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DYNAMO: a Mars upper atmosphere package for investigating solar wind interaction and escape processes, and mapping Martian fields

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Abstract

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

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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 5,000 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, sinergistically 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.

Keywords: Mars; Upper atmosphere; Escape; Magnetic field; Gravity field

1. Introduction

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, see Fig. 2), coupled with simultaneous measurements of gravity field anomalies.

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

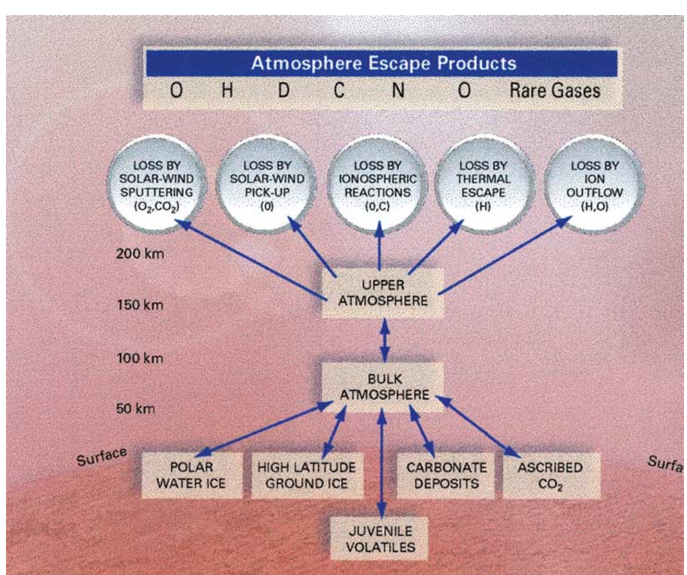

Fig. 1. Escape process is mediated by the Martian upper atmosphere (from Killeen et al. (1998)).

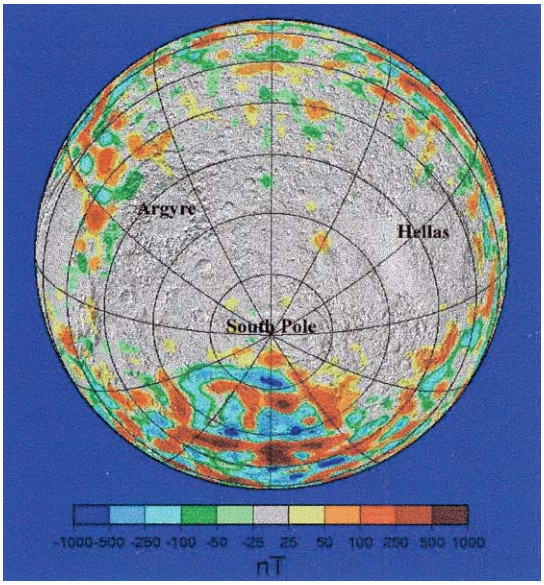

Fig. 2. The radial component of the magnetic field at 120 km altitude (from Purucker et al. (2000)).

Executive Summary of this report slates: "…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 US 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).

2. Main scientific objectives

The main objectives of DYNAMO, in the field of escape studies, are to understand how the different layers of the atmosphere work, under the combined effects of solar radiation and dynamics, and how they interact together, by exchanging matter, energy and momentum. They may be summarized as follows: (i) understand how dynamics and ion-molecule chemistry work in the high atmosphere, and how the thermosphere chemically and dynamically couples with the ionosphere, (ii) better characterize dynamical, wave-related, processes coupling low-middle atmospheric layers and the high atmosphere, through a synergistic use of DYNAMO data and meteorological measurements performed by microwave sounding and other remote sensing techniques, (iii) determine, as a function of solar conditions, the nature and efficiency of the various phenomena involved in the interaction of the upper atmosphere with solar wind, (iv) study, as a function of solar conditions, how energy is transferred from the solar wind to the upper atmosphere and ionosphere, and how its dissipation affects the dynamics and structure of the high atmosphere, (v) analyze the role of the complex structure of the Martian magnetic field in solar wind interaction processes, (vi) characterize, in terms of composition, energy, angular and geographical distributions, the escape fluxes of neutrals and ions, (vii) study, as a function of solar conditions, the nature and the rate of solar wind absorption, (viii) estimate, with the help of physical–chemical models, the long term consequences of solar wind interaction processes on atmospheric mass and composition, from planet formation to the present epoch, and implications for past climate evolution.

In the field of solid planet studies, a few major goals, to be reached through a synergistic use of NETLANDER and DYNAMO observations, have been identified: (i) investigate at the planetary scale the crust and mantle electrical conductivity, (ii) better define crustal magnetic anomaly sources and elastic thickness for small geologic features, enabling systematic process-oriented studies, (iii) place these sources in the stratigraphic context and understand the origin of the remnant magnetic field, (iv) find possible evidence of magnetic reversals, understand the magnetic field history and, by inference, the thermal evolution of the planet, (v) determine by gravimetry the elastic thickness and loading structure of a variety of geologic features and provinces, (vi) search for traces of ancient tectonism as imprinted on magnetic high resolution maps.

Tables 1 and 2 summarize the main objectives of the DYNAMO payload, in the disciplines of atmospheric and escape research (Table 1) and of internal geophysics (Table 2).

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)	Ionization (UV, electron impact, charge exchange) and ion escape	Escape fluxes (nature, composition, dynamical state)
Ionosphere (composition ions/electrons, physical parameters, suprathermal populations)	Dissociative recombination	Absorption fluxes of solar wind (H, He)
	Formation of pick-up ions and sputtering	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)	Electrical conductivity of the mantle (magnetic measurements of DYNAMO/NETLANDER)	Understanding of planetary dynamos
Gravity field: elastic thicknesses, loading structures, **B/g** correlations	Search for traces of an ancient tectonism (**B/g** signatures)	Impact of core convection history on thermal history of the core/mantle system
		Impact of magnetosphere history on escape and climate history

3. DYNAMO payload

3.1. Description of the 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. A few details about the instruments are given below.

MEMOIRE: Magnetic experiment on Mars orbiting instruments (M. Mandea/F. Primdahl): The first objective of the magnetic experiment will be detailed mapping of the Martian magnetic field from orbit, with a sampling rate of 2–20 Hz and with an accuracy of the order of 1 nT. The second objective will be to provide to the international community the first set of simultaneous in-orbit (MEMOIRE) and ground (NETLANDER) magnetic measurements. A further objective, facilitated by a possible inclusion of the DTU Advanced Stellar Compass for absolute attitude, is to use this autonomous system's ability to track non-stellar objects for detecting and cataloguing new Asteroids and NEOs.

IENA: Ion electron neutral atom analyzers (H. Rème/R. Lin): The *Electron electrostatic analyzer* (EEA instrument) will measure electrons with energies from ~0.1 to 10 keV that are important for electron impact ionization and to understand the magnetic field topology. Solar wind and pickup ion measurements will be performed by the *Time-of-flight ion composition experiment* (TOF-ICE), which covers most of the Sun-facing hemisphere with an energy range from the spacecraft potential to 20 keV/q. TOF-ICE also looks at large angles from the Sun, where the pickup energies of ions heavier than He are low enough to be analyzed. These measurements are complemented by the *Pickup ion detector* (PID), which covers the Sun-facing hemisphere with an energy range from ~3 keV to ~7 MeV. This combination allows nearly complete coverage of the energy/angle distributions of solar wind, interstellar, and Mars pickup ions. The combination of these sensors with an *Energetic neutral analyzer* (ENA) detector, measuring energetic neutrals up to 60 keV, will allow an accurate description of the atmospheric losses from Mars and the solar wind interaction with Mars.

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): This instrument is composed of the Ion neutral spectrometer (INS) and the Hot neutrals analyzer (HNA). INS will be used for suprathermal ion survey in the energy range from 10 to 200 eV. Thermal ion populations will be measured over densities from 10^{-2} to 10^{+6} ions/cm^3, temperatures from 200 to 10^4 K and velocities from ~100 m/s to 10 km/s. Atmospheric neutrals with thermal energies will be detected using a quadrupole filter, which extends the dynamic range to over eight orders of magnitude. The lowest detectable density is ~10^3 n/cm^3. The measurable energy range for neutrals is from 1 to 20 eV. In the ion mode, DEMAI can measure mass spectra up to ~48 amu with a mass resolution of better than 0.7 amu at mass 44. In the neutral mode, mass resolution can be enhanced with the quadrupole in which case it will reach a mass resolution of 0.2 at mass 40. The second mass spectrometer unit, HNA, is dedicated to hot neutrals of several eV energy (between 1 and 20 eV), such as atomic oxygen. These particles will be detected through an entrance that looks downward towards the planet at an angle with respect to nadir which can be varied from ~15° to 60°. HNA will thus provide the energy spectrum of hot neutrals and their mass spectrum, from 4 to 48 amu, as a function of direction as they escape from the atmosphere.

PLASMA-PACKAGE: Investigation of magnetic and electric fluctuations, and measurement of thermal plasma parameters (J.-G. Trotignon/M. Parrot): The MIDST (Martian ionospheric electron density, speed, and temperature investigations) instrument will make possible accurate in situ measurements of the electron density, plasma drift velocity, and mostly electron temperature, which is known to play a fundamental role in these processes. MIDST would also determine boundaries and identify the various plasma layers. It will detect natural waves from 2 kHz up to 4.5 MHz, monitor the spacecraft potential, and possibly estimate the integrated solar EUV flux. The MSC (Magnetic Search Coil) experiment will study the fluctuating magnetic field from a few Hz up to 20 kHz. Finally, the Wide angle imager, WAI, will address the meteors and dust storms monitoring.

SOURCE: Spectrographe pour l'observation ultraviolette du rayonnement coronal et de léchappement (E. Chassefière/J. Clarke): The SOURCE instrument is an EUV/FUV airglow spectrograph with a solar occupation capability along a line of sight at 90° from the airglow direction. Airglow emission spectra at 0.3–0.5 nm resolution will be obtained at a limiting sensitivity of fractions of Rayleighs. The EUV spectrograph, working in the 80–170 nm range at a resolution of 1 nm, will operate in several modes: (1) In the airglow mode, remote observations from above the atmosphere will be obtained scanning in altitude near the limb. These will measure the brightness of various emissions with altitude along the slant column through the atmosphere. (2) In the atmospheric sounding mode, when the orbiter is flying through the Martian atmosphere at low altitudes, the EUVS pointed to the side will measure the emission brightness with altitude for the various spectral features. (3) In the solar occultation mode the solar spectrum will be recorded from above the Martian atmosphere as the line of sight penetrates into the atmosphere at the limb.

RSE: Radio science experiment for atmosphere, ionosphere, and gravity opportunity (J.-P. Barriot/W. Folkner): RSE will be composed of a X-band transponder, a couple of micro-accelerometers (resolution better than 10^{-7} m s^{-2}), and an ultra-stable oscillator (USO). The main objectives of the RSE are: to improve knowledge of the dynamics of the atmosphere by measuring profiles of pressure and temperature with high accuracy, high vertical resolution up to 100 km altitude, and global coverage; to improve knowledge of the ionosphere by measuring vertical profiles of electron density; to measure the density of the upper atmosphere by measurement of drag on the spacecraft; and to improve knowledge of the gravity field. The RSE gravity experiment will allow to: (i) measure under similar geometry both magnetic and gravity fields, and correlate them; (ii) reach degree and order 120, that is about twice better than MGS, from the 170×1000 km orbit (phase Ph2b); (iii) provide the definitive, high resolution, mapping of the Martian gravity field, together with that of the magnetic field, as performed by MEMOIRE, which will be used as a reference for any further study of Mars' internal structure and dynamics.

3.2. General purpose of the DYNAMO payload

These instruments are used for the following purposes: (i) in situ probing of thermospheric composition, temperature, and tentatively wind, full vertical/horizontal coverage (follow up of MGS), (ii) in situ probing of the ionospheric chemical/dynamical structure: vertical, latitudinal and seasonal variations, (iii) 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), (iv) in situ characterization of the solar wind/ionosphere three-dimensional magneto-hydrodynamic interaction, (v) remote sensing of neutral and ion populations at thermospheric and exospheric levels, and ionospheric electron profiles, (vi) mapping of planetary magnetic field, full coverage (improving by a factor of 5 the MGS coverage), (vii) retrieval of electrical structure of Mars through measurement of magnetic variations, (viii) mapping of planetary gravity field, at high spatial resolution (improving by a factor of 3–5 the MGS resolution).

3.3. DYNAMO mass, power and telemetry budgets

The total mass of DYNAMO, including the common DPU, the structures (main assembly, deployable and rigid booms assemblies, to host the instruments), and the harness, is 26.6 kg (mass of instruments, including their own DPU, is 17 kg). DYNAMO consumes 30 W on a regular basis, and the requested fraction of the Orbiter telemetry rate is 40% during Oph 1, 45% during Oph 2a, and 60% during Oph 2b (respectively, 250, 270, 370 Mb/day).

3.4. Synergies and differences with Mars-Express

Two instruments of DYNAMO (IENA and SOURCE) present similarities with Mars-Express instruments (respectively, ASPERA and SPICAM Light). Nevertheless:

- Mars-Express will orbit Mars on a near-polar orbit every 6.7 h, coming to within 250 km of the surface from a high point of 11,500 km. The altitude range from 170 to 250 km, which includes a major interface with respect to escape (the exobase, around 200 km), will not be sounded by ASPERA. Additionally, the period of the Mars-Express orbit will be three times greater than that of MO-07, resulting in a smaller fraction of the time spent at low altitude.
- IENA and SOURCE observations will be made in coincidence with measurements of ambient atmosphere and ionosphere (DEMAI, PLASMA PACKAGE), of escaping neutrals (DEMAI), of wave activity (PLASMA PACKAGE) and of background magnetic field (MEMOIRE, PLASMA PACKAGE).
- These two experiments include new capabilities (energetic ions for IENA, up to several MeV, ions and noble gases for SOURCE in the unexplored 80–115 nm window), which make them original.

- They will be operated during the 2008–2010 period, during a phase of rapid increase of solar activity, allowing to directly measure the sensitivity of escape rate (noticeably by sputtering) to solar activity.

Using all DYNAMO instruments together on a low orbit platform, in an increasing phase of solar activity, will bring crucial information about escape, its different modes and their correlations, between each other and with solar activity. From this point of view, DYNAMO will provide an unprecedented view of Mars atmospheric escape, which will benefit from previous, incomplete, observations by Mars-Express. Note that the scientific return of Mars-Express in the field of atmospheric escape will benefit from DYNAMO results, which will allow to fully understand escape, and to make the bridge between two opposite periods of the solar cycle (low-activity, low-to-high-activity).

No mapping of magnetic and gravity fields will be done by Mars-Express. Note that, with respect to MGS and following US orbiters, DYNAMO will allow to improve by a factor 2–3 the coverage and resolution of observations.

4. DYNAMO accomodation on the CNES PREMIER orbiter

The five instruments and the associated 13 sub-instruments are regrouped in three assemblies mounted on three different major parts of the orbiter (plus two elements in specific locations): (i) the main assembly (MA), whose volume corresponds to the INS-2 instrument (the "escape package", according to the AO); (ii) the rigid boom assembly (RBA); (iii) the deployable boom assembly (DBA).

Fig. 3 presents the main assembly. The DYNAMO equipment is mounted on an "equipped structure", which is a platform parallel to the +V panel of the orbiter, linked to its face by a set of 12 struts and 4 screws. The mechanical interfaces are the holes for the four screws (on the corners of a square shape of 430 × 430 mm) with low conductive washers for thermal insulation.

The platform is an aluminum honeycomb carbon fiber sandwich panel and the struts are carbon fiber tubes with aluminum junctions. Heaters are implemented on the panel for temperature control. The thermal control is a passive one, the main assembly is thermally decoupled from the orbiter and it is mostly insulated by MLI blankets. Two kinds of heaters are implemented: (i) a set specific for safe mode, connected to survival heating lines with thermoswitches; (ii) a set specific for nominal modes, managed by the DYNAMO common DPU/PDU.

The common DPU/PDU ensures the electric, electronics and software interfaces with the orbiter (power, telecommand, housekeeping data, science data). This common DPU/PDU has a storage capacity of 1 Gbit and Orbiter CCU could collect DYNAMO data in CCSDS packets in an asynchronous mode.

Fig. 4(a) presents the rigid boom assembly, which is fixed on the +V panel of the Orbiter. The location of this assembly is driven by two constraints: (i) distance between main assembly and RBA as large as possible in view to minimize view factor with DEMAI-INS, IENA-PID and IENA-TOF/ICE; (ii) distance between MIDST antenna and orbiter or INS-1 (the "microwave sounder", according to the AO) payload larger than 0.8 m. The length and location of this boom must be compatible with the Ariane 5 fairing and the associated launch load, and also with the AOCS thrusters located near the eight corners of the Orbiter spacecraft, presently the length is 0.85 m. Fig. 4(b) presents the 6 m deployable boom assembly, which is fixed on the −V panel of the Orbiter, near the edge between the Nadir platform and the −V panel. During launch, the arms of the boom are

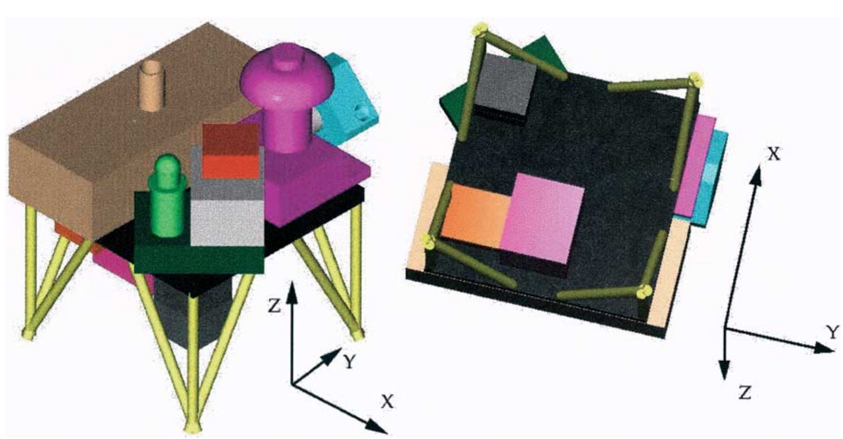

Fig. 3. DYNAMO main assembly. SOURCE: beige, DEMAI-HNA: cyan, IENA-PID: red, IENA-TOF/ICE: clear green, COMMON PDU: purple, MEMOIRE-ELECTRONIC BOX: orange, DYNAMO PANEL: black, STRUTS: yellow, DEMAI-INS: magenta, IENA-ENA: dark green, IENA-DPU: clear grey, PLASMA-WAI: drak grey.

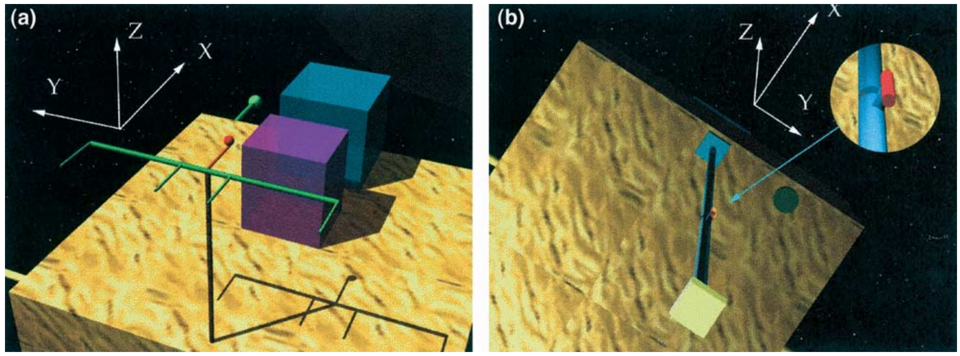

Fig. 4. (a) DYNAMO rigid boom assembly. PLASMA-LP: red, BOOM: dark, PLASMA-MIDST (antenna and wire netting sphere): green, DYNAMO main assembly: blue, INS-1: purple. (b) DYNAMO deployable boom assembly MEMOIRE: yellow, PLASMA-MSC: red, IENA ES: green, DEPLOYABLE BOOM: blue.

linked on the −V panel and a pyrotechnic device for deployment is needed. The volume of this boom, during launch, is $2 \times 0.25 \times 0.25$ m in the case of a folded boom concept, allowing the accomodation of MEMOIRE and PLASMA-MSC on the same boom at different locations.

5. Main heritages

The MEMOIRE magnetometer is derived from the compact fluxgate magnetometer developed at the DSRI/DTU and the miniature magnetometer for the CNES NETLANDER Mars surface stations. This best-of-class magnetometer has a flight heritage from the high-precision, near-Earth's magnetic field missions of the Decade of Geopotential Research [ØRSTED (1999), CHAMP (2000), SAC-C (2000)] and from the Sweedish Earth's Ionosphere research satellite Astrid-2 (1998–1999). For Absolute Attitude Determination of the magnetometer, the new Micro ASC (Autonomous Stellar Compass) from DTU is proposed. This is the newest development based on ØRSTED and CHAMP, and it represents the "cutting edge" technology in autonomous stellar attitude systems.

The hardware and software of the PLASMA PACKAGE shall be derived from previous missions, in particular Mars-96/ELISMA, Rosetta/MIP (MI), DEMETER (LP, MSC), and SMART1 (AMIE camera, for WAI).

In IENA, the EEA sensor will be identical to the SWEA electron sensor of the STEREO Mission to be delivered by CESR in 2003. The IENA/PID, from SSL Berkeley, is a new version of a detector used with a full success since many years on-board the WIND spacecraft, whereas the IENA/TOF-ICE instrument, provided by the University of Michigan, is identical at the instrument part of NASA's MESSENGER mission, the first Mercury orbiter. The IENA/ENA sensor has been developed as a part of ASPERA (Mars-Express mission).

The DEMAI instrument is in part the progeny of the DYMIO experiment flown on the unsuccessful Russian mission Mars-96, but with significant improvements including the capability of performing detailed measurements of the neutral atmosphere structure and composition and of the hot neutral population.

The layout for SOURCE is a modification of a classic design that has flown on earlier missions. Recently, a lower mass instrument was designed for the HIPPS proposal for the PLUTO FAST FLY-BY mission. This instrument design in turn has been accepted for the Rosetta UVS, named ALICE, and it is now constructed.

The common DPU/PDU will be implemented by the hungarian KFKI. This laboratory participated in the development of electronics and software for the navigation and imaging onboard TV system on the VEGA mission. It also provided the PHOBOS onboard computer of the landing unit, the DPU (and its EGSE) of five instruments measuring and analyzing electron and ion fluxes. KFKI realized the EGSE for the magnetometer MAG, and for the plasma analyzer CAPS of the CASSINI mission. In the frame of ESA's Prodex program, KFKI provided the EGSE and PDU of the plasma detector packet for the ROSETTA orbiter, and the fault tolerant central data acquisition and control computer (with its EGSE) for the ROSETTA lander.

6. Conclusion

The DYNAMO project has been on the track for nearly five years and is now quite mature. It addresses the fundamental questions of the past climate evolution of Mars under the effect of solar-wind stripping, which is assumed to have played a major role in the period following the extinction of the planetary dynamo, by removing potentially large amounts of water and carbon dioxide from the atmosphere. An important, and complementary, secondary goal of DYNAMO is the detailed mapping of magnetic and gravity fields at the best achievable spatial resolution from orbit. For all these purposes, the DYNAMO payload must be placed in an elliptical orbit with a periapsis altitude definitely lower than 200 km (ideally 120–150 km). Most of the payload is derived from already existing instruments, which have been flown, or are going to be flown, with the exception of the suprathermal neutral spectrometer (HNA). The total weight of the payload is about 30 kg in the complete version of DYNAMO, for an average power consumption of nearly 30 W, and a (rather flexible) telemetry rate of a few hundred Mb/day. The magnetometer, together with its own attitude restitution system, is accommodated on a long boom (typically 5 m), whereas a short boom (1 m) is used for the plasma package.

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 (1STRB), who met on July 1st and 2nd, 2002, as one of the three possible payload options. The final selection was first expected before December 2002.

In the time between, the US contribution has been denied funding and, due to severe budgetary problems at CNES, the French Mars PREMIER orbiter has been cancelled, implying that the DYNAMO package, as described in the present paper, will not be flown in a near future.

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