The Diagnosis of Unknown Satellite Anomaly by Using Space Weather Data

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ABSTRACT

It has been reported that during the period of high solar activity cycle 22 around the years 1989 and 1990 there were 464 satellite anomaly cases, but this number was dropped into 271 cases during the solar cycle 23. This analysis took several low earth orbit (LEO) satellites as an example which experience anomaly during the years 2000-2009. This analysis give information that there are 10 anomaly cases thought to be caused by proton (P) and electron (E) simultaneously, 2 cases caused by proton, 3 cases caused by the electron and 6 cases caused by other sources (unknown anomaly). This research tries to analyze the causes of anomaly for these six satellites by using proton and electron particle data distributed along satellite trajectory provided by NOAA satellite and geomagnetic activity data represented by Kp and Dst indices. The results of this analysis give information that attitude control system (ACS) on satellite sub system suffers more damage than other instruments. Anomalies on Fuse (1), Fuse (2) and Monitor-E satellites are probably caused by the influence of increased plasma by the time geomagnetic storms happened. Other anomalies on Kirari , Obrview 3 and HST satellites require further analysis because space weather data doesn't show the close correlation between satellite anomaly events and space weather phenomena such as proton and electron impacts on satellite and plasma enhancement through geomagnetic storm.

Key words : Satellie anomaly - Proton and electron - Geomagnetic activity - IWSW 2011

1 INTRODUCTION

The case of satellite damage, which is known as satellite anomaly, is potentially experienced by satellites which are placed at low earth orbit (LEO) and high-earth orbit (GEO). In the space environment, the dominant cause of those anomalies come from the charged particles such as protons and electrons that are scattered randomly around the earth (Barth and Gorsky, 1997). These particles are generated mainly from coronal mass ejection (CME) from the sun and galactic cosmic rays (GCR) in the form of protons and electrons or in the form of plasma as a result of ionization process from those both particles. (Schwenn, 2006).

Solar activity enhancement on cycle 22 gave information about the total number of satellite anomaly cases over the period 1989-1990 was 464. At the peak of solar cycle 23 around the years 2000 – 2001, the total number of anomaly cases was 41. The satellite anomaly case is also predicted to occur on solar cycle 24 which reaches the maximum around mid- year 2013 . In 2005, based on reports from http://sat-nd.com/failures/ website, it has been registered the total number of anomalies as many as 23 cases, 21 cases in 2006, 28 cases in 2007, 24 cases in 2008, 21 cases in 2009, and 14 cases in 2010. These anomaly cases were also reported over the period 1990 – 2001 that total number of satellite experienced anomaly was 31 cases or

4.07 percent of the total launch (Robertson and Stoneking, 2001).

Basically, all satellites which was reported to experince anomaly triggered by space weather that has variation following the level of solar activiy. All satellite anomaly cases can be studied and then used as reference in studying and analyzing the probability of anomaly on other satellites.

In this paper, it has been trying to analyze the cause of unknown satellite anomaly which are placed at LEO by using some space weather data. Thus, it can be expected that this research will answer some questions about potentially hazard of anomaly event on satellite including some information about parts of satellite system which are susceptible to experience failure.

2 DATA AND METHOD

To analyze the case of satellite anomaly, one need some information such as satellite name, time of anomaly consists of date, month, year, local time when anomaly was reported and description about satellite damage itself. In general, the satellite anomaly information can be accessed through the internet which is contain of anomaly report and short description of satellite damage without giving information about local time when anomaly reported. This local time is needed to track the satellite position and to find the information about energy and flux of particles that trigger the case of satellite anomaly.

Data used in this research consist of particles data from http://omniweb.gsfc.nasa.gov/form/dx1.html and http://www.ngdc.noaa.gov/stp/NOAA/noaa_poes.html. This data contains information about energy, flux and distribution of particle itself at near earth environment. Besides particles data, this research also used geomagnetic variation data represented by Kp and Dst indices. These data can be accessed through http://omniweb.gsfc.nasa.gov/form/dx1.html. These geomagnetic data was needed to analyze the coincidence between anomaly event and plasma enhancement by the time geomagnetic storm occured.

Satellite anomaly data can be derived from http://sat-nd.com/failures/. There are 18 selecting satellite within period of time 2000 – 2009. Some of those satellite have been analyzed related to the source of anomaly (Ahmad, 2010).

Generally, The methodology used in this research can be seen in Figure 1.

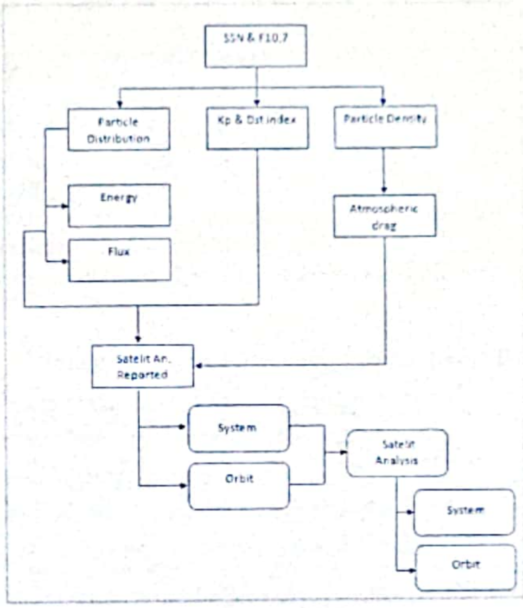

Figure 1. Methodology of diagnosing unknown satellite anomaly

The influence of space weather on satellite can be seen through the characteristic of space environment along the satellite trajectory (Hasting and Garret, 1996). This characteristic can be determined by analyzing the level of variation each year for solar cycle 22 and 23. This research only determines the variation for solar cycle 22 and 23 to simplify reviewing and analyzing low orbiting satellites that have been reported to experience anomaly. Besides space weather data, satellite anomaly report from some satellites are also needed to check the parts of satellite subsystems which susceptible to experience failure. All These information will be used as reference to analyze the probability of anomaly for other low orbiting satellites which are not reported to have anomaly. Variations in cycle 22 and 23 are reviewed at this early step including the analysis of the sunspot numbers (SSN) and F10.7 index as a reference to see the variations of space weather parameters such as Kp and Dst indices that will be used in this research. The final step is looking at the case of satellite anomalies in the range of values of SSN and F10, 7 to determine the correlation between solar activity levels and the incidence of satellite anomalies reported.

3 RESULT AND DISCUSSION

Analysis of the source of satellite anomaly on given satellites gave information that there were 10 anomaly cases thought to be caused by proton (P) and electron (E) simultaneously, 2 cases caused by proton, 3 cases caused by the electron and 6 cases caused by other sources (unknown anomalies - L). Satellite subsystems that are often experience anomalies can be seen in Table 1

Table 1. Satellite anomalies at low earth orbit

Satellite Name	Anomaly Time	Height (Km)	Subsystem Anomaly	Caused Predicts
ERS 1	16-Mar-00	772	ACS	P,E
ASCA (Astro-D)	15-Jul-00	140	ACS	P
Terra	26-Oct-00	702	COMM	P,E
FUSE	25-Nov-01	752	ACS	L
FUSE	10-Dec-01	752	ACS	L
Yohkoh	15-Dec-01	159	ACS	P,E
Aqua	27-Jun-02	702	EPS/ACS	P,E
Radarsat 1	27-Nov-02	792	ACS	E
Radarsat 1	30-Dec-02	792	ACS	P,E
Landsat 7	31-May-03	702	PAY	P,E
ICESat	30-Mar-03	595	PAY	P
Midori [ADEOS] II	24-Oct-03	805	EPS/ACS	P,E
DART	15-Apr-05	554	PROP/ACS	E
Monitor E	18-Oct-05	527	ACS	L
Kirari [OICETS]	24-Nov-05	593	ACS	L
KOMPASS 2	29-May-06	422	EPS/COMM	E
HST	30-Jun-06	564	ACS	L
MetOp-A	04-Nov-06	821	PAY/COMM	P,E
Orbview 3	04-Mar-07	707	PAY	L
Orbcomm	10-Nov-08	758	EPS/ACS	P,E
Orbcomm	22-Feb-09	758	EPS/ACS	P,E

In Tabel 1, there are five satellites and six anomaly cases come from other sources (L). These five satellite are Fuse , Monitor-E, Kirari , Obrview 3 and HST. Fuse (1) means this satellite experienced anomaly for the first time on November 25, 2001 and Fuse (2) means this satellite experienced anomaly for the second time on December 10, 2001.

The position of satellite when it reported to have anomaly including the information about particles distribution and geomagnetic variations at the anomaly time can be seen in some following figures. In this paper , not all figures are displayed. It has been chosen some cases which the cause of anomalies were estimated did not come from protons and electrons, but from other sources (L). Geomagnet activity levels were also analyzed by using method which has been tested in other satellite anomalies research by Ahmad, 2009. This method took the time span with period of 3 days before and after the anomaly time was reported. By using the same method, it can be tracked the position of satellites including the particles distribution along satellite orbit and the level of geomagnetic activity related to satellite anomalies which are shown in Figure 2 until Figure 7.

1. FUSE Satellite (1) (25 November 2001)

Fuse satellite was reported to have anomaly for the first time on November 25, 2001.

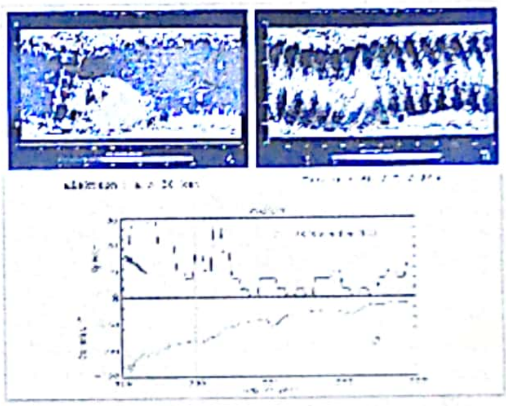

Figure 2. Distribution of electron (A), proton (B) and geomagnetic variation on FUSE (1) anomaly.

In Figure 2, the position of FUSE satellite was not within area of high flux of particles. Geomagnetic variation in Figure 2C did not show the increment on Kp index. Altough Kp index small enough, geomagnetic variation at low latitude, represented by Dst index, decreased significantly up to -150 nT. It can be estimated that the source of anomaly on FUSE satellite related to plasma enchancement coincided with the high geomagnetic activity.

2. FUSE Satellite (2) (10 December 2001)

Fuse satellite re-reported to have anomaly on December 10, 2001. The position of satellite at that time can be seen in Figure 3. Even this satellite passed over equatorial region, it was not within area of high flux of particles. Geomagnetic variation, both Kp and Dst, at that time did not show significant values. Preliminary analysis estimated that the anomaly was caused by the effect (aftereffect) of the previous anomaly.

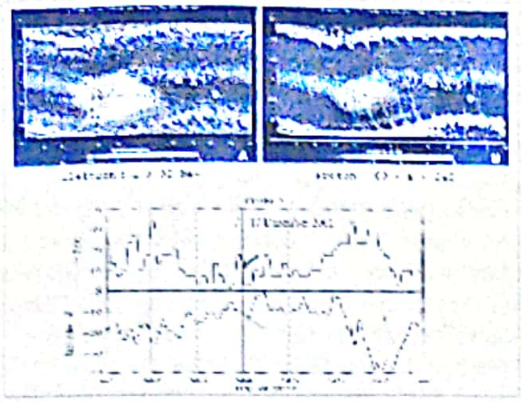

Figure 3. Distribution of electron (A), proton (B) and geomagnetic variation on FUSE (2) anomaly.

3. Monitor-E Satellite (18 October 2005)

Monitor- E satellite was reported to have anomaly on October 18, 2005. Satellite position at that time can be seen in Figure 4.

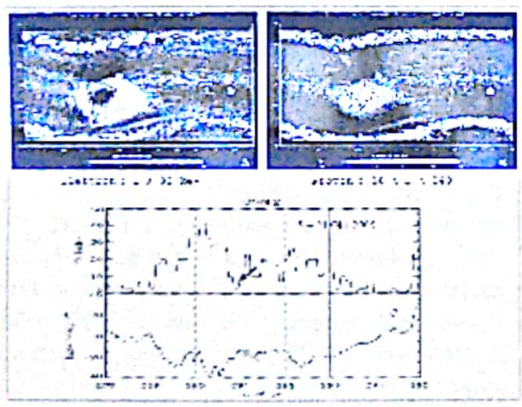

Figure 4. Distribution of electron (A), proton (B) and geomagnetic variation on monitor-E anomaly.

In Figure 4, satellite passed over high latitude region, but there was no indication that the flux of particle so high at that time. Geomagnetic variation also did not show the increment on Kp index. Eventhough Kp index was small, Dst index decreased significantly (moderate) before anomaly was reported. Tracking the satellite position at that time gave information that Moniter-E passed over equatorial region. Hence, it can be estimated that anomaly on Monitor_E satellite probably related to plasma enhancement coincided with the high geomagnetic activity.

4. Kirari Satellite (24 November 2005)

Kirari satellite was reported to experience anomaly on November 24, 2005. Satellite position at that time can be seen in Figure 5.

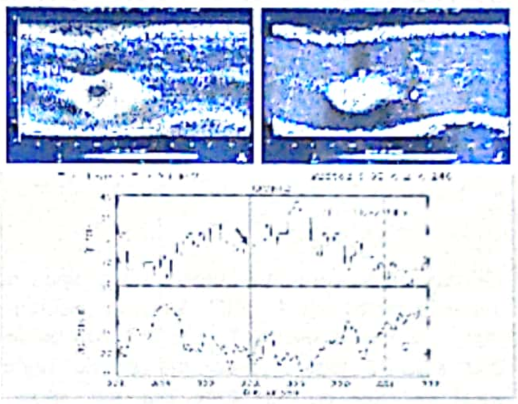

Figure 5. Distribution of electron (A), proton (B) and geomagnetic variation on Kirari anomaly.

In Figure 5, it can be seen that satellite passed over mid-latitude region. Particles flux was too small to give effect to satellite. Geomagnetic variation was also too small to give effect on satellite. It can be estimated that the cause of anomaly probably not came from space weather, but It could be came from satellite internal problem itself.

5. HST Satellite (30 June 2006)

HST satellite was reported to experience anomaly on June 30, 2006. Satellite position at that time can be seen in Figure 6. By the time anomaly occured, HST passed over equatorial region. Even this satellite passed over equatorial region, it was not within area of high flux of particles. Geomagnetic variation was small enough to give effect to satellite. It can be estimated that the cause of anomaly probably not came from space weather . Hence, the cause of anomaly in this satellite still need further analysis.

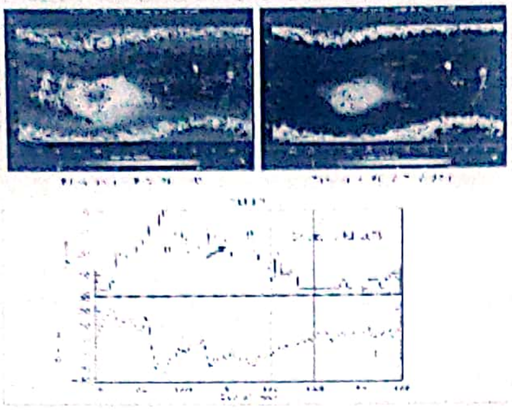

Figure 6. Distribution of electron (A), proton (B) and geomagnetic variation on HST anomaly.

6. Orbview 3 Satellite (4 March 2007)

Orbview 3 satellite was reported to experience anomaly on March 4, 2007. Satellite position at that time can be seen in Figure 7. It can be seen that satellite passed over mid-latitude region. Particles flux at that time did not show a significantly increased. Geomagnetic variation was also small enough to give effect to satellite. It can be estimated that the cause of anomaly probably not came from space weather. Therefore, anomaly on this satellite is also need further analysis.

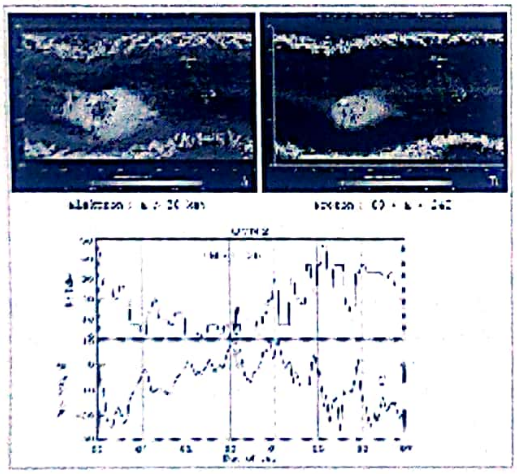

Figure 7. Distribution of electron (A), proton (B) and geomagnetic variation on Orbview 3 anomaly.

In Tabel 1, it can be seen that most anomaly was occured on ACS subsytems. According to analysis which was done by Robertson and Stoneking, 2001, Guidance, Navigation and Control (GN&C) subsytems on satellite have a high number of anomalies that result in a mission critical failure when compared to other subsystems. These subsystems are comprised of Attitude Control System (ACS), Propulsion (Prop), Electrical Power System (EPS), Command & Data Handling (C&DH), Mechanical (MECH), Software (Soft), Payload (Pay) and the others. ACS is the most susceptible subsystem among the other subsystems. It can be seen in Figure 8 (Robertson and Stoneking, 2001).

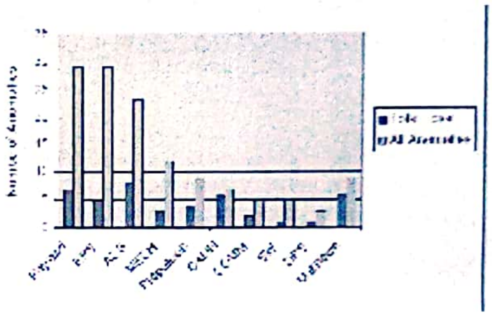

Figure 8. Subsystem anomalies

Parts of other subsystems which often experience anomaly are payload, C&DH, EPS, etc. All of these subsystems can be categorized as parts of GN&C satellite subsystems. From these total anomaly, it can be said that approximately 29 percent of anomalies impacted the GN&C subsystems and of that number about 37 percent caused total loss on satellite missions.

4 CONCLUSION

Satellite anomaly cases over the period 2000 – 2009 give information that there were 10 anomaly cases thought to be caused by proton (P) and electron (E) simultaneously, 2 cases caused by proton, 3 cases caused by the electron and 6 cases caused by other sources (unknown anomalies - L). Some space weather data were used for analyzing the cause of unknown anomalies. It can be concluded that anomalies on Fuse (1), Fuse (2) and Monitor-E satellites are probably caused by the influence of increased plasma by the time geomagnetic storms occured . Other anomalies on Kirari , Obrview 3 and HST were estimated came from satellite internal problem and it was still require further analysis because space weather data did not show the close correlation between satellite anomaly events and space weather phenomena such as proton and electron impacts on satellite and plasma enhancement through geomagnetic storm. It also give information that Attitude Control System (ACS) on satellite sub system suffers more damage than other instruments. Therefore, it is needed to make some modifications on ACS design to reduce the effects of space weather on this subsystem.

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