OVERCOMING SOLAR ARRAY ANOMALIES WITH THE STRETCHED LENS ARRAY (SLA)

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ABSTRACT

Solar array anomalies are a serious issue affecting the satellite industry and are responsible for increased insurance premiums and a negative perception. The major recommendation of *Prospector XII - Space Solar Array Cost Reduction Workshop* was to increase solar array reliability. This paper will focus on orbital array anomalies and approaches to design against associated failures. The SLA can overcome solar array anomalies and improve the reliability and cost affordability of solar arrays.

1. BACKGROUND

Reliable power delivery over mission life is critical to all satellites; therefore solar arrays are one of the most vital links to satellite mission success. However, in the last ten years, the Ascend Division of Airclaims has documented 117 satellite solar array anomalies with 12 resulting in total satellite failure. These failures make solar array reliability a serious issue. Solar array anomalies account for the majority of satellite power system anomalies. Also, solar array claims are much more costly than any other power system claims, causing almost half of insurance claim payouts as shown in figure 1. Geo-synchronous Earth Orbit (GEO) shows the greatest failure rate, believed due to the solar storms and biannual shadowing.

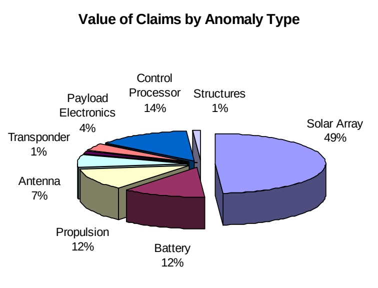

Fig. 1 Solar array claims

2. ORBITAL ARRAY ANOMALIES

2.1 Types of Failures

Most satellite incidents occurring in space today are tracked by Ascend's SpaceTrak database which is the space industry's leading events-based launch and satellite database. This database separates anomalies into four types to address the impact of the anomaly on the satellite. A type 1 anomaly indicates a complete failure for either deployment or operation of the satellite. A type II operating anomaly is non-repairable and affects the operation on a permanent basis. Type III anomalies are non-repairable failures that cause lack of redundancy to the operation on a permanent basis. Type IV anomalies are temporary or repairable and do not have a significant permanent impact on operation. The actual cause of failure can be inexact leading to the need for more instrumentation that should be added to satellites to help determine the root causes of these anomalies.

2.2 Solar Array Issues

Solar arrays are exposed to the harshest environment of virtually any satellite component. In the last ten years, sixty percent of the 117 solar array anomalies are type II anomalies. Thus they are non-repairable and affect the satellite operation on a permanent basis.

Solar array anomalies show the classic infant mortality trend as depicted in Fig. 2. Infant mortality generally indicates that the design is poor and/or there are defects in construction. This observation raises fundamental questions about solar array designs, construction, and testing prior to launch. It has also been determined from the SpaceTrak database that no single manufacturer is having all the problems. These failures are a worldwide phenomenon; therefore, defects in construction are an unlikely cause. Unfortunately, new solar array designs are usually not considered due to the

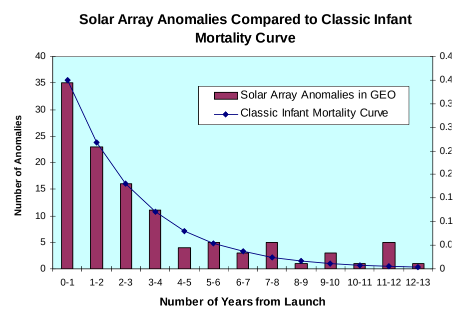

Fig. 2 Solar array failure trend showing a classic infant mortality profile

conservative belief that flight heritage is the best proof of performance and that requiring more pre-launch testing will fix the problems. However, more pre-launch testing can lead to over testing resulting in additional failures. Thus the opportunity arises to consider a new solar array that may mitigate these failures.

2.3 Stretched Lens Array

The Stretched Lens Array (SLA) developed by ENTECH Inc. is a refractive concentrator array with an array efficiency greater than 27%. Because of the concentrator design, the small area cells designed for 8x concentration can be shielded against radiation damage at about 1/8th the mass of a conventional planar array.

From 1998-2001, NASA flew the Deep Space 1 mission that validated the use of solar-powered ion propulsion for extended space missions. This highly successful mission also used the novel SCARLET solar array that has now evolved into the SLA. The SCARLET array performed flawlessly and within 2% of its projected performance over the entire mission.

That design has evolved into the Stretched Lens Array. The SLA has demonstrated its durability to the space environment through its proven flight history, stringent ground testing, and computation modeling and analysis. The SLA is reliable, scalable, cost-effective, durable, and efficient. It is an optimal candidate for SEP missions to GEO, the moon, Mars, and beyond. Figure 3 shows a model of this design under illumination.

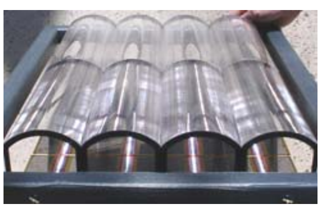

Fig. 3 SLASR model in sunlight

SLA offers unprecedented performance (>80 kW/m^3 stowed power, >300 W/m^2 areal power, and >300 W/kg specific power), high voltage operation (300-600 V), and cost-effectiveness (>50% savings in $/W compared to planar arrays). SLA achieves these outstanding attributes due to its 8X optical concentration by employing flexible Fresnel lenses. This minimizes solar cell area, mass, and cost and allows for super-insulation and super-shielding of the solar cells to enable high-voltage operation and radiation hardness in the space environment without detrimental mass penalties.

2.4 Environmental Testing

Extensive environmental testing of the SLA has been conducted over the past 15 years. The stretched lens has been tested under UV/VUV and electron and proton radiation simulating the radiation found in GEO. With an additional thin protective coating, the lens is resistant to the UV/VUV radiation. The lens and cell structure have been subjected to hypervelocity impact testing at velocities up to 12 km/sec with particles of 100 µm diameter. No arcing was seen in these tests even though the module was held at >1000V and it was in a plasma environment. Furthermore, corona testing of this cell structure in vacuum has been proceeding for more than 200 days at 2250V bias without failure. This is due in large measure to the unique structure of the cell assembly shown in figure 4.

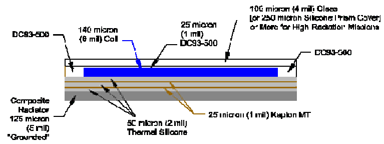

Figure 4 Cross section of SLA cell assembly

2.5 Radiation Resistance

Radiation shielding can be increased with little impact on array mass, hence providing a "super shielded" system for operation in high radiation environments such as the heart of the Van Allen belts or in those found around Jupiter. To understand and compare the various radiation environments for these orbits, simulations have been run using The European Space Environment Information System (SPENVIS) to obtain the 1 MeV equivalent electron radiation doses for given orbits and durations. Performance losses are calculated as a function of protective layer thickness. We have chosen a high radiation orbit of 6000 km with a 28 degree inclination angle to compare the SLA to a planar array. The results of this comparison are shown in figure 5. SLA advantage over planar by displaying the areal power density loss for the heaviest SLA analyzed versus the lightest one-sun array analyzed. It is important to note that the heaviest SLA is 14% lighter than the lightest one-sun array, thus the remaining power advantage of SLA is spectacular. SLA's advantage over planar will grow larger for higher radiation missions.

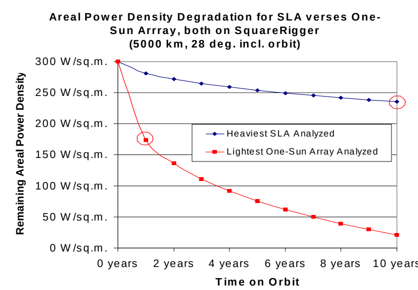

Fig. 5 Areal power density comparison

3. SUMMARY

The Stretched Lens Array shows remarkable advantages over a conventional planar array that suggest it will survive GEO orbit without failure. It is light weight, less expensive and can be "super-shielded" for high voltage operation. Extensive ground and flight testing has proven the SLA's durability to the space environment. The SLA can overcome solar array anomalies and improve the reliability and cost affordability of solar arrays.