Atmospheric Mars Entry and Landing Investigations & Analysis (AMELIA) by ExoMars 2016 Schiaparelli Entry Descent Module

Conference or Workshop Item

ATMOSPHERIC MARS ENTRY AND LANDING INVESTIGATIONS & ANALYSIS (AMELIA) BY EXOMARS 2016 SCHIAPARELLI ENTRY DESCENT MODULE

F. Ferri[1], O. Karatekin[2], A. Aboudan[1], B. VanHove[2], C. Bettanini[1], G. Colombatti[1], S. Debei[1], N. Gerbal[2], S. Lewis[3], F. Forget[4]

[1]Università degli Studi di Padova, Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo" (CISAS) (francesca.ferri@unipd.it)

[2]Royal Observatory of Belgium (ROB), Brussels, Belgium

[3]School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK.

[4]Laboratoire de Météorologie Dynamique, UPMC BP 99, 4 place Jussieu, 75005, Paris, France,

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Introduction:

The *ExoMars* program, with the Schiaparelli Entry Demonstrator Module (EDM) in 2016 and the entry module containing the Surface Platform and Rover in 2020 provides the rare (one-per-mission) opportunity for new direct *in situ* measurements over a wide altitude range and with resolution not achievable over the full altitude range by remote sensing observation.

The Atmospheric Mars Entry and Landing Investigations and Analysis (AMELIA) experiment aims at exploiting the Entry Descent and Landing System (EDLS) engineering measurements for scientific investigations of Mars'atmosphere and surface.

The data recorded during the different phases are used for an accurate trajectory and attitude reconstruction and for the retrieval of atmospheric vertical profile to study the atmospheric structure, dynamics and static stability and to assess the landing site context.

ExoMars2016 Schiaparelli mission:

Schiaparelli, the Entry Demonstrator Module (EDM) of the ESA ExoMars Program entered into the martian atmosphere on 19th October 2016; although it did not complete a safe landing on Mars, it transmitted data throughout its descent to the surface, but the signal was lost about 1 minute before the expected touch-down on Mars'surface.

The EDL sequence (Fig. 1) should have lasted for 6 minutes starting with a hypersonic atmospheric entry protected by an instrumented heatshield, followed by a passive descent under parachute and an active proximity phase during which retrorockets are activated in order to slow down and ensuring a final horizontal position of the Schiaparelli platform at touch down, and finally a landing on a crushable structure for damping the impact.

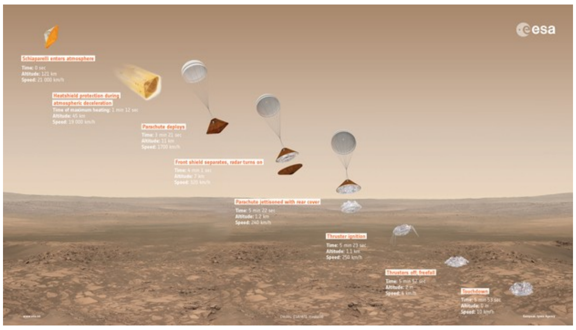

Fig.1 ExoMas2016 Schiaparelli EDL scenario

The atmospheric entry and the majority of the descent phases were performed nominally: the aerobraking under the frontshield occurred as expected, the parachute deployed normally at an altitude of 12 km and a velocity of 1730 km/s, and the heatshield, having served its purpose, was released 40 seconds after (as programmed) at an altitude of 7.8 km. The unexpected dynamics of the vehicle at parachute inflation resulted in the saturation of one of the gyroscope that caused the fatal error in the guidance and control system. The erroneous information in the attitude generated a negative altitude estimation that in turn successively triggered a premature release of the parachute and backshell, a too brief firing of the retrorockets and finally the activation of the on-ground systems (including DREAMS) as if Schiaparelli was landed.

In reality Schiaparelli was still at an altitude of around 3.7 km, therefore it continued in free fall to the crash landing on the surface of Mars (33 seconds later at a velocity of 150 m/s) (Fig. 2).

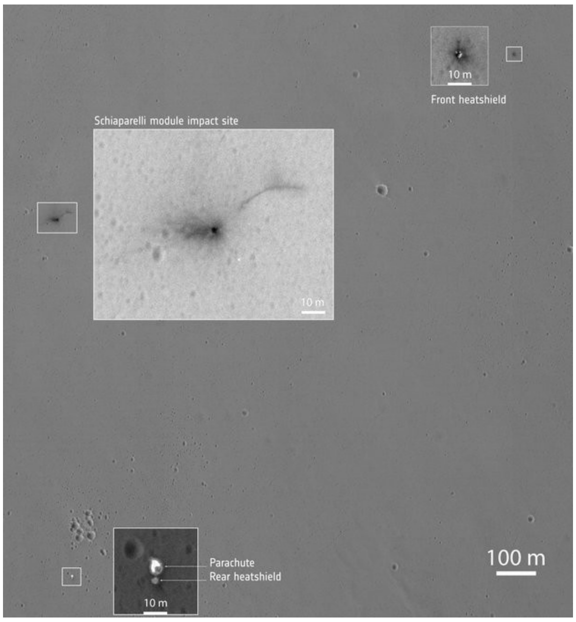

Fig. 2 HIRISE image of Schiaparelli crash landing.

Schiaparelli continuously transmitted telemetry that was received from the TGO (Trace Gas Orbiter) while the signal carrier was recorded by the Giant Metre-wave Radio Telescope (GMRT) in Pune (India) and by MarsExpress. until the loss of signal.

The radio signal and the telemetry data set, although limited, are essential to investigate the anomaly that caused the crash landing, but also for the achievement of AMELIA experiments scientific objectives.

At present these data are under analysis to investigate the reasons for the Schiaparelli's landing failure and are under embargo.

Atmospheric science:

To date only seven profiles of density, pressure and temperature have been derived from *in situ* measurements performed by *Viking 1* and *2* in day time [Seiff & Kirk, 1977], *MarsPathfinder* at night time [Schofield et al. 1997; Magalhães et al. 1999], two more profiles from *Mars Exploration Rovers* (MER): *Spirit* and *Opportunity* [Withers & Smith 2006] with much lower accuracy, *Mars Phoenix*: first profile from the martian polar region [Withers & Catling 2010] and more recently by *MSL-Curiosity* [Holstein-Rathlou et al. 2016].

Such profiles are vital for cross-calibrating remotely-sensed observations (such as from the Mars Climate Sounder instrument [McCleese et al. 2011, Kleinboehl et al. 2009,2013] on board NASA Mars Reconnaissance Orbiter), testing atmospheric models used in numerous studies of atmospheric variability on a range of temporal and spatial scales, as well as for the practical issue of reaching the martian surface reliably [e.g. Montabone et al. 2006, 2015] and to investigate the climate of Mars.

New data from different sites, seasons and time periods are essential to investigate the thermal balance of the surface and near-surface atmosphere of Mars, diurnal variations in the depth of the planetary boundary layer and the effects of these processes on the Martian general circulation. Temperature *in situ* measurements together with pressure and wind are fundamental for studying the martian atmospheric structure and dynamics, and also for the investigation of the meteorology and the planetary boundary layer on Mars.

ExoMars 2016 Schiaparelli provides the opportunity for new direct *in situ* measurements during the martian statistical dust storm season. These data contribute to exploring an altitude range and a vertical resolution not covered by remote sensing observations from an orbiter, proving a surface and atmosphere 'ground thruth' for remote sensing observations and imposing important constraint on the validation of Mars atmosphere models.

Within the AMELIA team, a strong effort has been put into atmospheric modeling and data assimilation (e.g. MGS-TES, MRO-MCS and MARCI records, MEx-PFS, optical depth from MER-Opportunity PanCam) in order to monitoring weather conditions and to assess the atmospheric context at entry, permitting comparison of the AMELIA profile with independent remotely sensed data, e.g. from Mars Climate Sounder. Finally, this expertise is fundamental for the scientific analysis and interpretation of the AMELIA results.

AMELIA simulation and reconstruction:

From the measurements recorded during entry and descent, an atmospheric vertical profile along the descent trajectory is retrieved. The AMELIA team uses different approaches algorithms and methods for simulation and reconstruction of the Schiaparelli-EDM trajectory and attitude during entry and descent phases in order to retrieve and validate the most accurate atmospheric profile.

A near-real-time reconstruction of the trajectory has been performed using the radio communication link between Schiaparelli and the radio receiver on board the orbiters (TGO and MarsExpress) and by the carrier detection by the GMRT ground station in India. The atmospheric vertical profiles of density, pressure and temperature are derived using different data and methods including: direct integration from deceleration measurement, from hypersonic dynamic pressure data recorded during entry, by data assimilation and matching an atmospheric standard model with Extended Kalman filtering (EFK) of the EDM dynamic models.

We will report the preliminary results on the atmospheric reconstruction and in terms of the assessment of the atmospheric science.

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