Available online at www.sciencedirect.com
SCIENCE DIRECT®
Advances in Space Research 37 (2006) 184–190
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

# Spacecraft operational anomalies and space weather impact hazards

N. Iucci [a], L.I. Dorman [b,c,*], A.E. Levitin [c], A.V. Belov [c], E.A. Eroshenko [c], N.G. Ptitsyna [d], G. Villoresi [a], G.V. Chizhenkov [c], L.I. Gromova [c], M. Parisi [a], M.I. Tyasto [d], V.G. Yanke [c]

[a] *Dipartimento di Fisica "E. Amaldi", Roma-Tre University, Rome, Italy*
[b] *Israel Cosmic Ray and Space Weather Center and Emilio Segre' Observatory, Affiliated to Tel Aviv University, Technion and Israel Space Agency, PO Box 2217, Qazrin 12900, Israel*
[c] *IZMIRAN, Russian Academy of Science, Troitsk, Russia*
[d] *SPb FIZMIRAN, Russian Academy of Science, St. Petersburg, Russia*

Received 31 October 2004; received in revised form 17 February 2005; accepted 8 March 2005

**Abstract**

Satellite anomaly data in the period 1971–1994 were analyzed in the search of possible influence of different space environmental parameters. The database was created by combining, beyond the malfunction information, various characteristics of space weather: geomagnetic activity indexes, fluxes and fluencies of electrons and protons at different energy, solar wind characteristics and other solar, interplanetary and geophysical data. Satellites were divided into several groups according to the orbital characteristics (altitude and inclination). It was found, that the relation of satellite malfunctions to the environmental parameters is different for various orbits. In particular, very intense fluxes (>1000 pfu at energy >10 MeV) of solar protons are linked to anomalies registered by satellites in high-altitude (>15,000 km) near-polar (inclination >55°) (the rate of anomalies increases by a factor ∼20), and to a much smaller extent to anomalies in geostationary orbits (they increase by a factor ∼4). The efficiency in producing anomalies is found to be negligible for proton fluencies <100 pfu at energies >10 MeV. Elevated fluxes of energetic (>2 MeV) electrons >$10^8$ (cm$^2$ day sr)$^{-1}$ are observed by GOES on days with satellite anomalies occurring at geostationary and low-altitude (<1500 km) near-polar (>55°) orbits. These elevated fluxes are not observed on days of anomalies registered in high-altitude near-polar orbits. Connections between anomaly occurrence and geomagnetic perturbations are also discussed.


*Keywords:* Space weather; Satellite anomalies; Energetic particles; Magnetic storms

## 1. Introduction

A body of evidence has been accumulated over the last few decades on the existence of anomalies in spacecraft operation caused by adverse space environment conditions (Feynman and Gabriel, 2000). Anomalies have been associated with intense fluxes of energetic particles inside the Earth's magnetosphere (Farthing et al., 1982), as well as with energetic events connected to geomagnetic storms or aurorally sub-storms (Allen and Wilkinson, 1993; Wrenn and Sims, 1993; Wrenn et al., 2002).

Analysis of available information has allowed the identification of space weather conditions and mechanisms producing adverse effects on satellite operation (see Feynman and Gabriel, 2000; and references therein). There is a rich set of possible interactions between the space environment and spacecraft, which may cause problems in spacecraft performance. Moreover, different adverse space conditions affecting spacecraft operation can be found in different magnetospheric regions

* Corresponding author. Tel.: +972 4 6964932; fax: +972 4 6964952.
*E-mail address:* lid@physics.technion.ac.il (L.I. Dorman).

0273-1177/$30 
doi:10.1016/j.asr.2005.03.028

(Vampola, 1994). As a consequence, the interactions in low Earth orbit (LEO) spacecraft are expected to be different from those occurring for high orbits, as in the geostationary satellites (GEO) (Hastings, 1995).

Statistical studies that are conducted on the basis of individual or an assortment of satellites, mostly in geostationary orbits (see e.g. Farthing et al., 1982; Wilkinson, 1994; Vampola, 1994), have shown that the number of some types of specific anomalies increased in periods of intense geomagnetic activity. Moreover, the portion of the satellite trajectories where faulty operations occurred is located in magnetospheric areas in which the most prominent electromagnetic disturbances and particle fluxes are observed. The distributions of anomaly occurrence time for different GEO spacecraft show that most anomalies are clustered in the midnight to morning sector (in Local Time). This is associated with the main peculiarity of the structure of magnetospheric fields and currents, and with related increases of electromagnetic disturbances and particle fluxes between midnight and the early morning hours. Local-time dependent anomalies, (mostly observed at GEO), were

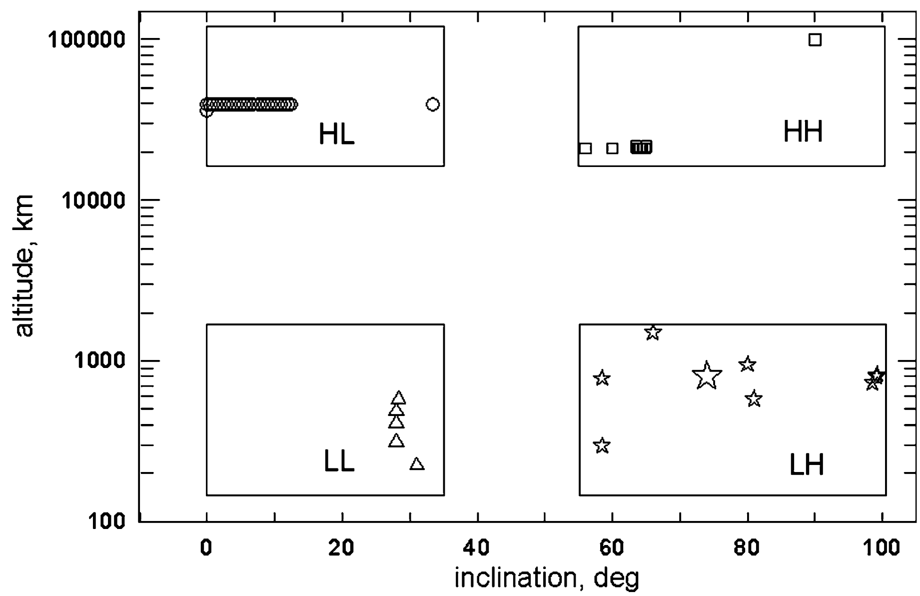


Fig. 1. The distribution of satellites used in this analysis, arranged by the altitude and inclination of their orbits (*circles*: HL, high altitude with low inclination; *squares*: HH, high altitude with high inclination; *triangles*: LL, low altitude with low inclination; *stars*: LH, low altitude with high inclination (Kosmos satellites are marked by the *bigger star*)).

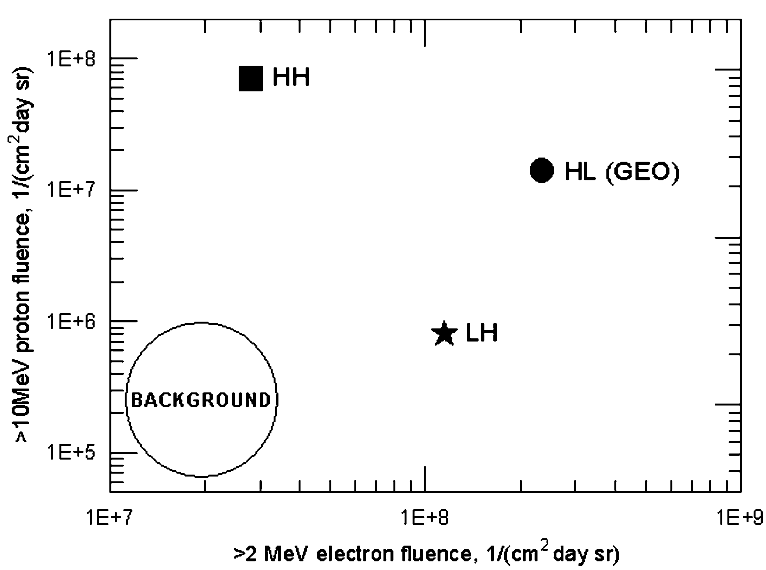


Fig. 2. Average proton and electron fluences (measured by GOES) in the anomaly day for different spacecraft orbits, over the period 1987–1994. A rough estimate of the proton and electron background fluence is also plotted.