EMERGING PROPULSION TECHNOLOGIES

Within NASA's In-Space Propulsion Technology Projects Office at the Marshall Space Flight Center, two emerging propulsion technologies are receiving substantial attention. These are plasma sails and a concept called MXER, which combines electrodynamic and momentum exchange tethers.

The pacing problems for plasma sails are not materials limited. Rather they have to do with understanding the physics of generating plasma sails, what are the thrust limitations, and developing methods to validate models.

CRITICAL REQUIREMENTS

Although the technology challenges limiting the use of the MXER concept include non-materials issues, significant advances in materials science are required for this system to mature into a useable technology for propulsion in and beyond low Earth orbit. Necessary materials-related advances are primarily to improve the tether itself, most importantly in its operational lifetime. The critical requirements for tethers include breakthrough increases in tensile strength, electrical conductivity, shock resistance, continued flexibility for up to 10 years in an environment rich in radiation and energetic atomic oxygen, and tolerance to repeated micrometeorite impacts without losing tensile strength or electrical conductivity. Decreases in density and cost per deployed unit of length are likewise required for viability. Other materials issues include increasing the strength-to-weight ratio of materials for the capture mechanisms and the flywheel energy storage system, and the development of distributed sensors to monitor tether health (remaining strength and electrical conductivity) with improved accuracy, survivability (radiation, UV, shock, atomic oxygen), deployability, and mass/volume reduction.

STATE OF THE ART

The state of the art for MXER tethers uses woven, multi-strand polymers such as highly oriented polyethylene (Spectra® fiber 2000) or polybenzoxazole (Zylon® PBO fiber) for strength with strands of aluminum or copper woven inside the polymer casing for electrical conductivity. The conductor is often inside because it must be electrically insulated from the surrounding plasma. It is multi-stranded to provide continued conductivity and in the case of a micrometeorite hit, cross-strapped to carry the full load if one strand is cut.

CRITICAL SCIENCE QUESTIONS

Because tremendous improvements over the present state of the art are required, the critical science questions extend well beyond improving the properties of materials used in existing tether designs. Is there a radically different design that would meet the critical requirements? Can a coating be developed which will provide protection against atomic oxygen and UV and other radiation? Is it possible to develop a polymer or other material with a better conductivity to weight ratio than aluminum? Can the conductor become part of the load-bearing capability without sacrificing conductivity due to mechanical shock or micrometeorite impact?