우주환경 이벤트에 의한 위성의 이상현상

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Satellite Anomalies due to Spce Environment Events

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요 약

태양폭발, 코로나물질방출(Corona Mass Ejection, CME)등의 태양활동을 포함한 우주환경(space environment)은 결코 인간에게 우호적이지만은 않다. 특히 인공위성에게는 치명적일 수 있다. 그 중에서 정지궤도에 있는 통신위성에게는 상기와 같은 급격한 태양활동뿐만 아니라 지속적으로 끊임없이 배출되는 전자, 양성자등 플라즈마 입자들로 인해 수명이 단축되고 있다. 통신위성을 구성하는 능동부품들은 플라즈마 입자들에 특히 약하기 때문이다. 이를 방지하기 위하여 방사능 차폐(Radiation Shielind)등을 하지만 이에 대한 비용이 매우 많이 드는 것이 사실이다. 그러므로 적절한 차폐가 필요하며 이를 위해서는 우주환경의 연구가 필요하다. 본 연구에서는 저궤도부터 우주탐사용 위성까지 모든 궤도영역의 인공위성의 이상현상등을 분석한 후 이것이 태양폭발, 지자기 폭풍등 우주환경이벤트와의 연관성을 조사해보고자 한다.

Key Words : Solar activities, Space Environment, Spacecraft anomaly, Radiation shielding

ABSTRACT

Space Environment including Solar activities such as Solar explosion, Corona Mass Ejection(CMS) is always not friendly for human. Especially it may be fatal to artificial satellites. The lifetime of geostationary communication satellites are reducing due to plasma such as electrons, protons etc. emitting from Sun. This is because the active components constituting communication satellite are easily affected by plasma. Even though the radiation shielding on the components can be a way to prevent, the cost will be high. So the appropriate shielding is necessary and the study on space environment is also. In this study spacecraft anomalies will be investigated from low earth orbit to deep space spacecraft and the correlation between spacecraft anomalies and space environment events including space explosion, geomagnetic storms etc is analyzed..

Ⅰ. Introduction

Space environment consist of particles from sun or galaxies, plasma and electromagnetic field but it is not always friendly for human and space infrastructure. Especially the space infrastructure including spacecrafts must operate for several years in this environment. High energy particles may be the cause of single event upset in microelectronic devices of satellite and low energy particles such as low energy electrons creates electric charges on the satellite surface and degrades solar battery[1]. Also high energy electrons may do damage to electronics directly or may create volume charging inside satellite[2].

So far, many papers have studied the space environment effect on satellites. Wilkinson(1990)[3] introduced the database of spacecraft anomalies about 3,000 from 1971 which were collected by NOAA. Barillot & Calvel (1996)[4], Belov et al(2004)[1], Dorman et al(2005)[5], Pilipenko et al (2006)[6] analyzed the various effects on spacecrafts by using NOAA database.

This paper macroscopically investigates the relationship between solar cycles, geomagnetic

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events and spacecraft failures based on the different database from NOAA database

II. Satellite Failure Data and Analysis Method

1. Satellite Failure Data

Satellite insurance company is the one of the most sensitive organization on spacecraft failures. Data in this paper comprise the 2042 failures and anomalies of GEO, LEO and deep space spacecraft from 1961 to 2009. Table shows the numbers according to satellite orbit.

Solar sunspot number(SSN) is the best index of solar activity Figure 1 shows SSN from 1961 to 2009

Table 1 Satellite Failure Data

Year	Total	Failure Numbers		
		GEO	MEO/LEO	Deep
1961	2	0	1	1
1962	9	0	7	2
1963	2	1	1	
1964	3	0	0	3
1965	8	2	2	4
1966	8	0	5	2
1967	11	5	5	1
1968	9	4	4	1
1969	16	11	2	3
1970	15	12	3	0
1971	24	19	3	2
1972	24	18	1	5
1973	14	11	3	0
1974	17	15	2	0
1975	21	18	1	2
1976	23	19	4	0
1977	22	20	2	0
1978	31	28	2	1
1979	40	37	3	0
1980	10	10	0	0
1981	30	24	6	0
1982	42	39	2	1
1983	48	43	5	0
1984	33	31	2	0
1985	27	25	2	0
1986	39	34	4	1
1987	22	22	0	0
1988	28	24	4	0
1989	50	44	6	0
1990	34	25	9	0
1991	55	41	13	1
1992	26	16	8	2
1993	35	26	8	1
1994	32	26	6	0
1995	41	34	6	1
1996	30	18	10	2
1997	107	44	57	6
1998	117	53	49	15
1999	94	31	39	24
2000	130	60	59	11
2001	106	58	36	12
2002	63	38	14	11
2003	133	55	52	26
2004	61	27	24	10
2005	61	19	27	15
2006	92	35	47	10
2007	61	24	30	7
2008	66	29	33	4
2009	70	21	36	13

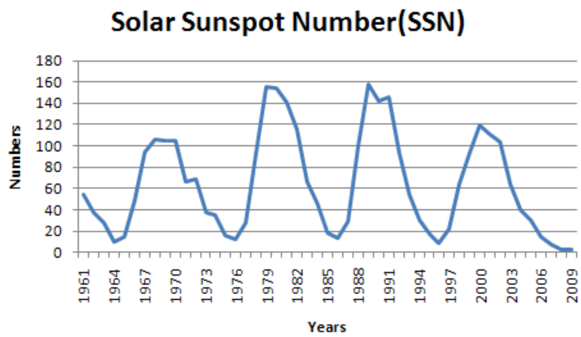

Figure 1 Solar Sunspot Numbers from 1961 to 2009

2. Analysis Method

In order to investigate the relationship between SSN and satellite failures, correlation coefficient is used as (1).

$$r = \sum_{i=1}^{n} \frac{(Xi - \overline{Xi})(Xj - \overline{Xj})}{\sqrt{(Xi - \overline{Xi})^2}\sqrt{(Xj - \overline{Xj})}^2} \quad (1)$$

where Xi and Xj mean the average of variables.

III. Satellite Failure and Solar Cycle

1. Relation between solar cycle and GEO

Except deep space mission, GEO is the most vulnerable to solar activities because GEO is the nearest orbit from sun and sometimes cannot be protected by earth magnetic field. GEO satellites are primarily affected by proton among high energy particles. Proton is directly related with solar activities.

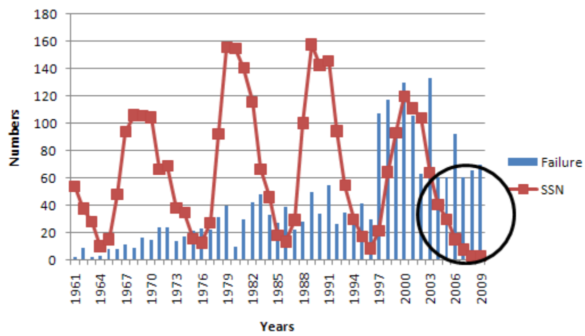

Figure 2 SSN and Total Failure Numbers of all kinds of Satellite Orbits

In order to show the relationship between SSN and satellites failure they are represented in one figure as figure 2 and figure 3. Figure 2 is for total failure numbers and figure 3 for GEO only.

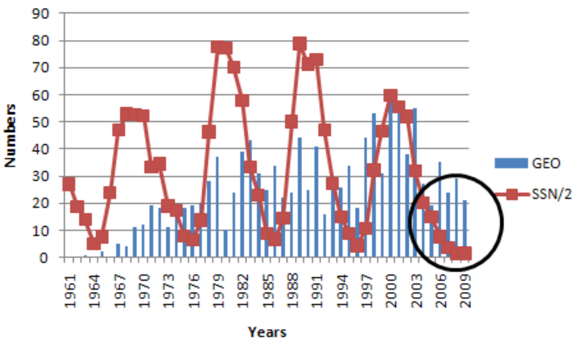

Figure 3 SSN and GEO Failures

Total numbers looks not so much relationship with SSN. The correlation coefficient is 0.02 which is quite low. Even though during the period from 1995to 2009 the correlation coefficient is 0.57, we cannot assure the relationship.

In case of GEO the correlation coefficient shows 0.70 during 1995 to 2009 as figure 4. This means high relationship. However in the solar minimum after 2005 there were so many failures (black circle). It is necessary to study more detail.

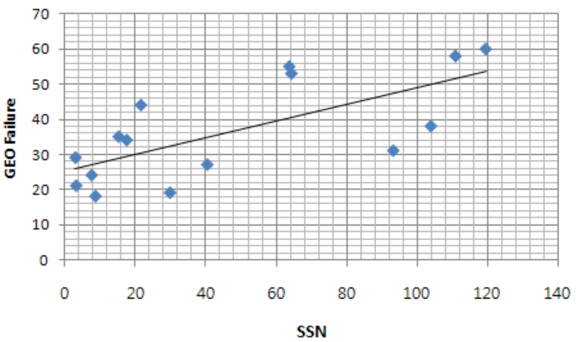

Figure 4 Correlation between SSN and GEO Failure

2. Relation between solar cycle and LEO/MEO

It is know that LEO and MEO satellites are affected by electrons in the magnetopause than protons[1]. Especially high energy electrons affect more seriously.

During the total period satellite failures has little relationship with SSN as figure 5. Black circle is very similar to GEO case. And as figure 6 during the periods from 1995 to 2009 there seem to be not much the relationship.

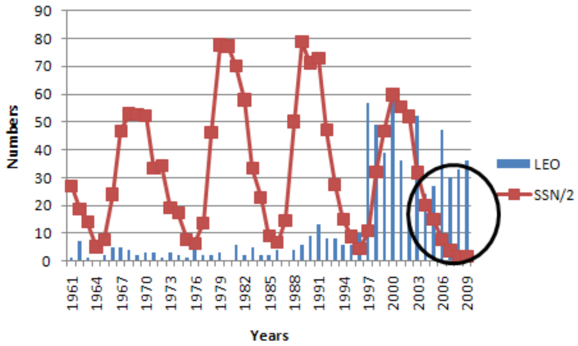

Figure 5 SSN and LEO/MEO Failures

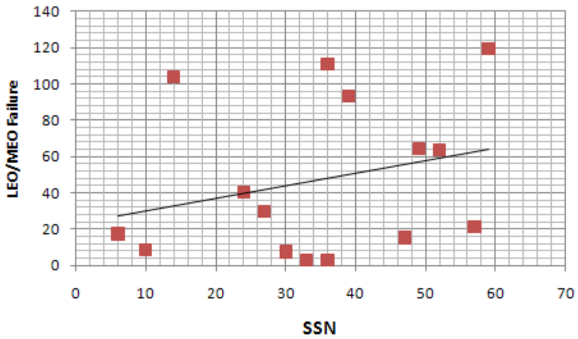

Figure 6 Correlation between SSN and LEO/MEO Failure

3. Relation between solar cycle and deep space mission

Spacecraft for deep space exploration cannot be protected by earth and is totally affected by sun and galaxies. Figure 7 shows the relationship with SSN from 1995 and 2009. The correlation coefficient 0.50 means the relation is more or less but we cannot say definitely because of few data numbers.

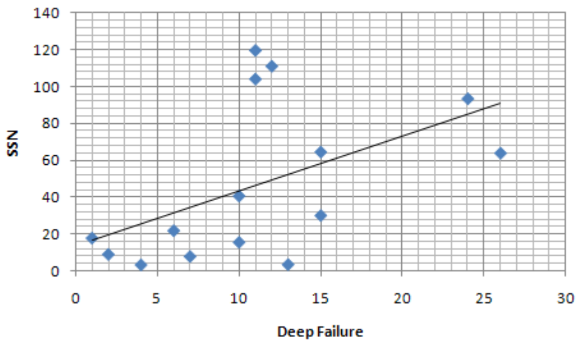

Figure 7 Correlation between SSN and Deep Space Explorer Spacecraft Failure

IV. Satellite Failure and Geomagnetic Storms

1. Geomagnetic storm data

Geomagnetic storm data are extracted in Min et al from Jan. 1997 to August 2001[2]. These data include 116 points which are Dst <-40 nT as figure 8.

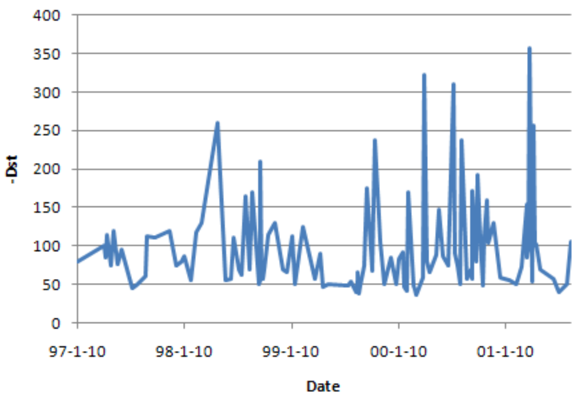

Figure 8 Geomagnetic Storm Data

2. Relation between geomagnetic storm and different orbits

We divide data into two group, GEO and LEO/MEO and investigate monthly failure numbers from Jan 1997 to July 2001. Figure 9 and figure 10 show these numbers with geomagnetic storm data.

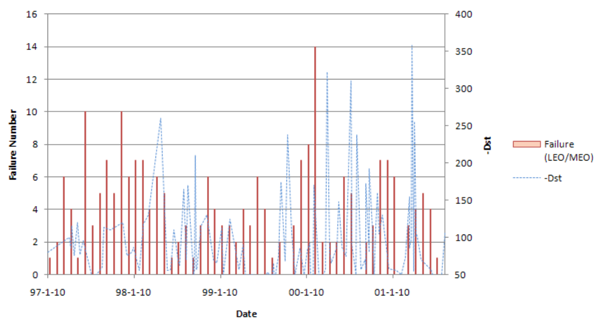

Figure 9 Geomagnetic storm data and LEO/MEO failure

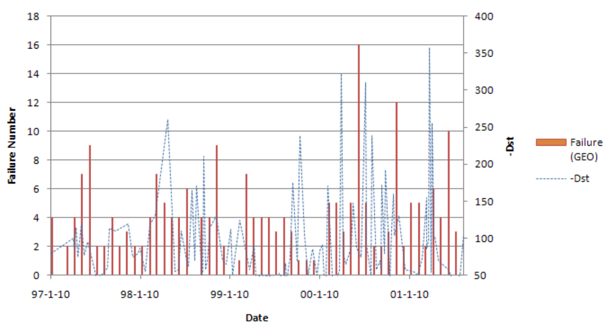

Figure 10 Geomagnetic storm data and LEO/MEO failure

Figures shows that GEO case is much more relationship with geomagnetic storm than LEO/MEO case. In case of GEO while failure cases are few when Dst index is small in the 1997, failure cases are increased when Dst index is relatively large after 2000.

Geomagnetic storm generally affect to spacecraft in a short time, so we need to investigate in detail daily.

V. Conclusions

So far we investigate the relationship between solar activities and geomagnetic storm which may affect to satellites and spacecraft failure numbers.

In the result we can find the GEO case is seem to be more vulnerable to space environment than LEO/MEO. This means geomagnetic field may be shielding effect.

It is definite that space environment such as solar activities and geomagnetic storm but the relationship is needed to study more microscopically. So, it may be more effective that two events are compared daily or monthly.

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