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From water to life: from Phoenix to EXOMARS

V. Giorgio

Thales Alenia Space - Italy, Strada Antica di Collegno 253, 10146 Torino, Italy
e-mail: Vincenzo.Giorgio@thalesaleniaspace.com

Abstract. Latest news: there definitely is water on Mars. NASA issued the announcement following measurements performed by the Phoenix Mars Lander spacecraft on samples gathered from the planet's surface. Such a discovery confirms what the scientific community has long posited: some kind of life form could have developed on Mars, and may still be there; a kind of life form that was undoubtedly able to adapt to the Red Planet's harshest environmental conditions. However, scientists won't stop here: quite the contrary, they intend to keep going. The next step is to find evidence of that life, traces of its past or current existence. That is the task that was assigned to EXOMARS European Mission, whose main purpose is carrying out research into Exobiology, that is to say research into the origin, evolution and spreading of life across the universe.

1. Introduction

The Exomars mission is taking on a huge scientific challenge: to achieve its goals, it embraces the best of available technologies. Exomars has also required the development of a whole set of technological solutions already implemented and applied to various fields of space research, but never put together and combined in a single mission. To achieve its scientific goals, Exomars needs as many as three different sets of instruments enabling it to, respectively, analyze the planet's external environment and obtain subsoil stratigraphy -the "panoramic instrument" - provide a description of its mineralogy and surface soil composition -the "contact instrument" - and analyze samples from the subsoil in order to detect possible traces of organic matter and identify their composition.

So the mission needs, first and foremost, a mobile lab or Rover to move as autonomously as possible in a hostile, semi-unknown environment. The space vehicle will have to reach and analyze the rocky formations which -like on earth-are most likely to have preserved remains of the planet's past. Exomars Rover movement capabilities are by far higher than those required and implemented in previous NASA missions, due to the higher difficulties the vehicle is expected to find in the area to be observed as well as to the higher distances between sites of possible scientific interest. The challenge of the rover's moving capability calls for the contribution of a number of technological developments from robotics (for locomotion) image acquisition and processing (vision and navigation) to avionics (development and miniaturization of components such as computer and power generation/distribution units).

The second big challenge is that of collecting Martian soil samples to be analyzed with a variety of available instruments; it is hoped such samples will contain evidence of life forms such as spores or bacteria that are still intact to possibly provide the largest amount of

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Send offprint requests to: V. Giorgio

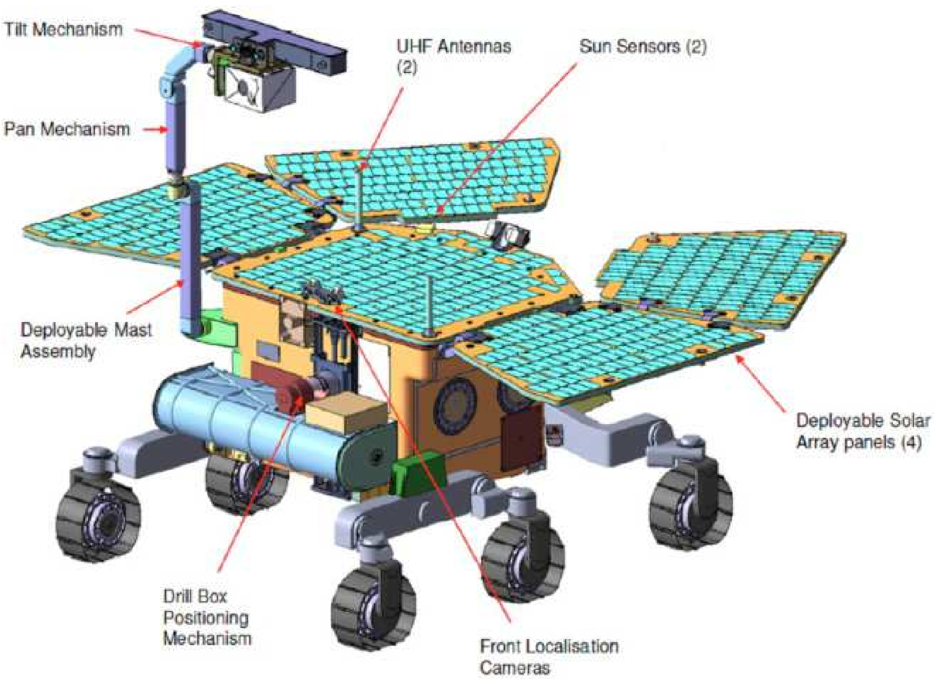

Fig. 1. EXOMARS rover view.

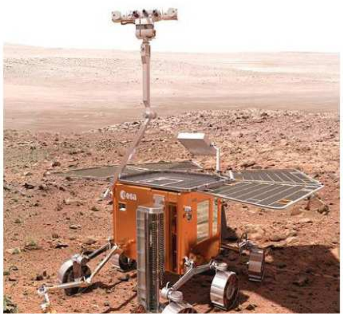

Fig. 2. The rover in action on Mars.

information. The big dilemma to tackle is, in a few words, linked to the fact that, unlike Earth, Mars lacks a layered atmosphere able to shield the planet from sun rays (and mainly from UV radiations) and their effects.

Hence, radiations can pass through its superficial layer thus damaging or even destroying the microorganisms that may be there. That is why samples have to be collected directly from the subsoil, where the integrity of possible life traces is more likely to be preserved. To this end, the Exomars Rover is fitted with a novel drill, manufactured in Italy, which can burrow 2 meter deep beneath the Martian soil, and gather samples from the hardest soil layers. This technology combines the heritage from previous European missions like Rosetta with the developments stemming from targeted studies implemented based on contracts with the Italian Space Agency. Once collected, the sample must be prepared and distributed among the various instruments in suitable and relevant form and quantity. This requires the development of a complex system - the Sample Preparation and Distribution System - able to prepare, or rather grind samples into dusts, dose them and submit them for analysis being very careful not to alter their

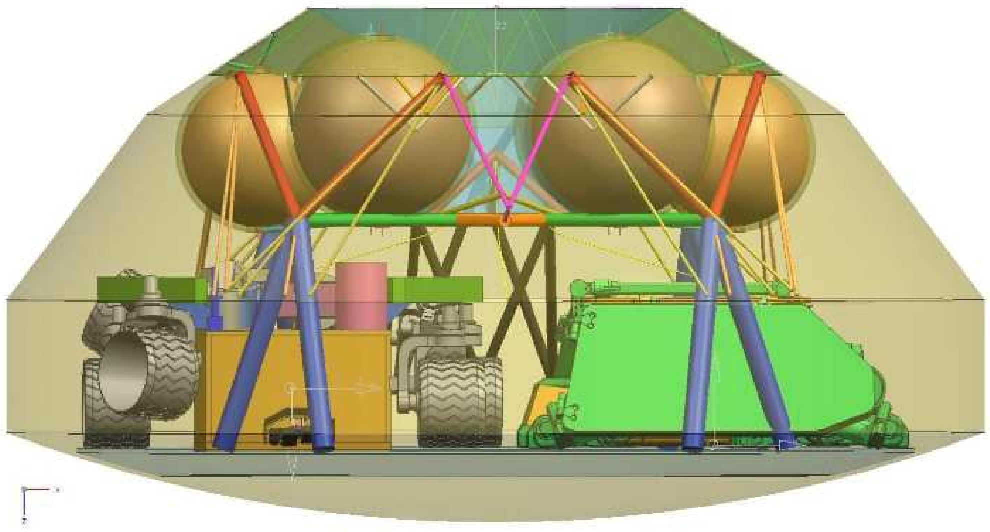

Fig. 3. EXOMARS Rover (right) and the American one (left) within the SkyCrane (Source: NASA).

components nor contaminate them with what may alter analyses results.

2. EXOMARS: two missions to the Red Planet

With its ExoMars program, and through its Space Agency (ESA) and leading edge aerospace companies, Europe prepares for a great comeback to Mars with a set of ambitious technological and scientific objectives to be implemented in two missions to be launched with a two-year interval between each other, the first being scheduled for January 2016, the second for May 2018. Both missions will be implemented in cooperation with NASA, the American Space Agency

2.1. 2016 mission

The first mission to the Red Planet will feature a spacecraft consisting of an orbiter plus a descent module. The spacecraft will be launched from Cape Canaveral with the help of an Atlas V 421 missile; the optimal launch window will last about 21 days, from the 7th to the 27th of January, 2016. The carrier will bring the spacecraft onto what is known as Type 2 trajectory, with arrival to Mars scheduled after a nine-month cruise. On the 16th of October, the descent module will separate from the orbiter and, following a three-day approach phase needed to get closer to the Planet, it will reach the boundary of the Martian atmosphere, the so-called entry interface point, 120 km from the Planet's surface. At that point, the fast descent sequence will begin: in about 4 minutes, the entry module will slow down due to atmospheric friction; at a height of approximately 10 km a parachute will deploy and remain open for a couple of minutes thus bringing descent speed to 70 m/s (250 km/h). Both the parachute and a portion of the descent module will detach at about 1000 m from the surface: that is when the control system, based on a radar altimeter, a gyroscope package and nine small braking engines will lead the spacecraft to Mars landing approximately 30 seconds after parachute detachment at a max. speed of 3,7 m/s (about 13 km/h). The landing phase will be further softened by a specially developed carbon fiber

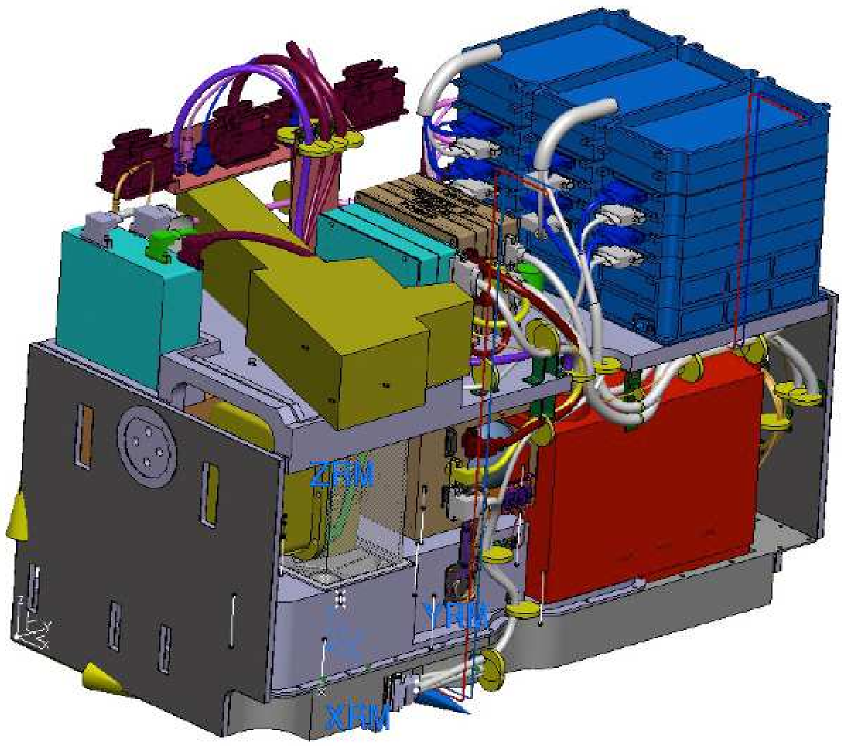

Fig. 4. View of the Rovers Analysis Lab.

shock absorption structure. Arrival on Mars is therefore scheduled for 19th October, 2016, between 1 and 2 pm, local time, on a location in the Meridiani Planum area, Longitude 6.1 deg West, Latitude 1.9 deg South. While the entry module descends onto the planet the orbiter will perform a braking manoeuvre which, by slowing it down, will enable it to enter an elliptical orbit around the planet. In fact, in its first steps on that orbit, the orbiter will be a few hundred kilometers from the descent module that it will keep following to gather the landing data the entry module will send through its UHF band system. Once the monitoring phase is over, the orbiter will change orbit with its propulsor, first by changing inclination and then shifting from an apocenter of 95000 km to a 34000 km one; the initial and final orbits correspond to four and one Martian day - sol - period respectively. The final operational orbit is then reached by the orbiter through a long braking phase achieved during the passage through the Martian atmosphere at a 180 km height; such a phase is going to last about six months, after which the orbiter will settle into its final, circular orbit - approx 400 km high. That is where the satellite will perform a series of observations of the Martian atmosphere and surface with a complex set of six scientific instruments. Scientific observation will stop after two Earth years (one Martian year) and the orbiter will start acting as a radiolink between Earth and the two rovers that will have landed in the meantime (see 2018 mission) and for missions to come until 2022.

To summarize, the objectives of the 2016 mission are :

– Acquire the largest amount of data during entry into the Martian atmosphere

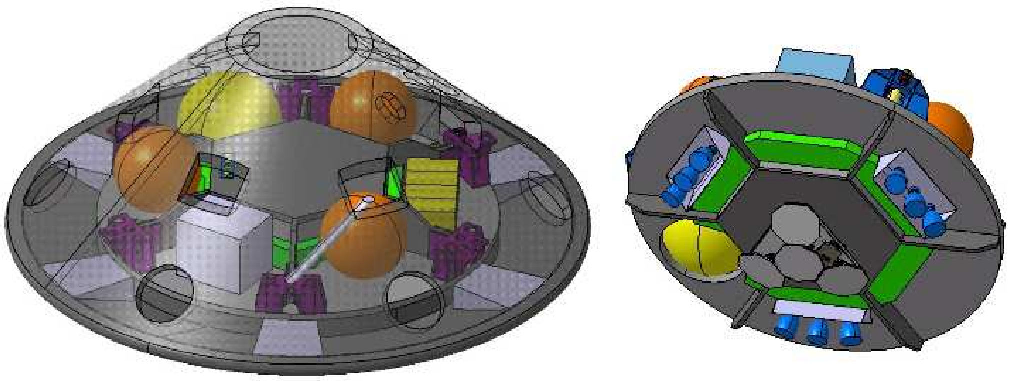

Fig. 5. Entry Descent and Landing demonstator.

- Land with a 600 kg capsule for demonstration purposes
- Operate a payload on the surface for a short period
- Observe the Martian atmosphere and surface for two years
- Act as a radio link for transmissions between the Rovers and Earth

2.2. 2018 mission: the Rover and its Control Centre

As to the second mission, the launch will take place in May 2018 at the Cape Canaveral American base with an ATLAS V rocket; the spacecraft is scheduled to arrive at Mars on the 14th of January 2019. The European Rover will travel along with an American one called Max-C. Both will be lowered to Mars' surface by a special system landing on Mars, the Sky-crane, provided by the NASA in the framework of USA-Europe cooperation for EXOMARS. The EOMARS Rover enjoys a high level of autonomy and will travel on the Planet's surface under the guidance of a navigation system based on stereo vision and sun and inertial sensors, which will make it able to choose the most suitable path towards scientific investigation sites. Its self-steering, lifting six-wheeled locomotion system provides the Rover with the capability to travel or walk on Mars surface and overcome obstacles up to 20 cm in height. On board electrical systems are solar powered with panels that charge a Lithium-ion battery. A set of small radioisotope generators, 1 watt each, is installed on the most sensitive Rover areas to provide heating during the cold Martian nights when the temperature can get lower than -100 degrees Celsius. During the day, radiating panels will dissipate excess heat.

The Rover is fitted with a UHF communication system that is compatible with that of other NASA operated orbiters. Communications with Earth are exchanged through the orbiter launched in 2016 to act as a radiolink with the Earth's stations; thus, signals and images from the Rover will be received at its Control Centre, located in Turin on Altec premises, as needed to plan and implement the mission and receive, store and spread scientific data detected on board. Said drill can collect small samples from surface ground and from the underground to a depth of 2 meters. The scientific community mainly aims to confirm that water was indeed present in Mars subsoil, and, with some good fortune, to uncover organic molecules and traces of past or present life in the form of bacteria or spores. That is why the Rover belongs to an integrated controlled cleaning environment, with all components that can come into contact with Martian samples undergoing a so called "ultra-cleaning" process to avoid bringing

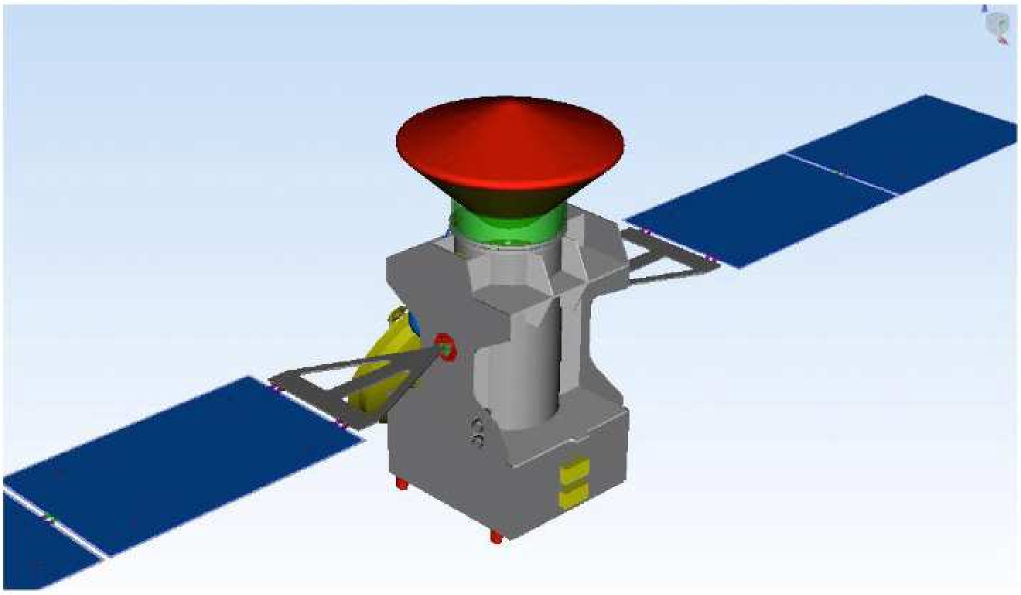

Fig. 6. View of the Exomars Orbiter.

Earth life forms on the Planet that may cause false positives in the search for life on Mars.

On board instrumentation also includes a Radar to detect underground water deposits, that can also be used, if needed, to pilot drilling operations. ExoMars Rover's mission will last about six months. The Rover weighs about 300 kg, but since Mars gravity is one third that of Earth, its actual weight on Mars will be approximately 100 kg.

The Preliminary ExoMars project phase, identified by the letter B in field of space science, started in March 2009 with Thales Alenia Space - Italia (TAS-I) as Prime Contractor. More specifically, the Turin Plant was tasked with designing the entire 2016 mission and building the entry and descent modules, plus the 2018 missions Rover, analysis lab, operating systems for the Control Centre, which as already mentioned, will be set up at Altec. The Turin plant will also take care of integrating into the Rover the drill system built by Galileo Avionica in Milan, and preparing for the implementation of both missions. The Orbiter for the 2016 mission will be built by Thales Alenia Space - France (TAS-F) at its Cannes plant.