# DYNAMO : A MARS UPPER ATMOSPHERE PACKAGE FOR INVESTIGATING SOLAR WIND INTERACTION AND ESCAPE PROCESSES, AND MAPPING MARTIAN FIELDS.

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**SUMMARY**

The planet Mars is a unique member of the solar system family that seems at first glance to have the potential for habitable conditions. It moreover has been found to manifest signs of a past milder, wetter climate, suggesting that its atmosphere was once more substantial than it is today. A major component of current Mars exploration plans is the determination of the climate, and hence the atmosphere's history. This includes knowledge of the fate of the lost atmosphere and water. Is it sequestered in the crust at all latitudes (c.f. 2001 Odyssey GRS findings), in spite of the apparent lack of evidence of substantial carbonate content of the surface, or did much of it escape to space, perhaps after the magnetic shield supplied by a Martian dynamo died? While available measurements and theoretical studies suggest that a number of escape processes are at work today (see Fig. 1), little is known about their efficacy, including temporal variations and dependencies on factors such as solar activity. Any extrapolation into the past of the effects of these processes must necessarily be based on sounder footing. This goal to "follow the water" is the key to Mars Exploration Program plans. An additional important goal is the mapping of crustal magnetic field anomalies, beyond the incomplete picture provided by the MGS mission (20% of the surface was made at the highest achievable resolution from the MGS aerobraking orbit), coupled with simultaneous measurements of gravity field anomalies.

DYNAMO is a small multi-instrument payload aimed at characterizing current atmospheric escape, which is still poorly constrained, and improving gravity and magnetic field representations, in order to better understand the magnetic, geologic, and thermal history of Mars. The internal structure and evolution of Mars is thought to have influenced climate evolution. The collapse of the primitive magnetosphere early in Mars' history could have enhanced atmospheric escape and favored transition to the present arid climate. These objectives are achieved by using a low periapsis orbit. DYNAMO has been proposed in response to the AO released in February

2002 for instruments to be flown as a complementary payload onboard the CNES Orbiter to Mars (MO-07), foreseen to be launched in 2007 ? in the framework of the French PREMIER Mars exploration program. MO-07 orbital phase 2b (with an elliptical orbit of periapsis 170 km), and in a lesser extent 2a, offers an unprecedented opportunity to investigate by in-situ probing the chemical and dynamical properties of the deep ionosphere, thermosphere, and the interaction between the atmosphere and the solar wind, and therefore the present atmospheric escape rate. Ultraviolet remote sensing is an essential complement to characterize high, tenuous, layers of the atmosphere. One Martian year of operation, with about 5000 low passes, should allow DYNAMO to map in great detail the residual magnetic field, together with the gravity field. Additional data on the internal structure will be obtained by mapping the electric conductivity, synergistically with the NETLANDER magnetic data. Three options have been recommended by the International Science and Technical Review Board (ISTRB), who met on July 1st and 2nd, 2002. One of them is centered on DYNAMO. The final choice, which should be made before the end of 2002, will depend on available funding resources at CNES.

The central thrust of the DYNAMO is to study quantitatively the various present-day atmospheric escape processes from Mars (see e.g. Chassefière *et al.*, 2001). However, in the process of carrying out these measurements, numerous other important questions of high scientific value associated with the upper atmosphere, exosphere, ionosphere, and solar wind interaction processes will also be addressed. Such a mission to study the upper atmosphere and plasma environment of Mars has been discussed and recommended in the NRC COMPLEX Committee's Assessment of Mars Science and Mission Priorities (*COMPLEX*, 2002). The Executive Summary of this report states: "…there is an absence of NASA missions that specifically address Mars' atmosphere…ionosphere and solar wind interactions…COMPLEX urges NASA to continue its support for U.S. participation in Mars missions conducted by NASA's international partners." A similar call for a Mars upper atmosphere mission appears in the just published report by the Solar System Exploration Survey Committee, also known as the Decadal Study (*Solar System Exploration Survey*, 2002).

## MAIN SCIENTIFIC OBJECTIVES

The following tables summarize the main objectives of the DYNAMO payload, in the disciplines of atmospheric and escape research (table 1) and of internal geophysics (table 2).

## DYNAMO PAYLOAD

### Instruments

The nominal payload consists of: a flux gate magnetometer, an energetic particle spectrometer (electrons, ions, neutrals), an ion/neutral mass spectrometer (thermal and suprathermal), a plasma package (consisting of a sensor of a thermal electron sensor, completed by a plasma wave detector), and an EUV airglow spectrograph. The geodesy instrument on DYNAMO is proposed separately, together with a double-arm accelerometer system and an USO. These instruments are listed below.

- ***MEMOIRE*** *: Magnetic Experiment on Mars Orbiting Instruments (M. Mandea/F. Primdahl)*
- ***IENA*** *: Ion Electron Neutral Atom Analyzers (H. Rème/R. Lin) :*
- ***DEMAI*** *: A Neutral and Ion Mass Spectrometer to Study the Dynamics and Escape of the Martian Atmosphere and Ionosphere (F. Leblanc/ J.-J. Berthelier/ H. Waite) :*
- ***PLASMA-PACKAGE*** *: Investigation of magnetic and electric fluctuations, and measurement of thermal plasma parameters (J.-G. Trotignon/M. Parrot) :*
- ***SOURCE*** *: Spectrographe pour l'Observation Ultraviolette du Rayonnement Coronal et de l'Echappement (E. Chassefière/ J. Clarke) :*
- ***RSE*** *: Radio Science Experiment for Atmosphere, Ionosphere, and Gravity Opportunity (J.-P. Barriot/ W. Folkner)* :

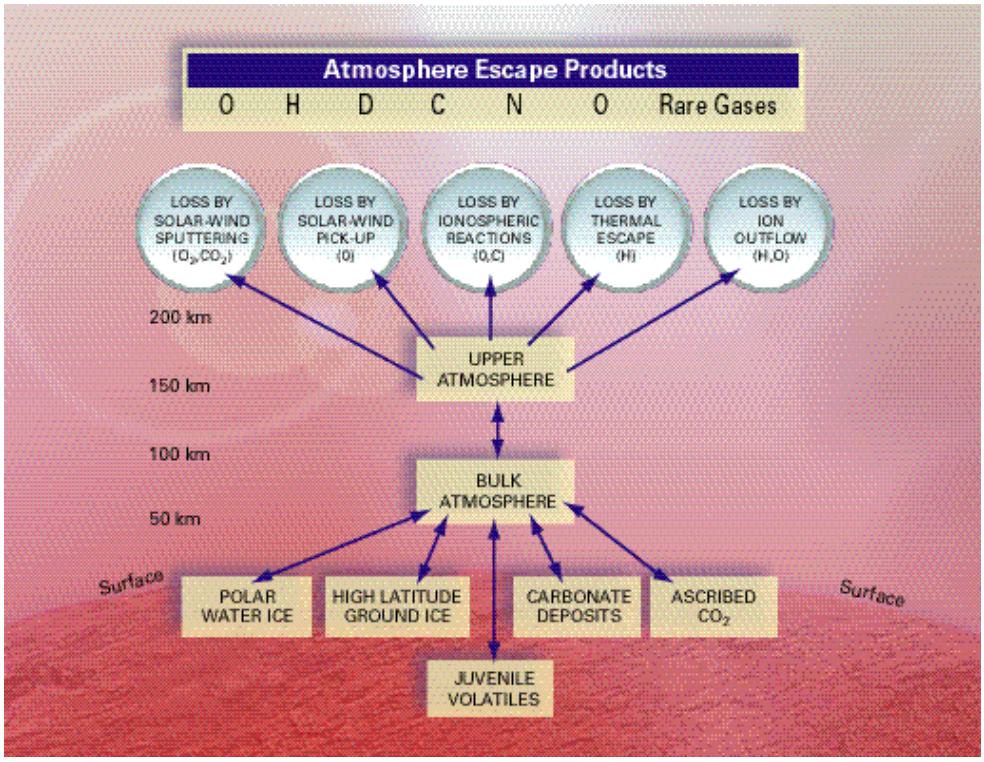


*Figure 1 . Escape processes are mediated by the Martian upper atmosphere.*

**Table 1. Main atmosphere/escape objectives**

| | | |
|---|---|---|
| Characterize reservoirs of matter available for escape | Characterize interaction processes between atmosphere and solar emissions (UV, particles) | Characterize atmosphere/SW fluxes of matter and energy (escape, solar wind absorption) |
| - Thermosphere/ exosphere (composition, physical parameters)<br>- Ionosphere (composition ions/electrons, physical parameters, suprathermal populations) | - Ionization (UV, electron impact, charge exchange) and ion escape<br>- Dissociative recombination<br>- Formation of pick-up ions and sputtering | - Escape fluxes (nature, composition, dynamical state)<br>- Absorption fluxes of solar wind (H, He)<br>- General configuration of interaction |

**Table 2. Main inner structure/dynamics objectives**

| | | |
|---|---|---|
| Improve characterization of the mechanisms of formation and evolution of the crust | Characterize the physical state and the mineralogy of the mantle, and its thermal history | Improve characterization of the birth, history and extinction of the internal magnetic dynamo |
| - Crustal magnetic field : sources (intensity, morphology, position)<br>- Gravity field : elastic thicknesses, loading structures, **B**/**g** correlations | - Electrical conductivity of the mantle (magnetic measurements of DYNAMO/NETLANDER)<br>- Search for traces of an ancient tectonism (**B**/**g** signatures) | - Understanding of planetary dynamos<br>- Impact of core convection history on thermal history of the core/mantle system<br>- Impact of magnetosphere history on escape and climate history |

**General purpose of the DYNAMO payload**

These instruments are used for the following purposes:

- in situ probing of thermospheric composition, temperature, and tentatively wind, full vertical/horizontal coverage (follow up of MGS),
- in situ probing of the ionospheric chemical/dynamical structure: vertical, latitudinal and seasonal variations,
- in situ probing of energetic neutral/ion/electron fluxes and energy spectra (in complement with Mars-Express, operating at $z \approx 400$ km, and Nozomi, working only in equatorial regions),
- in situ characterization of the solar wind/ ionosphere three-dimensional magneto-hydrodynamic interaction,
- remote sensing of neutral and ion populations at thermospheric and exospheric levels, and ionospheric electron profiles,
- mapping of planetary magnetic field, full coverage (improving by a factor of 5 the MGS coverage),
- retrieval of electrical structure of Mars through measurement of magnetic variations,
- mapping of planetary gravity field, at high spatial resolution (improving by a factor of 3-5 the MGS resolution).

## CONCLUSION

DYNAMO has been proposed as a French-led project, with partners from Europe (Denmark, Belgium, Sweden, Hungary, United Kingdom, Italy, Germany, ESTEC), United States (notably Universities of Michigan, Boston, and Berkeley) and Japan (University of Tokyo), in response to the AO released in February 2002 for instruments to be flown as a complementary payload onboard the CNES PREMIER Orbiter to Mars (Chassefière et al., 2002). The US part of DYNAMO has been simultaneously proposed in response to the NASA Scout Mission of Opportunity AO (Nagy et al., 2002). DYNAMO has been pre-selected by the International Science and Technical Review Board (ISTRB), who met on July 1st and 2nd, 2002, as one of three possible payload options. The final selection is expected before December 2002.

**References**

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