A GENERIC PACKAGE FOR LONG TERM MONITORING OF THE MARTIAN THERMOSPHERE ON THE TELECOM ORBITERS OF THE MARS MICROMISSION PROGRAM. E. Chassefiere, F. Forget, F. Hourdin, F. Vial, F. Jegou, J. J. Berthelier, L. Duvet, P. Touboul, S. Bougher, and G. Keating.

Future missions of Mars exploration will require an intensive use of aero-assistance techniques. Because of their limited Delta-V capabilities, the micro-orbiters (Science/ Communication) of the Mars Micromission program will be inserted in highly elliptical orbits, with systematic use of aerobraking for subsequent circularization. The possibility of "ballute" aerocapture, which would allow a substantial increase of payload capability, is presently being studied at JPL for post-05 missions. The Micromission program is not limited to Mars, and future exploration of other planets of the inner Solar System, like Venus, is anticipated. Independently, the CNES-provided orbiter of the 05 Mars Sample Return mission is expected to be inserted in Martian orbit by aerocapture. Besides, ESA is presently developing Martian climate databases, which will be extended to the Martian thermosphere, through combined observation/ modelling studies, in view of providing a realistic climatology of the whole Martian atmosphere, partially oriented toward designing future aero-assistance strategies. ESA is also interested in developing climate databases for Venus.

Improving aeroassistance strategies needs a better understanding of dynamical processes controling the thermosphere. The solar cycle, seasonal, wave, and "dust heating" responses of the Mars upper atmosphere (above 100 km) are very poorly constrained at present. Upcoming Mars missions (Planet-B and Mars Express) plan to sample the Martian upper atmosphere (above 150 km) for only a small portion of the solar cycle. Furthermore, their in-situ probing altitudes do not extend to the Mars lower thermosphere (100-150 km) where considerable variability has been observed recently by the Mars Global Surveyor (MGS) Accelerometer during aerobraking campaigns. A long-term program for Mars thermospheric monitoring (100-250 km), using the telecom orbiters of the Mars Micromission Program, would provide multiple opportunities (at each orbiter aerobraking window) to monitor these thermospheric variations. Ultimately, a climatology of the Mars lower thermospheric densities, temperatures, and winds can be constructed. The goals of such a monitoring program are twofold :

(1) To fully characterize the Martian thermospheric structure and dynamics. This leads naturally to comparison to the terrestrial lower thermospheric (100-250 km) mean structure and its variations. Thermal and dynamical processes can then be studied in great detail for two planetary thermospheres (Earth and Mars). Wave effects (planetary, tidal, and gravity) are of great importance to study for these planets.

(2) To provide a realistic Mars thermospheric climatology for the design of future aerobraking strategies.

The Mars Thermospheric General Circulation Model (MTGCM) is a 3-D modeling tool that is presently being used to simulate Mars upper atmosphere structure and dynamics (70-300 km) (e.g. Bougher et al. 1990). An archive of case runs for various solar fluxes, seasons, and dust heating conditions is crudely constrained by Mariner, Viking, Pathfinder, and MGS upper atmosphere data (Keating et al. 1998; Bougher et al. 1998). Nevertheless, the fields produced in this archive are presently ill-constrained since the available in-situ data span only a fraction of the solar cycle and the Mars seasons. Such coverage is important for evaluating the changing importance of dust and wave effects on the Martian thermosphere. The long-term thermospheric studies proposed here can truly provide the needed MTGCM constraints for the proper evaluation of Mars thermospheric processes and their variations (solar, seasonal, wave, and dust).

The proposed package, named ADIP (Aerobraking Diagnostics Instrumentation Package), consists of a three-axis accelerometer coupled with two density gauges. It is devoted to the measurement of densities, temperatures and winds in the 100-250 km altitude range, that is inside and up to ≈80 km above the aerobraking range (100-170 km). Because a network of relay satellites is planned to be put in orbit around Mars, as well as several scientific satellites, a complete monitoring of diurnal, seasonal and solar cycles could be achieved in this way. Due to propellant limitation, aerobraking will be intensively used for inserting these satellites in their final orbit and low thermospheric altitude ranges will be frequently reached during relatively long periods of times. Among the various objectives of the martian upper atmosphere studies, one important goal is to determine the density and temperature profiles and their temporal and spatial variations. Of particular interest are those linked to the propagation of gravity waves which were advocated to explain the observations of the Viking landers. Such observations are necessary both to improve the knowledge of the planet upper atmosphere and understand its erosion by the solar wind and also to model the general circulation in the lower atmosphere. In order to achieve this specific objective we propose to fly, together and synergistically with the accelerometer, an instrument which aims at making local measurements of the density and temperature of the atmosphere, and the wind velocity, from an altitude of ≈250 km down to the periapsis.

The accelerometer operates in the aerobraking range (100-170 km). Whereas measurements of cross-track and radial components are expected to give access to the horizontal wind (mainly zonal in near-polar orbit) and possible transient vertical winds (due to propagating waves of different kinds), as shown by previous satellite investigations of Earth's thermosphere (see e.g. Marcos and Forbes, 1985), combined measurements of both on-track acceleration and density (see below) might allow to discriminate between density and wind effects along on-track direction (mainly meridional). The sensitivity of the accelerometer would be larger than on MGS (see Keating et al, 1998) by at least one order of magnitude, and the three-dimensional measurement would provide an access to the detailed wind field. The three axis acceleration measurement system will be provided by ONERA-Chatillon. It consists of exploiting already developed one-axis linear accelerometer, by mounting together three such accelerometers in a specific package optimized for the accomodation on board the satellite. The nominal range of the accelerometers, greater than 10 g (g : acceleration of gravity) will be reduced to 0.3 mg, with an anticipated noise of 50 ng at frequencies larger than 10^{-2}-10^{-3} Hz. The output signals could be filtered out at high frequencies with a 0.1 Hz cut-off frequency, and sampled with a typical rate of one measurement per two seconds. The corresponding spatial resolution, along satellite trajectory, is ≈40 km. The cross-track and radial winds could be measured with a precision of ≈40 m/s. The precision on the on-track wind, which will be retrieved with the help of the independent density measurement, is more difficult to estimate.

The density measurement system operates in the full 100-250 km range. It makes use of two pressure gauges. The first one is based on the concept of an open gauge and determines the atmospheric density. The second one is a classical closed pressure gauge with a small entrance hole looking forward; the normal to this hole, and thus the direction of sight of the gauge, can be varied periodically at several angles to the ram direction during a sequence of measurements. The corresponding set of observations can be processed to retrieve the direction and amplitude of the wind as well as the gas temperature. We anticipate to reach a temporal resolution of the order of 2 to 4 seconds for the determination of the velocity and temperature while the density could probably be obtained each 0.1 s. Preliminary estimates of the accuracy are in the range of ±10% for the density, ≈30 K for the temperature and ≈30-50 m/s for the velocity. Accelerometer and density gauge measurements are quite complementary. The partial redundancy on velocities in the aerobraking range (100-170 km) will be of a great interest for comparison and cross-calibration purposes. It should allow to improve the retrieval on-track velocity, which is a difficult task.

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