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SCIENCE APPLICATIONS

Franco Mariani
Dipartimento Fisica II Universita

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1 GENERAL.

The possibility of doing science by tethers and/or tethered vehicles is now in the process of becoming a reality in the next few years.

Following early qualitative suggestions and studies, a serious start of quantitative studies is due to G.Colombo and M.Grossi, who in the early 1970's suggested to tether satellites to the Shuttle by means of long strings up to a length of 100 km.

A cooperative program was estabilished in the following years between USA and Italy, until in 1983 a M.O.U. was signed by the two countries; this was followed in 1984 by an A.O. stating that NASA and PSN/CNR "jointly announce an opportunity for partecipation in the first three flights of the Tethered Satellite System (TSS) on the Space Shuttle. These flights are expected to occur between 1987 and 1990. The TSS is comprised of two major elements, the Deployer, to be supplied by NASA, and the Satellite, to be provided by PSN/CNR. In addition, it is the intention of NASA and PSN/CNR to supply two items of core equipment for these flights; a three-axis accelerometer, placed on-board the Satellite, and an electron gun, to be mounted on the Deployer. Science instrumentation can be accommodated on both the Deployer and the Satellite".

Theoretical and experimental proposals for the definition and development of investigations for the first three flights and for analysis and interpretation of data were solicited. The answer by the scientific community was very encouranging: about 80 proposals were presented, approximately 1/5 from Europe and Italy in particular, 4/5 from USA and non-european countries.

It is my intention in this presentation, to summarize possible scientific applications in the field of the neutral or ionized atmosphere and of the solid Earth. As concerns the field of electrodynamic interactions, it will be the subject of another presentation so, here, I shall only list as an appendix a summary of the satellite and deployer scientific instrumentation selected for the first mission (the electrodynamic mission).

It is very important to remark that the TSS environment is a sort of huge laboratory where many different physical parameters influence each other in a very complicate way, under the external influences of the solar EUV radiation and the magnetospheric particles and the internal influence of the terrestrial gravity and magnetic field. It is worth to point out that while the interpretation of data from some types of experiments does not require a very precise determination of the geographic coordinates of the TSS-satellite, in other cases there are very stringent precision requirements, to the point that these may be the absolutely essential feature before significant physical interpretation can be attempted; this is the case of all parameters defined in a reference system anchored to the solid earth (gravity and geomagnetic field).

In this respect the study of TSS dynamics is interesting and useful "per se" because of the novelty of the system and the related need of better understanding. But from the view point of other experiments, the TSS dynamics is also inherently related to the possibility of measuring fine quantities. For example doubts have been expressed about the feasibility of gravity gradient measurements because "the dynamic noise expected in a tethered satellite is far higher than in a free flyer and may negate the advantages of flying at this unusually low orbital height". This same comment also applies to geomagnetic field measurements.

2 NEUTRAL ATMOSPHERIC MOTIONS AND COMPOSITION.

To study vertical, zonal and meridional neutral winds and temperature, whose extensive variations suggest importance of energy transfer mechanism in modifying the structural properties of the region. Thermospheric circulation models suggest existence of horizontal scale vortices generated by auroral processes at high latitudes, between 120 and 200 km altitude.

In this region, minor neutral constituents generated by auroral and solar particles are conveyed to other atmospheric regions by the winds. Also, the distribution mechanism of the EUV energy is an important goal. The EUV energy flux is relatively small (≈1eV/cm /sec), but the gas density also is small, so large effects are produced by this energy source. Another energy flux reaches the upper atmosphere from the solar wind and the ionization through the magnetosphere, in the form of precipitating particles. This effect is dominant at high latitudes, but global effects can also be observed during geomagnetic disturbances. Electric currents and ion drifts transfer energy and momentum to neutrals, producing winds at velocity of 1 km/sec.

Energy of tidal motions can also propagate from lower atmosphere to the thermosphere where it is finally dissipated. In this region also important ionospheric effects are generated by the wind system (S_q dynamo currents, electrojects, etc.).

All above processes strongly affect the composition and the thermal and dynamic regime of the neutral atmosphere, in the range from 100 to 200 km altitudes where only a few <u>in-situ</u> observational data do exist.

A major factor which may limit the accuracy or even the feasibility of in-situ measurements by hypersonic vehicles at TSS low altitudes is represented by the collisions suffered by free stream neutrals and ions as they pass through the ram cloud ahead of the satellite.

Also important is the ionization produced by neutrals impacting the exposed surface of the s/c and the instrument sensors.

3 IONOSPHERIC ELECTRON AND ION COMPOSITION. IRREGULARITIES AND DISTURBANCES.

Below the F region, "intermediate layers" of high plasma density are often observed. These layers propagate to lower altitudes with drift velocities of the order of 20 m/sec. Composition and motion of this layers are important parameters to be measured by the TSS, in order to understand their phenomenology, also in conjunction with ground-based radar observations. A variety of plasma structures at different spatial and temporal scales in the lower F region will be studied.

Local measurements of electron densities and temperatures, as well as of d.c. electric fields and ionospheric current will contribute basic informations on the overall energy balance.

Large and medium scale travelling ionospheric disturbances will also be studied. These disturbances have typical wavelengths of some thousands km and can propagate from high to equatorial latitudes. Also, acoustic-gravity waves generated in the E region, which might be the source of the spread-F, will be possibly observed.

A number of metallic ions (Na , Mg , Si , Fe , etc) are mixed to the most commom ions. Some of them are long-lived and can be transported by both neutral winds and electric field. Ion composition measurements will help to sort out the most important ion sources and to determine the role played by meteoritic ions.

4 FLUIDODYNAMICS.

Basic fluidodynamics problems can be studied onboard tethered satellites. In particular, aerodynamic and heat transfer coefficients within a variety of conditions which cannot be obtained by the current wind tunnel technology, due to the impossibility of making thermo-fluid-dynamic measurements at combined low Reynold number and large Mach number regime. An additional advantage of using the TSS as "open wind tunnel" is the long time range of operation, as compared with any existing or proposed ground facility.

5 MAGNETIC FIELDS.

The magnetic field at TSS altitudes is the sum of fields from different sources: the global geomagnetic field of internal origin, the field due to anomalies of limited extent associated with permanently magnetized subsurface structures, ionospheric currents driven by large scale atmospheric motions or originating in the magnetosphere and, finally, the induced electric current flowing along the tether (in the case it is conducting).

Separation of the different contributions may become a formidable task unless the dynamics of the tethered satellite (location and attitude) is perfectly known and any possible spurious field from the s/c is below the magnetic sensors sensitivity.

Studies will be conducted on the structure of the equatorial electrojet, in particular its longitudinal and meridional extent. Also, the closure of the current loop as a whole will be studied. Toroidal magnetic field structures, not observable from ground, have been suggested, which can only be detected by in-situ measurements.

The S_q diurnal field variation will also be observed and the induced effects on the Earth will be possibly determined in a more direct way by comparison with ground observations.

Crustal field anomalies will be detectable, hopefully, expecially for the lower altitudes flights.

Magnetic measurements will also be used to probe the tether current distribution in the plasma sheath around the s/c, as a necessary complement to the local plasma parameters determinations.

6 GRAVITY ENVIRONMENT.

Exact knowledge of the Earth's gravitational field is important in many technical and scientific areas (Earth resources, oceanphysics, motions of tectonic plates, inertial navigation, etc.). The low altitude TSS missions will be useful to this end, if the dynamics of the tethered satellite will be sufficiently well known to determine gravity gradients with the required, high, accuracy. Studies presently in progress seem to indicate good chances of flying gravimetric gradient instruments in the following missions.

7 REMOTE SENSING.

The TSS facility for remote sensing purposes may prove useful to increase significantly the accuracy of future real time cartographic systems from space. In this framework, two operational missions have been suggested: one using two linear array systems for along-track stereoscopic observation; the other using a synthetic aperture radar combined with an interferometric tecnique. Feasibility studies are presently in progress.

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APPENDIX

SCIENCE FOR THE FIRST TSS ELECTRODYNAMIC MISSION

SCIENTIFIC OBJECTIVES

- STUDY OF ELECTRODYNAMIC INTERACTION BETWEEN THE TSS AND AMBIENT PLASMA
- STUDY OF DYNAMICAL FORCES ACTING ON THE TETHERED SATELLITE

SATELLITE INSTRUMENTATION (and P.I.'s)

- RESEARCH ON ELECTRODYNAMIC TETHER EFFECTS (RETE) - M. DOBROWOLNY CNR/IFSI - FRASCATI - ROME
  WAVE SENSORS ON TWO EXTENDABLE BOOMS (4 m EACH) TO EXPLORE SPACE CHARGE REGION AROUND SATELLITE.
- TETHER MAGNETIC FIELD MEASUREMENT (TEMAG) - F. MARIANI - 2ND UNIVERSITY OF ROME - TOR VERGATA - ROME
  TWO MAGNETOMETERS ON FIXED BOOM (85 cm) TO MEASURE MAGNETIC FIELD AND DYNAMICS OF TETHERED SATELLITE.
- RESEARCH ON ORBITAL PLASMA - ELECTRODYNAMICS (ROPE) - N. STONE - NASA/MSFC HUNTSVILLE - ALABAMA
  PARTICLE SENSORS ON FIXED BOOM (85 cm) AND ON SATELLITE TO STUDY SATELLITE PLASMA INTERACTION.

DEPLOYER INSTRUMENTATION

- SHUTTLE ELECTRODYNAMIC TETHER SYSTEM (SETS) - P. BANKS - STANFORD UNIVERSITY - STANFORD - CALIFORNIA
  VARIOUS INSTRUMENTS TO STUDY TETHER CURRENT - VOLTAGE CHARACTERISTICS, CHARGE CONTROL AND EMISSION AT ORBITER, OTHER PLASMA AND IONOSPHERIC PROCESSES.

THEORY AND GROUND - BASED OBSERVATIONS

- THEORY AND MODELING IN SUPPORT OF TETHER - K. PAPADOPOULOS - SCIENCE APPLICATIONS, INC. - McLEAN - VIRGINIA
- INVESTIGATION ON TSS DYNAMICS S. BERGAMASCHI - UNIVERSITY OF PADOVA PADOVA
- INVESTIGATION AND MEASUREMENT OF DYNAMIC NOISE IN TSS - G. GULLAHORN - SAO CAMBRIDGE - MASSACHUSSETS
- DETECTION OF ELECTRODYNAMIC ULF/ELF EMISSIONS BY THE TETHER - G. TACCONI UNIVERSITY OF GENOVA - GENOVA
- INVESTIGATION OF ELECTRODYNAMIC EMISSIONS BY THE TETHER R. ESTES - SAO CAMBRIDGE MASSACHUSSETS.

ITALY IS RESPONSIBLE FOR THE INTEGRATION OF THE SCIENTIFIC INSTRUMENTATION ON THE SATELLITE

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TSS CORE EQUIPMENT
TETHER CURRENT-VOLTAGE CONTROL (TCVC) SYSTEM

PURPOSE

FOR THE ELECTRODYNAMIC MISSIONS THE TCVC SYSTEM WILL SPECIFICALLY ALLOW INVESTIGATION OF THE TSS-S ELECTRICAL POTENTIAL BY CONTROLLING THE CURRENT THAT FLOWS BETWEEN THE SATELLITE AND THE ORBITER THROUGH THE TETHER AS A RESULT OF THE EMF GENERATED (UP TO 5 KV) BY MOTION OF THE TSS THROUGH THE GEOMAGNETIC FIELD
THIS FUNCTION IS FUNDAMENTAL TO THE OPERATION OF THE ELECTRODYNAMIC TETHER AND IS ESSENTIAL FOR THE TSS SCIENTIFIC INVESTIGATIONS.

THREE-AXIS ACCELEROMETER-GYRO SYSTEM

PURPOSE

THE THREE-AXIS ACCELEROMETER-GYRO SYSTEM WILL PROVIDE A HIGHLY ACCURATE ASSESSMENT OF DYNAMIC PERTURBATION TO THE MOTION OF THE TETHERED SATELLITE.
THIS INFORMATION IS REQUIRED TO DETERMINE THE SUITABILITY OF THE TETHERED SATELLITE AS A PLATFORM FOR A VARIETY OF INVESTIGATIONS OF CRUSTAL - INDUCED MAGNETIC AND GRAVITATIONAL EFFECTS.