Tethered-Satellite System (TSS): Preliminary Results on the Active Experiment Core Equipment (*).

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Summary. – The first Tethered-Satellite System (TSS-1) Electrodynamic mission has been launched aboard the Space Shuttle STS-46 on July 31, 1992, as a joint mission between the United States and Italy. A 500 kg spherical Satellite (1.6 m diameter) attached to the Orbiter by a thin (0.24 cm), conducting, insulated wire (Tether), has been reeled upwards from the Orbiter payload bay to a distance of 257 m when the Shuttle was at a projected altitude of 300 km. ASI, the Italian Space Agency, had the responsibility for developing the reusable Satellite, while NASA had the responsibility for developing the Deployer system and the Tether, integrating the payload and providing transportation into space. One of the main scientific goals of this first mission was to demonstrate the possibility of energy conversion from mechanical to electrical by using a long Tether orbiting through the Earth’s magnetic field. ASI designed and developed an active experiment, referred to as Core Equipment, in order to carry out this demonstration. The experiment used two Electron Generator Assemblies (EGAs), located on the Orbiter, to re-emit into the ionosphere as an electron beam the electrons collected on the Satellite from the ionosphere. Each EGA had the capability to emit an electron beam with a programmed intensity from 10 mA up to 750 mA with a resolution of 3 mA. The perveance of each EGA was 7.2 microperv, and the beam energy, up to 3 kV, was provided as part of the e.m.f. induced across the TSS due to its motion through the Earth’s magnetic field. Other instruments provided current, voltage, and ambient-pressure measurements, and allowed, via a series of switches, different electrical configurations of the TSS. Moreover, the Core Equipment provided a dynamic package, to study the TSS dynamics, as a first goal, and to verify the possibility of using the TSS Satellite as a platform for future experiments in the microgravity field. The expected voltage across the TSS was estimated to be 5 kV for a full Tether deployment of 20 km. During the mission, and due to unforeseeable

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reasons, the Tether deployment achieved was only of 257 m. Despite this limitation, there is evidence that the experiment was working nominally in the very low-voltage range across the TSS. This result strongly increases the confidence in the possibility of high-voltage operation of the electrodynamic TSS, as the Tether deployment will achieve the 20 km, as expected in the future reflight. The paper describes the experiment, and reports some preliminary results achieved during the first mission.

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1. – Introduction.

The first Tethered-Satellite System (TSS-1) Electrodynamic mission has been launched aboard the Space Shuttle STS-46 on July 31, 1992, as a joint mission between the United States and Italy. Based on a 1984 Memorandum of Understanding between NASA and ASI, the Italian Space Agency had the responsibility for developing the reusable Satellite, while NASA had the responsibility for developing the Deployer system and the Tether, integrating the payload and providing transportation into space. In addition, the US Air Force Phillips Laboratory provided an experiment that supported the TSS-1 mission as well as Air Force research interests. Both NASA and ASI sponsored experiments to accomplish the goals of the TSS-1 mission. An Investigator Working Group, composed of the TSS-1 Principal and Associated Investigators, advised NASA and ASI in the design, development, and operation of the TSS-1. This group was also responsible for the science activities during the flight.

During the TSS-1 mission a 500 kg, spherical conducting Satellite (1.6 m diameter), attached to the Orbiter by a thin (0.24 cm), conducting, insulated wire (Tether), was supposed to be reeled upwards from the Orbiter payload bay to a distance of 20 km when the Shuttle was at a projected altitude of 300 km.

TSS-1 was innovative for space experiments in general and Shuttle experiments in particular. In fact, it was the first flight in which the Shuttle was used as part of the experiment and not only as a launching or observing platform. It was the first mission with an integrated approach to science, with the instrumentation, particular experiments, and operation modes selected to characterize the dynamic and electric properties of the TSS. It was a unique mission in combining the potential for resolving a fundamental problem in physics: the determination of the current-voltage (I-V) characteristics for a body charged to high potential, located in a magnetized plasma in the absence of physical boundaries, with the implementation of a technological capability of a critical importance to space electrical power and propulsion [1].

Moving through the ionosphere, the Satellite-Tether-Orbiter system (i.e., the TSS), intersected the Earth's magnetic field, creating an electromotive force (e.m.f.) between the Satellite and the Orbiter, whose value is given by e.m.f. = $v \times B \cdot L$, where $v$ is the Orbiter velocity, $B$ the Earth's magnetic field, and $L$ the Tether length. The expected maximum e.m.f. is about 0.25 V/m, which results in a maximum voltage of 5 kV across the TSS at 20 km Tether length. For the eastward moving Orbiter, the Satellite charged positively with respect to the ambient ionospheric plasma.

The circuit properties and power-generating capabilities of the TSS critically depend