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Advances in Radiation-Tolerant Solar Arrays for SEP Missions

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Abstract

As the power levels of commercial communications satellites reach the 20 kWe and higher, new options begin to emerge for transferring the satellite from LEO to GEO. In the past electric propulsion has been demonstrated successfully for this mission – albeit under unfortunate circumstances when the kick motor failed. The unexpected use of propellant for the electric propulsion (EP) system compromised the life of that vehicle, but did demonstrate the viability of such an approach. Replacing the kick motor on a satellite and replacing that mass by additional propellant for the EP system as well as mass for additional revenue-producing transponders should lead to major benefits for the provider. Of course this approach requires that the loss in solar array power during transit of the Van Allen radiation belts is not excessive and still enables the 15 to 20 year mission life. In addition, SEP missions to Jupiter, with its exceptional radiation belts, would mandate a radiation-resistant solar array to compete with a radioisotope alternative.

Several critical issues emerge as potential barriers to this approach: reducing solar array radiation damage, operating the array at high voltage (>300 V) for extended times for Hall or ion thrusters, designing an array that will be resistant to micrometeoroid impacts and the differing environmental conditions as the vehicle travels from LEO to GEO (or at Jupiter), producing an array that is light weight to preserve payload mass fraction – and to do this at a cost that is lower than today's arrays. This paper will describe progress made to date on achieving an array that meets all these requirements and is also useful for deep space electric propulsion missions.

From 1998-2001, NASA flew the Deep Space 1 mission that validated the use of ion propulsion for extended space missions. This highly successful two-year mission also used a novel Solar Concentrator Array with Refractive Linear Element Technology (SCARLET) solar array that concentrated sunlight eight-fold onto small area solar cells. This array performed flawlessly and within 2%

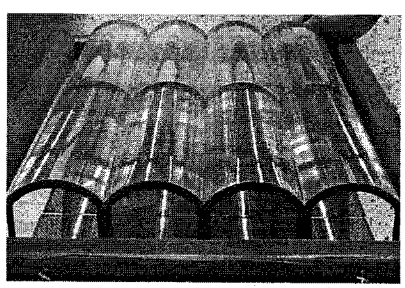

Figure 1: Lightweight SLA module

of its projected performance over the entire mission. That design has evolved into the Stretched Lens Array (SLA) shown in figure 1. The primary difference between SCARLET and the SLA is that no additional glass cover is used over the silicone lens. This has led to significant mass, cost and complexity reductions. The module shown in figure 1 is the latest version of the design. This design leads to a specific power exceeding 300 W/kg at voltages exceeding 300 V. In addition, this module has been tested to voltages over 1000 V while under hypervelocity particle impact in a plasma environment with no arcing. Furthermore array segments are under test for corona breakdown that can become a critical issue for long term, high voltage missions.

Because of the concentrator design, the ~10 cm^2 cells, designed for 8x concentration can be shielded against radiation damage at about $1/8^{th}$ the mass of a conventional planar array. Comparisons of the mass differences in this design compared to planar arrays will be presented for an orbital transfer and Jupiter missions. Because the glass covering the lens has been eliminated, much attention has been devoted to showing that the lens is durable to the space environment. Combined electron and proton testing has been conducted that confirms the durability to those hazards. UV and VUV testing of lens segments coated with resistant materials show no damage over more that 1000 hrs of testing. In addition, space tests on the Materials International Space Station Experiment 1 (MISSE 1) on uncoated lenses and lenses coated with early coating compositions show excellent performance. Samples of the current lenses will be flown on MISSE 6. Additional durability results will be presented in the paper.

One of the key design issues includes the deployment mechanism. Figure 2 shows a 2.5 x 5 m SLA SquareRigger module that would produce approximately 3.75 kWe if fully populated with SLA units. It weighs only 10 kg and has been deployed successfully many times. Designs of 100 kWe arrays for LEO-GEO transfer missions show that after seven round-trip missions, the array will still have a specific power of 250 W/kg compared to only 70 W/kg for a planar array. The SLA uses more protective cover glass to reduce the radiation damage yet incurs only a small mass penalty. The SLA technology can also be deployed with the conventional array designs in use today.

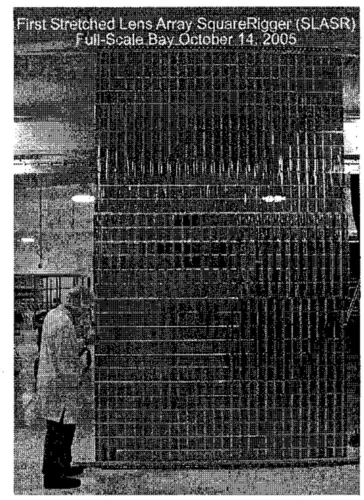

Figure 2: SLA SquareRigger demonstration module

In order to confirm all of these advances through a space demonstration, a small test experiment is being built. It is called the Stretched Lens Array Technology Experiment (SLATE). The experiment is designed to be self-powered so that it can fly as an attached payload on a host spacecraft and only minimal interface with the host is required. This experiment will compare performance of the SLA concentrator technology with that of conventional planar arrays. In the present design, this experiment will test four SLA segments, four commercial large area cells from two manufacturers and four samples of thin film technologies. This experiment will be ready for flight by the end of 2007 and potential host spacecraft are being investigated.

Finally, examples of calculated SEP missions showing the performance of the SLA compared to planar arrays will be presented. The SEP tug mission study supported by NASA will be described in detail as well as a mission to Jupiter's radiation belts.