SPACE SYSTEMS SYMPOSIUM (D1)
Enabling Technologies for Space Systems (2)

Author: Prof. Salvo Marcuccio
Sitael Spa, Italy

Dr. Emanuele Capuano
Università di Pisa, Italy

KINETIC STUDIES ON A SOLAR WIND SHIELD BASED ON PLASMA INFLATION OF MAGNETIC FIELD

Abstract

Particle radiation from the Sun is one of the main obstacles to safe interplanetary human missions. Since the early 60s, various protection methods have been proposed to this purpose. One of the most attractive concepts involves the creation of an artificial magnetosphere around the spacecraft, similar to what occurs naturally around the Earth. In principle, this could be done by using a magnet placed on the spacecraft in order to produce the magnetic field necessary to the deflection of solar wind particles; however, a very large magnetic dipole moment is required to create an artificial magnetosphere strong enough to shield the spacecraft, making this concept unpractical. In order to keep the onboard magnetic moment to feasible values, one could inflate the magnetic bubble by injecting an artificial plasma from the spacecraft, freezing the magnetic field lines so that they are effectively carried further away with the flow, thus enlarging the size of the magnetosphere.

Feasibility of such plasma shield was analyzed by our group using a simple analytical model (Marcuccio, S., Capuano, E., "Preliminary Assessment of a Solar Wind Shield Based on a Plasma-Inflated Artificial Magnetosphere", IAC-11.B3.7.4). In this paper we present a refinement of the previous preliminary assessment, based on the use of a kinetic numerical model of the solar wind proton trajectories in the magnetized plasma bubble. In particular, the model allows for evaluation of the fraction of incoming solar protons that actually manages to hit a pre-defined "safe" region around the space vehicle. In the close vicinity of the spacecraft to protect, the injected plasma can be restricted to selected regions of space, thanks to the focusing capability of dedicated plasma sources (such as Hall effect or gridded ion thrusters), so that the magnetic field enhancement effect is tailored to a specific shape. The use of multiple magnets and multiple plasma sources allows for further refinement of the shielding effect.

The simulation results suggest that, for realistic values of magnetic moment and injected plasma density, energy and angular distribution, the number of solar wind particles that penetrate the protected zone can be reduced to less than 2% with respect to the pure dipole case, even using as little as two coils with reasonable values of magnetic moment. We present an outline configuration scheme for a spacecraft shielding system based on our model and discuss the viability of the concept for near-to-medium term space missions.