Electrodynamic Tethers for Transportation and Power Generation

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Electrodynamic tethers can provide propellantless thrust for free-flying spacecraft or the *International Space Station (ISS)*. As was demonstrated on the Tethered Satellite System Reflight (TSS–1R) mission, they can also generate electrical power. Studies are underway at MSFC to examine the utility of electrodynamic tethers for power generation and reboost of the *ISS* and for propulsion of free-flying spacecraft and upper stages.

TSS–1R drew currents on the order of 1 A, which corresponded to a magnetic force on the Shuttle-tether system of around 0.4 N (though as a drag rather than a thrust due to the direction of current flow in the tether).

An electrodynamic tether can work as a thruster because a magnetic field exerts a force on a current-carrying wire. This force is perpendicular to the wire and to the field vector. If the current flows downward through a tether connected to a spacecraft in Earth orbit, the force exerted by the geomagnetic field on the system has a component that accelerates the spacecraft along the direction in which it is already moving (fig. 184).

An orbiting system, by virtue of its motion through the Earth's magnetic field, experiences an electric field (**V**x**B**) perpendicular to its direction of motion and to the geomagnetic field vector. For an eastward-moving system, such as the *ISS*, the field is such that the electrical potential decreases with increasing altitude (at a rate of around 100 V/km for the *ISS* orbit). In order to drive a current down the tether, it is necessary to overcome this induced voltage. Thus, such a system requires a power supply and may be considered a type of electrical thruster. Preliminary calculations indicate an average thrust of 0.5 N from 5 kW and 0.8 N from 10 kW. In each case, the tether is 10-km long with a mass less than 200 kg.

Outfitting *ISS* with an electrodynamic reboost tether severs the most critical and constraining dependency on Earth—propellant resupply. The Station can currently supply its own power but not its own propellant. Add a tether to the *ISS* and it is theoretically possible to eliminate the need for propellant resupply!

In addition to *ISS* application, an electrodynamic tether can be used on a free-flying spacecraft or upper stage to raise orbit or change inclination without the use of propellant. MSFC is defining an electrodynamic tether upper stage flight demonstration that will, for the first time, show a measurable boost and inclination change from such a system. The demonstrator would be launched into a 220-km orbit, boost to 500 km, change inclination by 5 degrees, and then deboost back to reentry.

As was demonstrated on TSS–1R and Plasma Motor Generator (PMG) missions, tethers can be used to generate electrical power. For *ISS* the tether would tap electrical energy from the Station's great reservoir of orbital energy to support either a supplementary system for temporary high-demand periods or emergency power applications. A flexible system could deliver a continual power of 6 kW (leveling batteries required to make up an average of 670 W), day and night, or variable output with orbital average power of 9 kW or more depending on requirements and drag

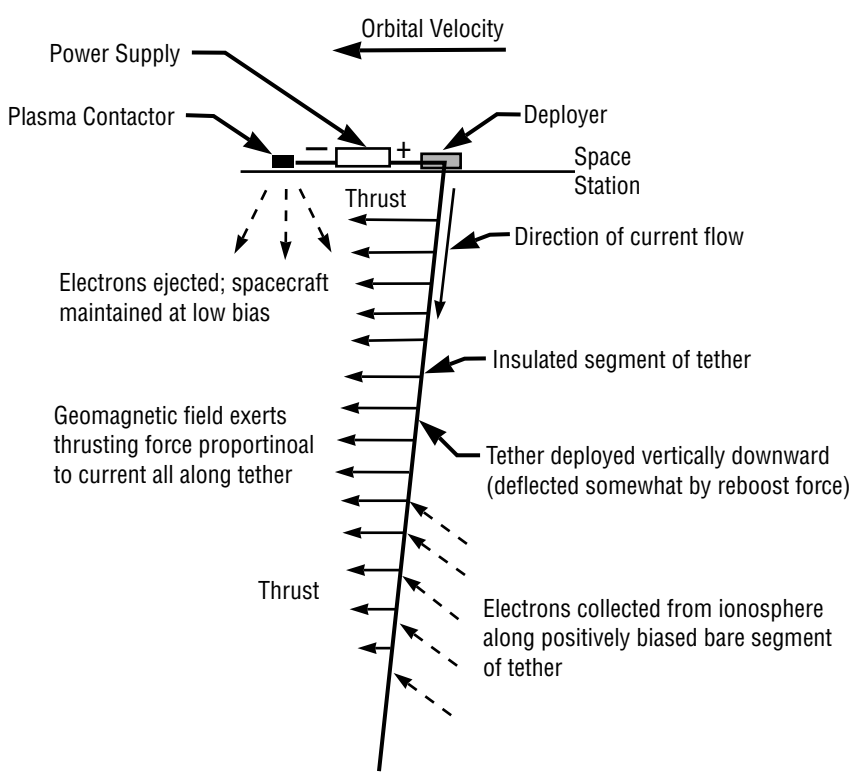

Figure 184.—An electrodynamic tether reboost system for the *International Space Station*.

tolerance. A relatively short and light tether (less than 20 km, 300 kg) is required, thus minimizing the impact on the *ISS*.

Tether power is not a "free lunch," however. The Earth's magnetic field exerts a drag force on the current-carrying tether (1 to 2 N for the 6- to 9-kW systems discussed above), thus increasing the reboost requirements of the ISS.

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