SEE Bulletin
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NASA's Space Environments and Effects Program
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Leonids 1998: *Will the Lion Show Its Fangs?*

Nights to Remember

On the night of November 12, 1833, the residents of the United States were thrown into a state of panic by a spectacular celestial fireworks display. To those out in the night, it appeared that almost every star in the sky was falling from heaven; even those asleep indoors were awakened by the brilliant flashes of meteors and peered fearfully out of their windows, sure that the world was coming to the end. However, there were cooler heads, some belonging to the Pawnee, who watched the meteors without fear, for they remembered the story of the man Pahokatawa. After being killed by enemies and left as animal fodder, he was revived by the gods and came among the Pawnee, exhorting them not to fear falling stars, for they were not a sign of the world's end. There was also some rationality along the Eastern seaboard, as can be seen in the writings of Agnes Clerke and others.

The Leonids would storm again in 1866 and 1867, but with a diminished intensity compared to the major displays of 1799 and in 1833. The 1866 apparition is especially notable, for it was then that a greater understanding of the nature of meteor showers was attained with the realization by the Italian astronomer Schiaparelli (famous for his drawings of the Martian canals) that the Perseid meteors were caused by particles ejected from Comet Swift-Tuttle. The source of the Leonid meteors was soon determined to be the newly discovered Comet Tempel-Tuttle, which completes one orbit about the Sun every 33 years. This being established, astronomers looked forward eagerly to 1899, when the Leonids were expected to roar once again.

However, mid-November of 1899 did not manifest a meteor storm, there being only a modestly enhanced shower (normally the Leonids have a rate of about 10-15 meteors per hour; in 1899 there were about 40 per hour). The same thing happened in 1932, when the Leonids barely managed about 200 meteor per hour. Astronomers forgot about the Leonids, thinking that the great meteor storms of the 18th and 19th centuries would not be seen again. 1965 proved them wrong, for the Leonids once again reached storm levels, achieving a rate of some 5000 per hour. The following year, 1966, was when the Lion really showed its teeth, for 150,000 meteors per hour were seen in the greatest Leonid display of all time.

1998-2000

Past Leonid meteor storms have been no cause for concern, for the meteors are so small that they never make it anywhere near the ground, vaporizing at altitudes greater than 90 km. However, nowadays we have hundreds of active satellites in Earth orbit and in near-Earth space, none of which have the protection of the atmosphere. Can these satellites be damaged by a storm of Leonid meteors, which, due to the orbit of the parent comet relative to that of Earth's, sweep by us at a

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Space Environments and Effects (SEE) Flight Experiment Workshop (FLEW)

The Space Environments and Effects (SEE)-sponsored Flight Experiments Workshop (FLEW) was held June 23-25, 1998, in Huntsville, Alabama, with over eighty participants attending the two and one-half day meeting. The objective of the workshop was to provide a forum for the exchange of information regarding the effects of the space environment on exposed spacecraft surfaces and on flight experiments designed to measure the space environment and its effects. Twenty-two presentations were given throughout the proceedings. Results from flight experiments and planned future experiments were discussed, and the implications of these observations on future missions were addressed. In addition, efforts regarding planned future experiments were also presented. The workshop focused on problems which need to be resolved in order for future spacecraft to survive space environments in light of changing technologies, priorities, and budgetary constraints. The space environment disciplines of materials, contamination, meteoroid and orbital debris, and spacecraft charging were emphasized at the meeting, and working sessions were established in each of these disciplines, chaired by SEE Technical Working Group Chairpersons, to determine the needs of the SEE community regarding future space missions and related efforts as input into SEE Roadmaps.

Orbiting Technology Testbed Initiative (OTTI)

by Stu Clifton

On June 30th and July 1st, NASA's Space Environments and Effects (SEE) Program hosted the Orbiting Technology Testbed Initiative (OTTI) Workshop in Washington, D.C. The purpose of the workshop was to present preliminary results of a trade study designed to determine the feasibility of launching one or more testbeds into high radiation orbits and to assess the interest by NASA enterprises, other government agencies, and industry partners in such an endeavor. The objective of the proposed technology testbed is to provide for flight demonstrations of emerging and advanced technologies in the harsh space environment such as that encountered in a mid-earth orbit (MEO) and/or geosynchronous transfer orbit (GTO). The initiative comprises a number of trade studies examining different aspects of the effort, while NASA's SEE Program has been leading the overall integrated trade study.

Dr. George Withbroe (NASA Headquarters Code S) led off the agenda showing the relationship of the OTTI program and a Code S augmentation of a seamless transition from science to technology. Other speakers from NASA included Drs. Dana Brewer (NASA Headquarters Code SM) and Michael Greenfield (NASA Headquarters, Code Q). Dr. Dwight Dustin, Manager of the Advanced Technology Program at the Ballistic Missile Defense Organization (BMDO) and Dr. David Hardy of the Space Vehicles Directorate at the Air Force Laboratory (AFRL) representing DoD concerns, presented the need for a high radiation testbed from their organization's perspectives and discussed potential ideas of co-sponsorship of OTTI with NASA. SEE Program representatives presented the overall NASA approach and preliminary results of the OTTI trade study.

A number of presentations given by NASA's industry partners indicated the strong interest from the commercial communications industry in OTTI. If not for the harsh space environment, caused primarily by the dynamic radiation belts, a MEO orbit would be an ideal location for future commercial communication satellites. This orbit offers greater coverage with fewer satellites than low-earth orbit (LEO) and requires less power transmission than a geosynchronous-earth orbit (GEO). There was also great interest expressed by government and industry technologists in the potential flight opportunity to flight qualify advanced devices and subsystems. One of the strong messages that came from workshop participants, however, was the need for NASA to remain focused on the overall initiative of taking flight data and correlating it with ground testing and improving existing SEE models.

At the direction of NASA Headquarters, the OTTI is now making a transition from the trade study phase to a pre-project phase leading to near-term development of a (1) OTTI Strategic Plan, (2) Preliminary OTTI Program Implementation Plan, and (3) Organizational Roles and Responsibilities. Pertinent information regarding OTTI may be found at the SEE Internet Web site at http://see.msfc.nasa.gov.

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blazing 72 kilometers per second? This question is not easy to answer, for it involves several factors, some of which are the probabilities of Leonid storms in the next few years, the expected intensity of the storm(s), and the vulnerability of a given satellite to the effects of a meteor impact. The latter can only be answered by the various satellite operators and designers, so the following paragraphs shall attempt to address the other two factors mentioned.

The storm probabilities for the next few years can be obtained via one of two methods - an analysis of past Leonid activity or by the generation of computer models of the stream of meteoroids, taking into account planetary perturbations, radiation pressure, and the characteristics of the meteoroids ejected from the comet. It should be noted that both methods suffer from incomplete data, almost to the point of absurdity. However, both techniques are consistent in that they give high probabilities (>50%) of Leonid storms in 1998 and 1999, with a lesser chance in 2000. The computer models also indicate a significant chance of a storm in 2001. The intensity of the meteor storm is also difficult to estimate, though based on the closeness of the comet orbit to that of Earth, we can estimate that the Leonids will show a rate somewhere between 500 and 10,000 meteors per hour, with the best guess being about 5000 per hour. This is, of course, for visual observers on the ground. Satellite operators are more interested in the fluence of Leonid meteoroids, which varies as a function of mass. At 10^{-7} grams, expect to see a fluence of about .0042 Leonids m^{-2} . Because of solar radiation pressure, we expect to see no Leonids with masses less than 10^{-8} grams.

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Electrical Bonding, a Survey of Requirements, Methods, and Specifications (NASA/CR-1998-207400)

by Ross Evans, Computer Sciences Corporation/MSFC

The NASA Space Environments & Effect (SEE) Program funded a task to develop a database of electrical bonding specifications and processes, to review each document for requirements and methods, and to determine its applicability to the basic requirements.

Electrical bonding specifications and some of the processes used in the United States were reviewed. The results were documented in NASA/CR-1998-207400 to provide information helpful to engineers imposing electrical bonding requirements, reviewing waiver requests, or modifying specifications on various space programs.

There are several reasons for requiring good electrical conductivity between equipment and structure and between various parts of structure. Improved electrical bonding with reduced effort can result from understanding the different types of bonding requirements and the reasons for each.

Mil-B-5087D has been the electrical bonding specification used by the military for many years. It has recently been replaced by MIL-STD-464, but the reasons for the various types of electrical bonding requirements remain the same. In addition to resistance limits, bonding requirements may vary with frequency or current carrying capability depending on the reason for the bond. Some examples of bonding for various purposes are given below along with short descriptions of the real requirements.

Bonding for fault protection is required to protect personnel from electrical shock and prevent hot spots at joints. The usual resistance limit is 0.1 ohms. However the fault current return path must have low enough resistance to allow enough current to blow

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Satellites near the Earth-Sun L_1 point should see about an order of magnitude greater fluence, due to the closer proximity of this location to the comet orbit. The probability of impact is about 4% for the smallest mass, a small, but not ignorable, number. The risk at the L_1 point is much greater, about 34%. Fortunately, the peak times of the Leonid showers are known with a fair degree of precision (uncertainty of about 15 minutes). The peak of the 1998 shower or storm is expected at about 19:45 UT on November 17, that for the 1999 event should occur at 1:50 UT on November 18, and that for the 2000 Leonids should be on November 17 at 8:05 UT. One should expect the duration of the storms (when they occur) to be about 7 hours or so, centered on the peak.

Conclusion

One of the greatest frustrations of satellite operators is the estimation of the impact of probable future events on their vehicle, be it an X class solar flare or the increase in atmospheric density at the peak of the solar cycle. The Leonid storms are yet another such set of events, save that in this case the uncertainties lie not in the event timing, but in the magnitude of the occurrence. It is probably safe to say that the probable error bars on the fluence numbers presented in this article span at least an order of magnitude – almost rendering the estimates meaningless. However, it has been made manifestly clear that the satellite community needs some idea of what to expect in mid-November of the next four years, and that is what the Space Environments and Effects Program has attempted to provide. The results of the latest observations and the interpretations of Leonid computer models have been incorporated into a computer program, the Leonid Fluence Calculator (available on the SEE web site at http://see.msfc.nasa.gov). The program computes the fluences on various spacecraft surfaces and the amount of time the Earth shields the spacecraft from the meteor stream, given the satellite orbital elements at the time of the Leonid peak. Being based on FORTRAN and JAVA, the calculator is available for various platforms including Windows 95/NT, OS/2, and Sun Solaris.

Operators are advised to start planning for the 1998 storm and should consider re-orienting their spacecraft to expose the minimum area if at all possible. Power should not be a problem, for the sun will be at an angle of ~88∞ with respect to the Leonid radiant (a = 153∞, d = +22∞). Therefore, a shift of only about 2∞ will enable the spacecraft to receive essentially full power and present the solar arrays edge-on to the meteor stream. Also, do not assume that there will be no storm in 1999 if nothing significant materializes in 1998.

On a final note, the numbers indicate that while the odds of any single spacecraft being struck are small, the odds of an impact on an active satellite out of the several hundred currently in space are not negligible, approaching unity. If these numbers are to be believed, it then boils down to whose satellite will be hit, which then begs the question of whether or not it will be a benign, disabling, or fatal event. Will the Lion strike with its fangs? The answer may be known just a few hours after 2:45 PM EST on November 17, 1998.

by Dr. William Cooke
Computer Sciences Corporation/MSFC

Coming in Fall 1998 Issue...

- ***Possible New NRA Initiative***
- ***Trapped Radiation Models - Uncertainties for Spacecraft Design***

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Electrical Bonding

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a fuse or breaker in a reasonable amount of time. Typical designs use resistive paths capable of carrying five times the maximum current being used, and individual joint resistance should be limited accordingly.

Radio frequency bonds must be low impedance at the frequencies of interest. The impedance usually depends upon the inductance of the configuration rather than the resistance across any joints in the path. Specifications typically require resistance across each joint to be less than 2.5 milliohms, but the joint should also be designed to reduce inductance to a minimum. The impedance of the path may be several ohms even in a well-bonded system. Verification of the impedance limit by test on an assembled spacecraft is very difficult and is usually not required.

Electrostatic charge can be dissipated with a fairly high resistance. One Megohm is usually adequate even though one ohm is typically specified. Items subject to charging should be bonded to structure unless it can be shown that they are small enough so that the energy levels of a static discharge would not be a threat.

The document, NASA/CR-1998-207400, discusses the specifications, the types of bonds, the intent of each, and the basic requirement where possible. Additional topics discussed are resistance versus impedance, bond straps, corrosion, finishes, and special applications.

Recent Website Addition:

- **Space Environment Information System (SPENVIS)**
  http://see.msfc.nasa.gov/see/general_spenvis.htm

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