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SPACE SOLAR ARRAY RELIABILITY: A STUDY AND RECOMMENDATIONS

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ABSTRACT

Providing reliable power over the anticipated mission life is critical to all satellites; therefore solar arrays are one of the most vital links to satellite mission success. Furthermore, solar arrays are exposed to the harshest environment of virtually any satellite component. In the past ten years 117 satellite solar array anomalies have been recorded with 12 resulting in total satellite failure. Through an in-depth analysis of satellite anomalies listed in the Airclaim's Ascend SpaceTrak database, it is clear that solar array reliability is a serious, industry-wide issue. Solar array reliability directly affects the cost of future satellites through increased insurance premiums and a lack of confidence by investors. Recommendations for improving reliability through careful ground testing, standardization of testing procedures such as the emerging AIAA standards, and data sharing across the industry will be discussed. The benefits of creating a certified module and array testing facility that would certify in-space reliability will also be briefly examined. Solar array reliability is an issue that must be addressed to both reduce costs and ensure continued viability of the commercial and government assets on orbit.

INTRODUCTION

Providing reliable power over the anticipated mission life is critical to all satellites; therefore solar arrays are one of the most vital links to satellite mission success. Furthermore, solar arrays are exposed to the harshest environment of virtually any satellite component. Over the last ten years Airclaim's Ascend SpaceTrak database has documented 117 satellite solar array anomalies, 12 of which resulted in total satellite failure. Through an in-depth analysis of satellite anomalies it is clear that solar array reliability is a serious, industry-wide issue. To make matters worse, solar array claims are more costly than any other power system element. They result in almost half the value of all insurance claims. Although these anomalies have decreased in the last few years, the consequences of previous failures still affect the industry through high insurance rates. For the future of the satellite industry, it is imperative to increase solar array reliability. Factors affecting satellite reliability including the type of anomaly, what manufacturers were involved, the average time after launch that an anomaly occurred, and how many of these anomalies proved fatal will be presented and discussed. Recommendations for improving reliability through careful ground testing, standardization of testing procedures such as the emerging AIAA standards, and data sharing across the industry will be discussed. The benefits of creating a certified module and array testing facility that would certify in-space reliability will also be briefly examined. Solar array reliability is an issue that must be addressed to both reduce costs and ensure continued viability of the commercial and government assets on orbit.

SOLAR ARRAY ANOMALIES

Overview of Solar Array Anomalies

It is well known that anomalies and failures of satellites are occurring, but the reality is that few people know the exact cause and conditions surrounding these failures. Most satellite incidents occurring in space today are tracked by Ascend's database which is the space industry's leading events-based launch and satellite database.[1] This database separates anomalies into four types to address the impact of the anomaly on the satellite and further separates anomalies into the general subsystem of the satellite where the anomaly occurred. This paper focuses on solar array anomalies which are a sub-set of all power anomalies. Figure 1 depicts the solar array anomalies that have occurred in the past ten years. The anomalies are

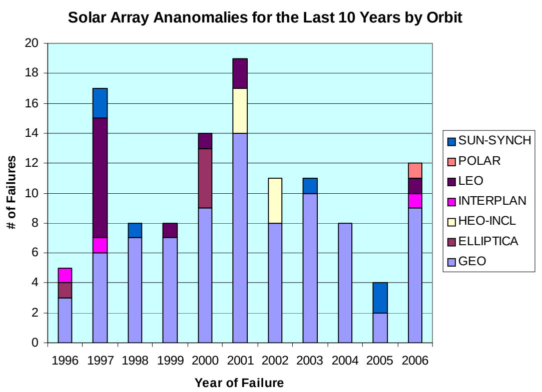

Fig. 1: Solar array anomalies by orbit

separated by year and orbit showing that the number of satellite failures in GEO is significantly greater than any other orbit. This is believed to be attributed to electrostatic discharge caused when an array comes out of an eclipse. By analyzing the known anomalies it is possible to pinpoint key issues where attention needs to be placed to find solutions.

Insurance Issues Associated with Anomalies

Solar array anomalies made up 33% of all insurance claims in the last ten years as seen

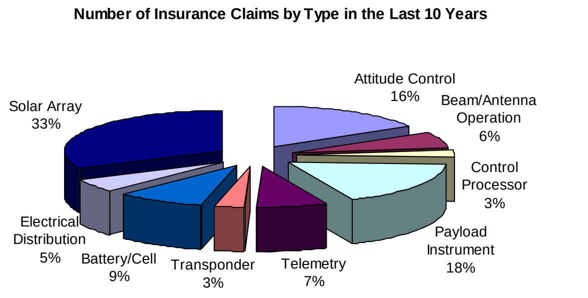

Fig. 2: Insurance claims from anomalies

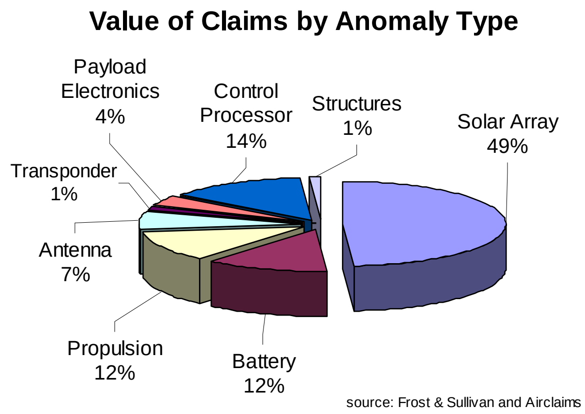

Fig. 3: Value of insurance claims for 2004

in Fig. 2. However, solar arrays made up 49% of the value of all insurance claims in Fig. 3.[2] Premiums are directly related to industry claims and past performance. One insurer reports that recent on orbit failures have exhausted the premium pool that had been established for such losses ($800M).[3] The consequences of previous failures affect the industry though high insurance rates (~50% of the satellite cost) and the requirement by the insurance industry to design additional margin into power budgets before even issuing a policy is considered. This ultimately increases the cost of the solar array which now must be designed to provide additional power due to reduced performance reliability, whether it is justified or not. Past insurance claims also decrease the confidence of new investors.

Permanent Impact of Anomaly

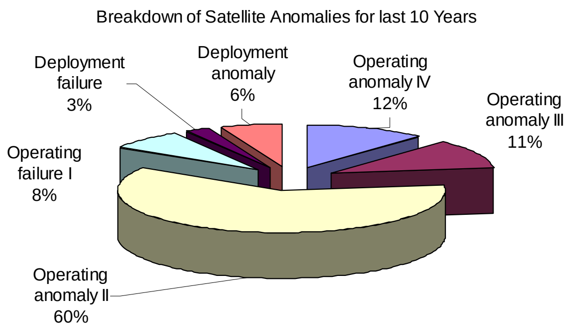

Fig. 4 : Satellite Anomaly Breakdown

To address the impact of solar array anomalies, it is important to understand the significance of an anomaly. Figure 4 shows a graph of solar array anomalies for the last ten years separated into anomaly type. 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 failure cause can be inexact but it is of great importance to note that 60% of all solar array anomalies are type II which results in a permanent impact on the operation.

Time between Launch and Anomaly

The time between satellite launch and the occurrence of a solar array anomaly coincides with the classic infant mortality trend as depicted in Fig. 5. Infant mortality generally indicates that the design is poor and/or there are defects in construction. This

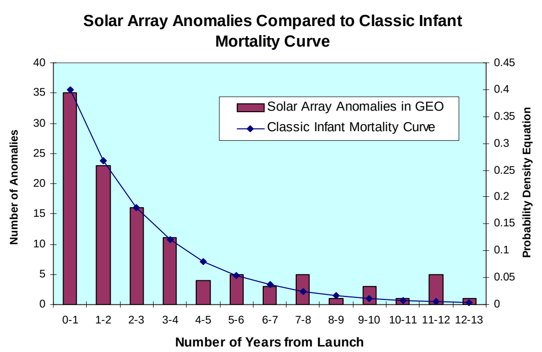

Fig. 5 : Infant mortality curve relation to solar array anomalies

observation raises fundamental questions about solar array designs, construction, and testing prior to launch. It has also been determined from the SpaceTrak data base that no single manufacturer is having all the problems as shown in Fig. 6. All satellite manufactures have had anomalies and failures. Figure 6 shows the top ten manufactures by the number of insurance claims issued. This list does not compare market share to the number of failures, so actual names have been left off so assumptions are not made on the reliability of certain manufacturers. The most important detail of this figure is that six different countries are represented in the top ten manufactures in relation to number of anomalies. Failures are a worldwide

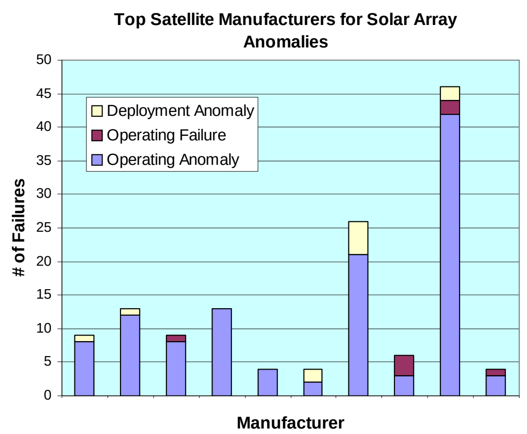

Fig. 6 : Top Satellite Manufactures for anomalies

phenomenon; therefore, defects in construction are an unlikely cause of the relation to infant mortality. Unfortunately, new solar array designs are usually not considered for flight due to the conservative belief that flight heritage is the best proof of performance and that requiring more pre-launch testing will resolve the problems. Most stringent testing will not correct an inherent design flaw.

SOLAR ARRAY RELIABILITY RECOMMENDATIONS

Data Sharing Across Industry

A common database on orbital failures can become an integral part of overcoming such failures. More feedback is essential to face the challenge of solar array failures on orbit, Currently there is lack of communication about the types and numbers of failures occurring in the satellite industry. Open disclosure of anomalies and industry group strategizing in overcoming them is essential. This communication can occur without disclosing proprietary information.

Embracing New Technology

Better designs that will improve solar arrays and eliminate current failures need to be tested and flown. New technology is usually not embraced due to the increased fear of failure. Satellite owners and manufactures would rather “stick with what they know” than to take any additional risks. This limits the opportunities to make major increases in solar array reliability. Newer designs are often engineered and built to withstand known anomalies, yet “heritage” is deemed more worthy. However, in retrospect, oftentimes sufficient changes have been made in the design to eliminate its heritage status.

Standardization of testing procedures

Solar array reliability can also be improved through careful ground testing. The emerging AIAA standards address the issue of standardization of testing procedures. These three standards documents are AIAA S-111-2005 “Qualification and Quality Requirements for Space Solar Cells”, AIAA S-112-2005 “Qualification and Quality Requirements for Space Solar Arrays”, and AIAA S-121-2005 “Electric Power Systems for Unmanned Spacecraft”. There are mixed feelings in the industry about incorporating these standards due to anticipated cost increases. However, if they serve to ameliorate failures, it will lead to a much more substantial cost saving. Also, because solar array failures on orbit is an international issue, extensive discussion and meetings are being held world wide to seek agreement on an international set of standards. Thus the attention of the world’s satellite producers is being focused on real, legitimate, costly issues whose solution will benefit all satellite suppliers.

Certified Testing Facility

Another recommendation that has the potential to increase solar array reliability is the creation of an international committee on satellite failures through an underwriters’ agency. This could take the form of a certified module and array testing facility (somewhat akin to the Underwriters’ Laboratory for terrestrial electrical appliances) that would be able to certify in-space reliability. Uniformity across the industry would help to validate appropriate testing methods. An underwriters laboratory would be the center for design validation and would be available to all satellite manufacturers. A working relationship between this entity and the satellite insurance underwriting industry is vital to help lower rates according to testing practices and certification results.

CONCLUSION

The reliability of solar arrays has a huge effect on the satellite industry though increased insurance premiums and lack of confidence by investors. The known anomalies have been analyzed to determine the most hazardous orbit, the period of time before an anomaly occurs, the manufacturers of the flawed satellites, the impact the anomaly had on the life and power of the satellite, and the value of associated insurance claims. This data has been presented and can be used by the industry to focus attention on the most serious areas effecting solar array anomalies on orbit. Recommendations to increase the reliability of solar arrays are to have a network available for disseminating data between manufacturers and working together to determine solutions to common problem areas, standardization of testing procedures to make sure all arrays are tested the same and can withstand the known variables of the space environment, and embracing new technology that is inherently designed to be durable and reliable. The creation of an international committee on satellite failures through an underwriters’ agency is also a suggestion that would help validate appropriate testing methods and create testing uniformity across the industry. Solar array reliability is an issue that must be addressed to both reduce costs and ensure continued viability of the commercial and government assets on orbit. The ideas presented in this paper are just a start but work must begin immediately to help bring confidence back to the industry and continue the success of the space satellite industry.

REFERENCES

[1]Airclaims Ascend SpaceTrak Database www.ascendspacetrak.com/Home
[2]P.Lecointe, “Satellites failures in orbit Focus on power systems,” Hiscox Syndicates Ltd. @ Lloyd’s, *Space Power Workshop,* 2005.
[3]Prospector XII: Space Solar Array Cost Reduction Workshop, 2006.