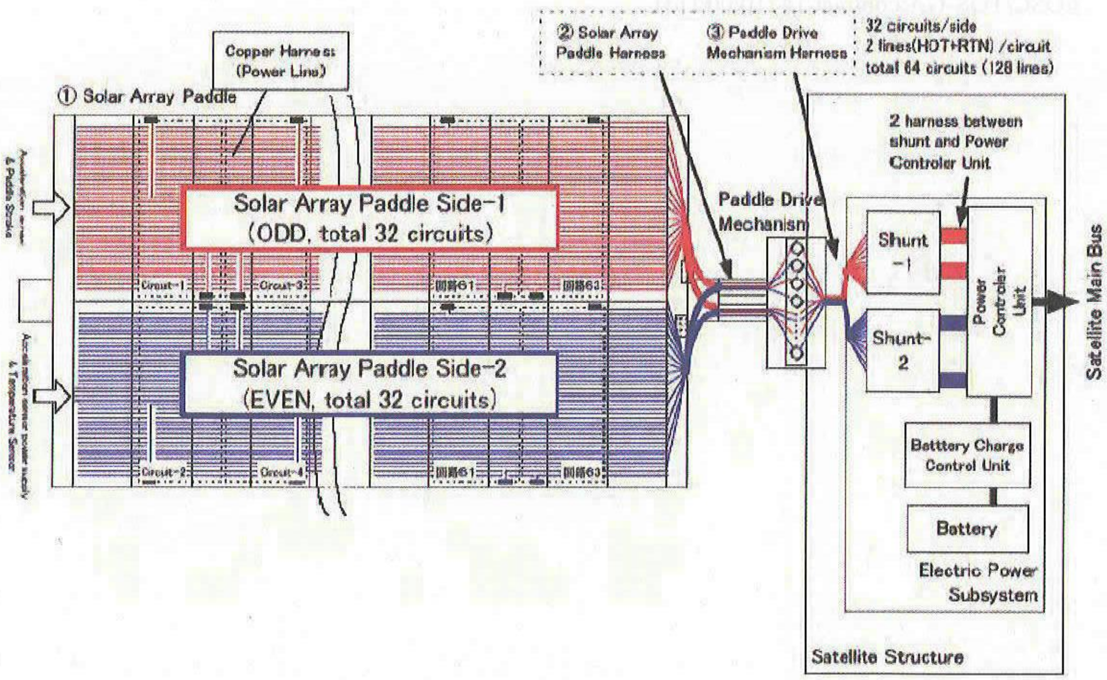

Figure 1 Block diagram of power system

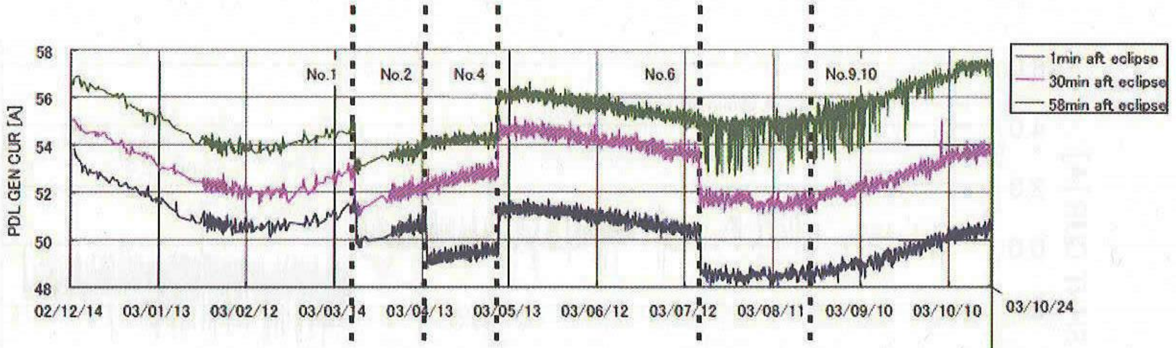

Figure 2 Generation current for side-1

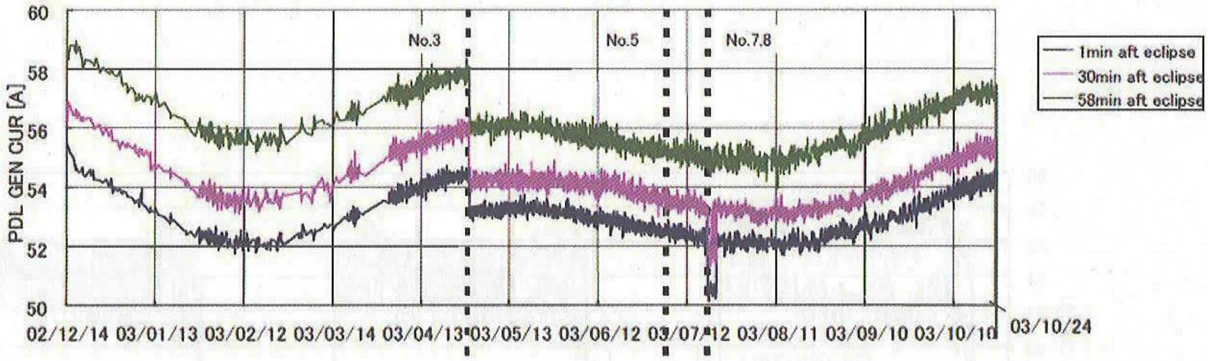

Figure 3 Generation current for side-2

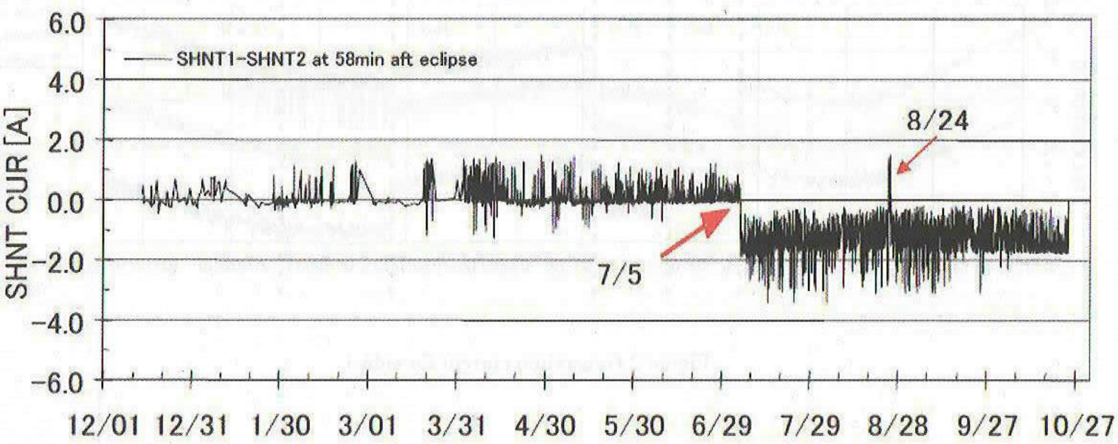

Figure 4 Difference between shunt -1 and 2 current

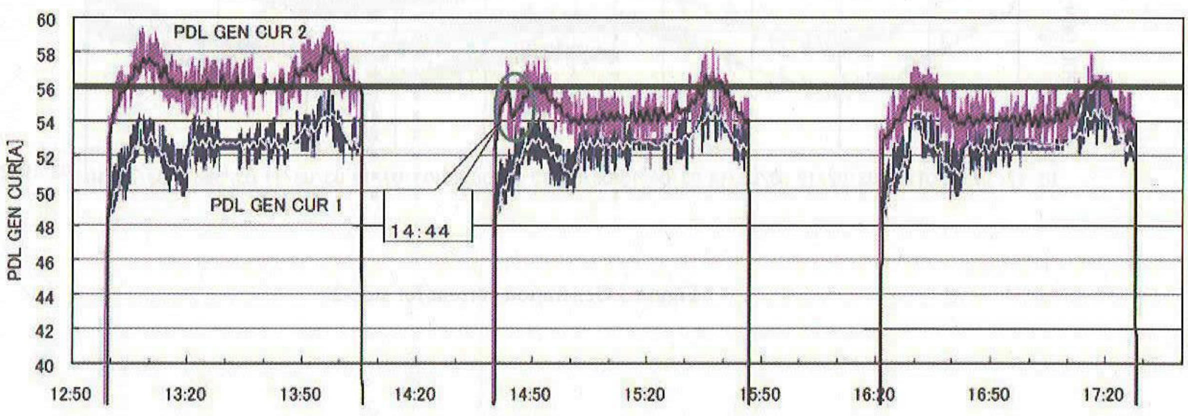

Figure 5 Generation Current Drop on April 29th

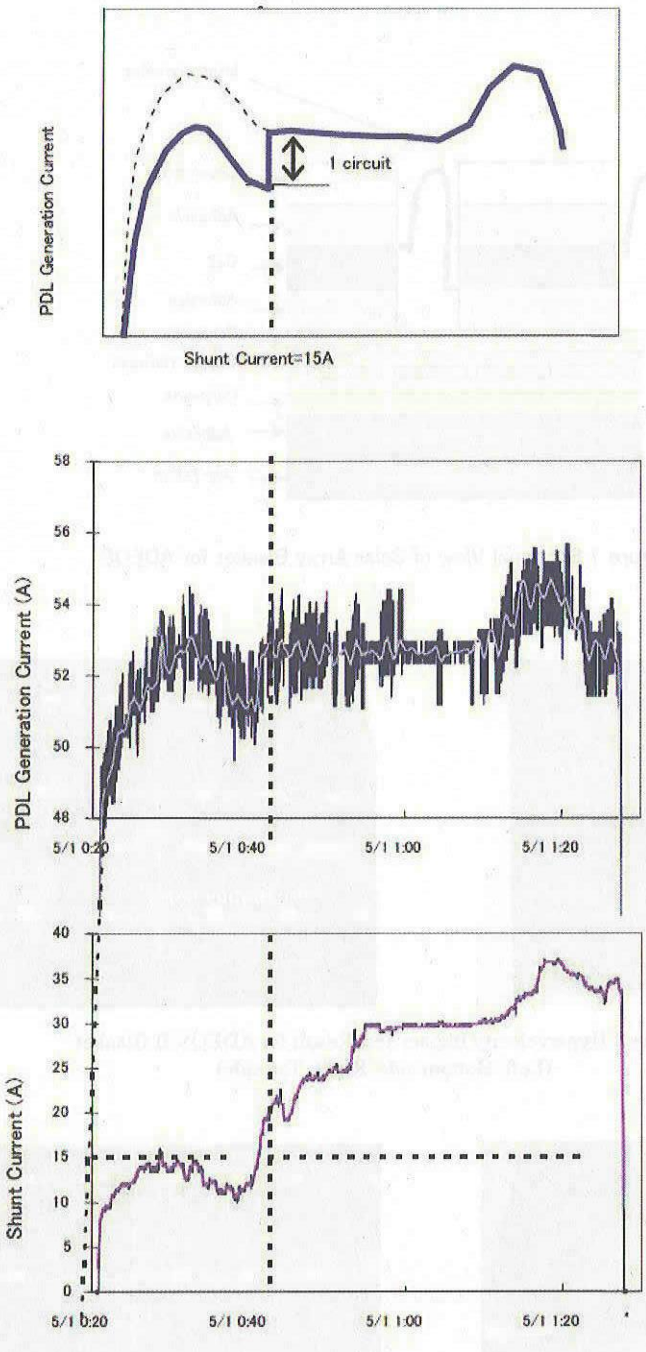

Figure 6 Relationship between Power Drop and Shunt Current

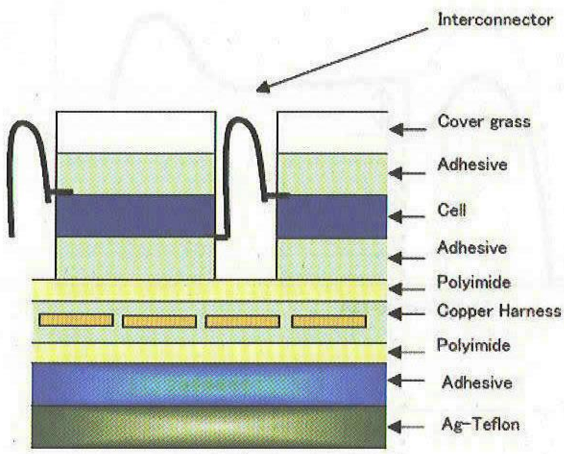

Figure 7 Sectional View of Solar Array Blanket for ADEOS

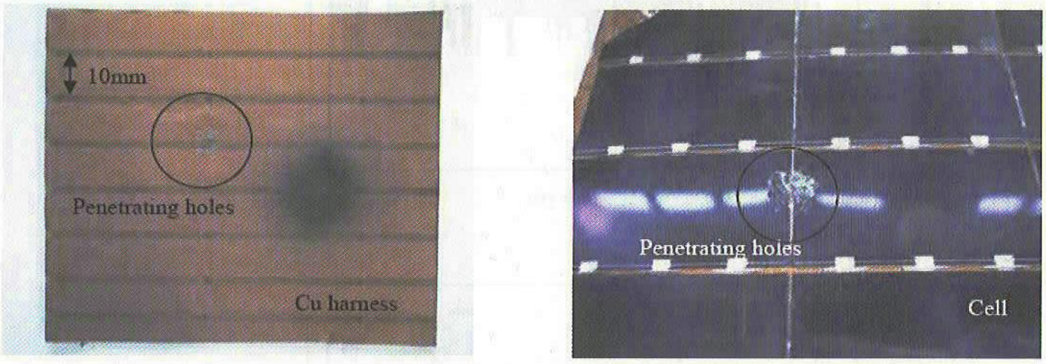

Figure 8 Hypervelocity Impact Test Result for ADEOS-II Blanket
(Left: Bottom side, Right: Top side)

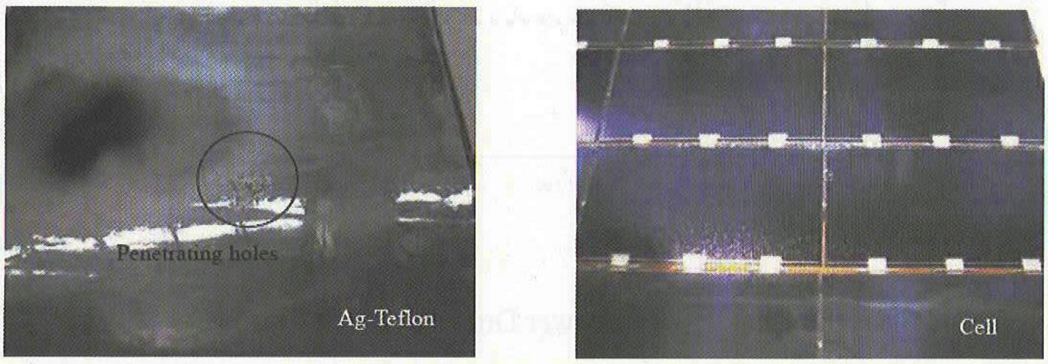

Figure 9 Hypervelocity Impact Test Result for ADEOS Blanket
(Left: Bottom side, Right: Top side)