Chapter

Introductory Chapter: Mars Exploration - A Story Fifty Years Long

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1. Introduction

Mars has been a goal of exploration programs of the most important space agencies all over the world for decades. It is, in fact, the most investigated celestial body of the Solar System. Mars robotic exploration began in the 1960s of the twentieth century by means of several space probes sent by the United States (US) and the Soviet Union (USSR). In the recent past, also European, Japanese, and Indian spacecrafts reached Mars; while other countries, such as China and the United Arab Emirates, aim to send spacecraft toward the red planet in the next future.

1.1 Exploration aims

The high number of mission explorations to Mars clearly points out the importance of Mars within the Solar System. Thus, the question is: "Why this great interest in Mars exploration?"

The interest in Mars is due to several practical, scientific, and strategic reasons. In the practical sense, Mars is the most accessible planet in the Solar System [1]. It is the second closest planet to Earth, besides Venus, averaging about 360 million kilometers apart between the furthest and closest points in its orbit. Earth and Mars feature great similarities. For instance, both planets rotate on an axis with quite the same rotation velocity and tilt angle. The length of a day on Earth is 24 h, while slightly longer on Mars at 24 h and 37 min. The tilt of Earth axis is 23.5 deg, and Mars tilts slightly more at 25.2 deg [2]. Further, Earth and Mars revolve around the Sun with about the same revolution velocity. The former orbits at 30 km/s and the latter at 24 km/s. A year is 365 days on Earth and almost double that at 687 Earth Days on Mars [2]. Both Earth and Mars have four seasons each. Severe dust storms occur during the summer in the Mars' southern hemisphere. They are so strong that block most of the surface from view by satellites. During the fall, in the Mars' polar regions, crystals of carbon dioxide (CO_2) form and so much of the atmosphere gets absorbed that atmospheric pressure drops up to 30% as seasons transition from fall to winter [2].

From the scientific point of view, it is worth noting that exploring Mars provides the opportunity to possibly answer origin and evolution of life questions and could someday be a destination for survival of humankind. In fact, the red planet is a stony body with atmosphere, like Earth, with the same age, yet with only half the diameter of Earth, and with similar geological structures, as cold and desert-like surfaces, mountains and volcanoes, lava plains, cratered areas, giant canyons, wind-formed features, ancient riverbeds and, a very important thing, the presence of water. Therefore, Mars could provide several information about what the Earth beginning was and, especially, what the future expected to Earth will be, if climate changes arise and persist.

Finally, in the strategic sense, exploring Mars demonstrates political and economic leaderships of a nation, improves the quality of life on Earth, inspires young generations, and helps learn about our home planet.

The first successful approach to the red planet was with the flyby of the US Mariner 4 spacecraft (see **Figure 1**), on July 15, 1965 [1].

The flyby mission allowed getting the Mariner 4 space probe very close to Mars so that it was able to collect photos of the red planet in passing, see **Figure 2**. They were first Mars images ever returned to Earth [3].

Since then, more than 50 missions were planned and partially successfully accomplished. The Mars exploration, in fact, is characterized by a high failure amount, especially the early attempts. Roughly 30% of all Mars missions failed before completing their goals and some failed even before their observations could start. As is well known, Mars missions represent a great success for aerospace engineering because of they feature several complex phases, like launch, interplanetary journey, approach, entry and descent flights, and landing; each one is unique and demands great efforts. These exploration missions answered several fundamental questions, such as dispelling the myth of canals that evidenced an ancient civilization and investigated the antique riverbeds present on the surface, which suggests the presence of liquid water and maybe of past life forms, which may lie hidden below the planet's forbidding exterior.

1.2 Mars missions timeline

The timeline of the most important Mars exploration missions is herein reported [5].

1965—Mariner 4 (see **Figure 1**) passes very close to Mars (within nearby 10,000 km) and provides the first closest images of the surface [5].

1969—Mariners 6 and 7 pass at around 4000 km from the planet and send several data of Mars atmosphere and surface [5].

November 3, 1971—Mariner 9 orbits on November 24. It is the first US probe orbiting around a celestial body other than Earth. Mariner 9 returns detailed data on the planet's atmosphere, maps its surface, reveals Martian topography, and captures many more images of the red planet [5].

December 2, 1971—The USSR's Mars 3 orbiter (see **Figure 3**) returns some 8 months of data that reveal much about the planet's topography, atmosphere, weather, and geology [5].

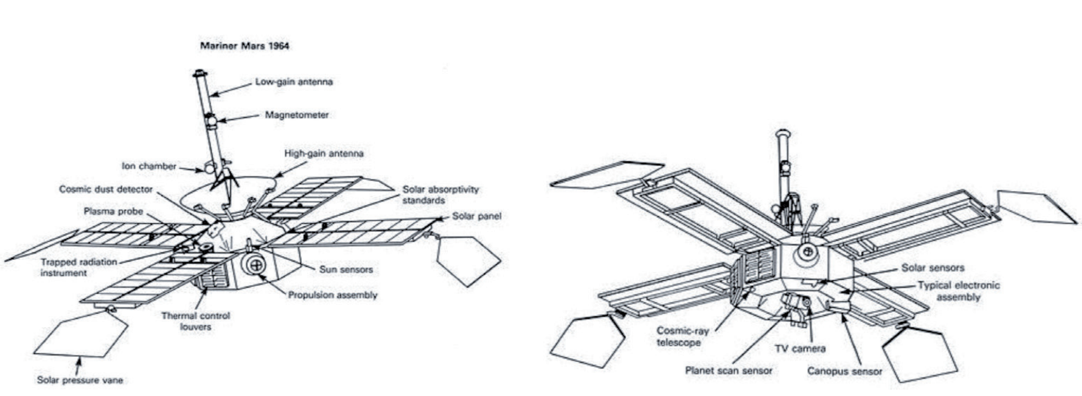

Figure 1.
The Mariner spacecraft. Credit: NASA [1].

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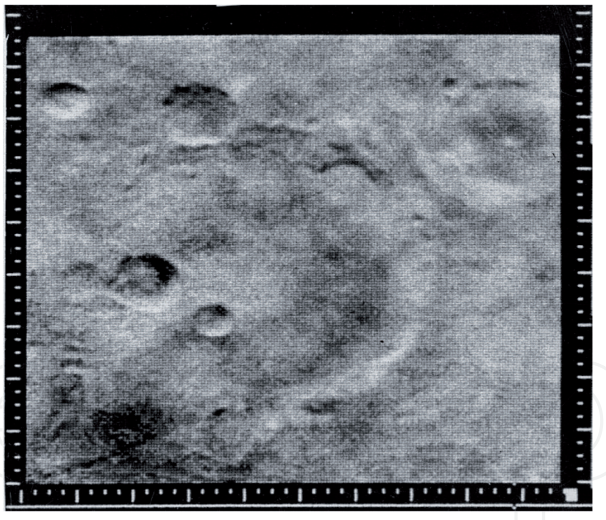

Figure 2.
Photo of Mariner crater on Mars taken by Mariner 4. Credit: NASA/JPL [4].

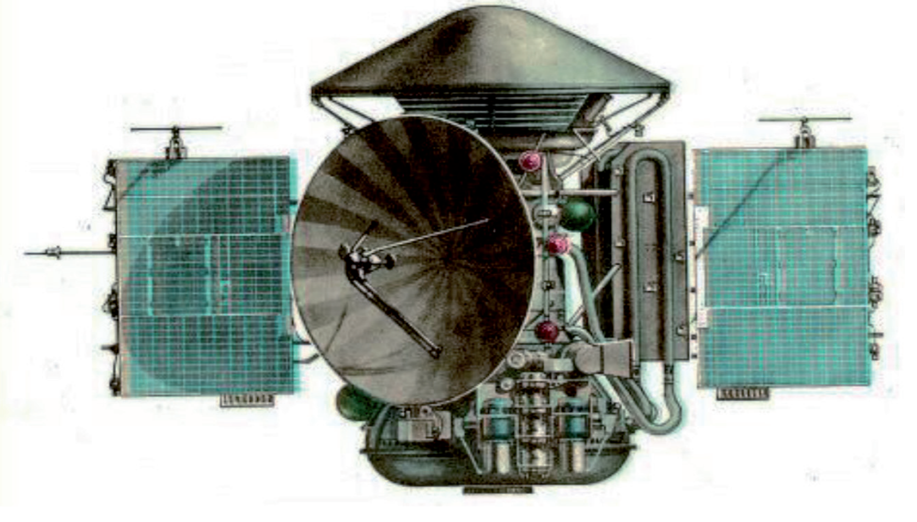

Figure 3.
The Mars 3 spacecraft. Credit: NASA [6].

But the major success is that for the first time, the Mars 3 lander successfully touches the planet's surface, see **Figure 4**. But, the lander sends data for only 20 s [5].

July and August 1973—The USSR launches Mars 4, 5, 6, and 7, but only Mars 6 lands [5].

July 19, 1976—Viking 1 (see **Figure 5**) arrives at Mars. It was launched on August 20, 1975. Viking 1's lander (see **Figure 6**) reaches the Mars surface on July 20 [5]. The primary mission objectives were to obtain high resolution images of the Martian surface, characterize the structure and composition of the atmosphere and surface, and search for evidence of life [8].

September 3, 1976—The lander of Viking-2 reaches the surface of the red planet. Viking 1 and 2 spacecrafts continues to send back data as late as 1982 [5]. They capture extraordinary images of the Mars surface that astound the public and excite scientists. The landers also conduct biological experiments on soil to search for evidence of life in space—but their results are inconclusive, though tantalizing [5].

September 25, 1992—NASA launches the Mars Observer (MO) [5].

September 1997—The Mars Global Surveyor (MGS) reaches Mars and begins its orbit up to the end of mission on November 2, 2006 [5]. NASA's MGS mission

Figure 4.
The Mars 3 lander. Credit: NASA [6, 7].

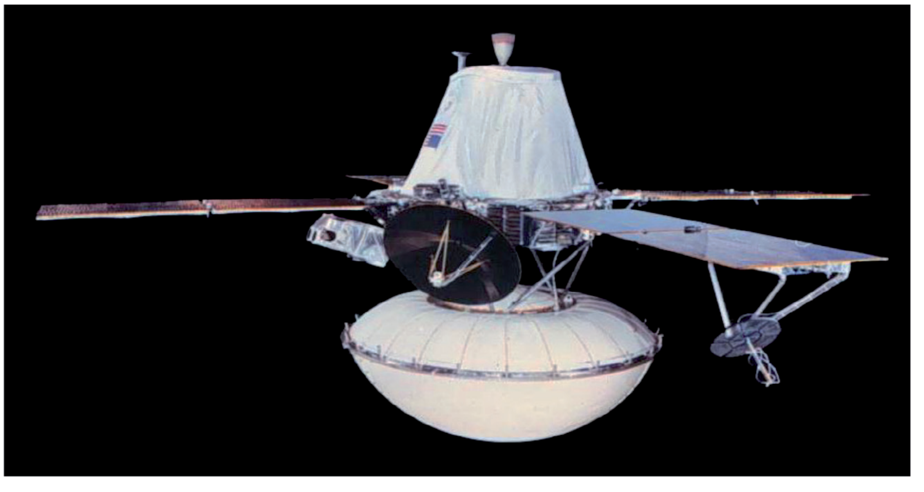

Figure 5.
The Viking spacecraft. Credit: NASA [8].

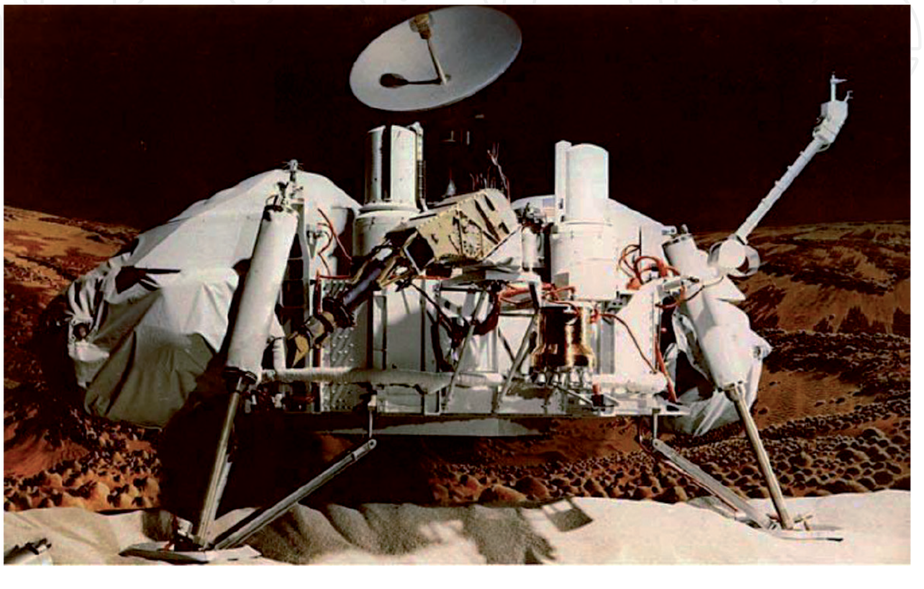

Figure 6.
The Viking lander. Credit: NASA [8].

objective is mapping and studying the Mars' surface. The mission provided insights into the dynamic changing seasons and shifting weather, including its strong dust storms [5].

July 4, 1997—The Mars Pathfinder lands on Mars and the rover Sojourner starts exploring the planet and sends back images to Earth for 4 months, see **Figure 7**. Sojourner proves that it is possible to land a free-moving rover vehicle that travels around the Mars surface, thus collecting scientific data, such as images, weather observations, and chemical soil analyses [5].

December 11, 1998—NASA launches the Mars Climate Orbiter (MCO) but unfortunately is lost on arrival in September 1999 [5].

January 3, 1999—NASA launches the Mars Polar Lander (MPL) but the spacecraft is not able to communicate with the ground control on December 3 [5].

October 24, 2001—The Mars Odyssey Orbiter (MOO) reaches Mars [5].

June 2, 2003—The Mars Express Orbiter (MEO) is launched by the European Space Agency (ESA), with the Beagle 2 lander [5]. MEO spacecraft successfully orbits around Mars, where it studies the planet for 2 years. Unfortunately, the Beagle 2, planned to land on December 25, 2003, never makes contact. January 16, 2015—NASA declares that the Beagle 2, has been found on Mars with solar panels not fully open upon landing. This probably not allowed communication with ground control [5].

June 10, 2003—The rover Spirit is launched [5].

July 7, 2003—NASA launches the rover Opportunity. Both Spirit and Opportunity (see **Figure 8**) belong to the NASA's Mars Exploration Rover Mission [5].

January 3, 2004—Spirit lands on the red planet and begins transmitting images of the Mars surface [5].

January 15, 2004—The rover Spirit leaves its lander and starts to study the rocks and soil for evidences of water [5].

January 25, 2004—The rover Opportunity reaches the Mars surface and starts its exploration mission that lasts 33 months longer than originally designed [5].

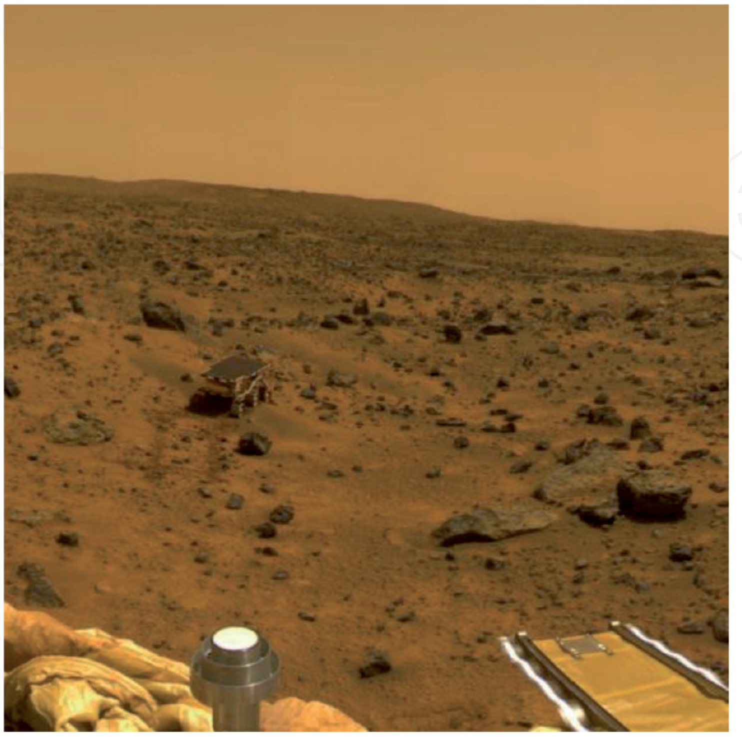

Figure 7.
Pathfinder lander camera image of Sojourner atop the "Mermaid Dune" on Sol 30. Credit: NASA [9].

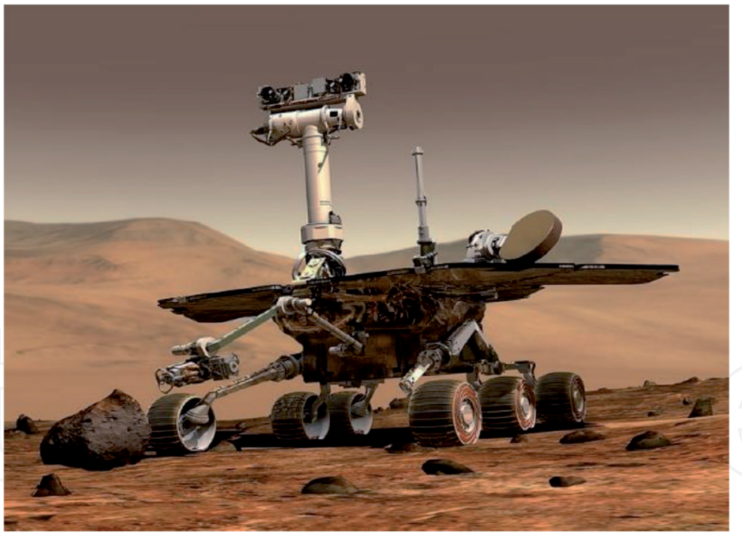

Figure 8.
An artist's concept portraying a NASA Mars exploration rovers opportunity and Spirit on the Mars surface. Credit: NASA [10].

February 2, 2004—Both Spirit and Opportunity rovers are fully operational and explore Mars surface by gathering soil samples and images, to find sign of the past Martian environment [5]. The last communication is heard from Spirit on March 22, 2010, while Opportunity is still operational. June 10, 2018, the last communication is heard from Opportunity in Perseverance Valley. Finally, on February 13, 2019, NASA announces the Opportunity mission complete. Spirit and Opportunity rovers cover several kilometers and return a lot of high-resolution photos. Probing soil and rocks, they also use their fully equipped lab modules to conduct geology tests on the surface and below it [5].

March 10, 2006—The Mars Reconnaissance Orbiter (MRO) reaches the red planet and starts to scan Mars for more signs of water. MRO features the most powerful camera ever to leave Earth, called HiRise [5].

August 4, 2007—NASA launches the Mars Phoenix Lander (MPL). It lands near Mars northern pole on May 25, 2008. [5]. Phoenix belongs to the Scout program for low-cost and small spacecraft of NASA and aims to analyze soil samples and scan the atmosphere. In November 2008, the MPL stops communications after the mission competition which last for 149 days. The mission is expected to last for 90 Martian solar days [5].

Finally, on September 10, 2010, scientists release data from the MPL where it appear that water has been weathering planet surface during history. Data also points out that CO_2 atmosphere has been supplied by geologically recent volcanic eruptions, suggesting the presence of a possible ongoing activity [5].

April 6, 2011—NASA shows Curiosity, see **Figure 9**. It is a rover bigger than Spirit and Opportunity, with about 900 kilograms weight and the dimensions of a small utility car [5]. Curiosity is launched on November 26, 2011 and successfully lands on Mars on August 6, 2012. June 7, 2018—NASA declares that an organic matter has been detected by the rover in the Gale crater soil samples. Curiosity has also found methane in the atmosphere [5].

September 21, 2014—NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission space probe orbits around the red planet with the aim to study the higher atmosphere in order to understand the Mars' past climate changes and habitability [5].

September 24, 2014—India's Mars Orbiter Mission (MOM) orbits around Mars. India is the first Asian nation to reach Mars and the first country to successfully accomplish the mission on its first attempt [5]. The spacecraft continues to operate after its 160-day mission.

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Figure 9.
NASA Mars exploration rovers Curiosity. Credit: NASA [11].

March 14, 2016—ESA launches Trace Gas Orbiter (TGO) with a lander called Schiaparelli, within the program Exobiology on Mars (ExoMars) [5]. TGO successful enters Mars' orbit, while Schiaparelli fails a soft landing and crashes. TGO detects atmospheric gases to prove the presence of life on Mars.

May 5, 2018—NASA launches Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) [5]. It is the first robotic explorer designed to study the interior of Mars. InSight lands just north of the planet's equator on November 26, 2018, joining five other NASA space probe working on and above Mars.

July 25, 2018—The results of a study of Italian Space Agency (ASI) scientists indicates the presence of a liquid water lake below the southern polar ice cap of Mars. This results have been achieved using the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument of ESA [5].

1.3 Next planned robotic missions

The end of July 2020 will see even three robotic exploration missions. Il will be multiple launches never seen before in the history of space exploration.

July 20, 2020—The United Arabs Emirates Mars Mission is a planned space exploration mission which aims at entering in Mars' orbit, the probe is called Hope.

July 23, 2020—Tianwen-1 is a planned mission by China. The space probe features an orbiter and a lander with a rover. Mission aims are to find out sign of both current and past life, and to investigate the Mars environment.

July 30, 2020—The NASA Mars 2020 mission belongs to Mars Exploration Program. It comprises the Perseverance rover to investigate Mars' surface geological processes and history, including the appraisal of its past habitability, ancient life forms, and the potential for the preservation of biosignatures within accessible geological materials.

1.4 The next frontier: human-rated missions

So far, the remotely unmanned exploration missions provided a huge increase in knowledge about the Martian system, especially for what concerns the understanding of its geology and habitability potential. But the red planet still represents the next frontier of space exploration.

The new goal, in fact, is to send astronauts to Mars with acceptable cost, risk, and performance. Proposals for human-rated missions have been made throughout the space exploration history and have also been an inspiration since the earliest days of Space Science. For instance, for Robert H. Goddard, the idea of reaching the red planet was fundamental to overcome all the difficulties he met in his research studies on the Space Flight.

Human exploration was identified as a long-term goal in the US space exploration vision. Conceptual works and plans of NASA focus on missions typically being stated as taking place after about 10–30 years from the time they are drafted. On September 28, 2007, NASA's then-administrator Michael D. Griffin stated that the US aims to send men on Mars by 2037. The Orion crew exploration vehicle (CEV) would be used to send a human mission to the Moon by 2024 within the Artemis program as a steppingstone to a Mars expedition [12]. A flight to Mars could follow this program.

Currently, active plans foresee the landing on Mars of a crew made of two up to eight astronauts that would visit the red planet for a period of a few weeks or a year. The aim is exploration at a minimum, with the possibility of sending settlers and terraforming the planet for the permanent colonization of Mars or exploring its moons Phobos and Deimos as well. On October 8, 2015, NASA unveiled its official plan for human missions to Mars, called Journey to Mars, leading up to fully sustained colonization. The plan develops through three phases, namely Earth Reliant phase, Proving Ground phase, and Earth Independent phase. During the first phase (Earth Reliant), the International Space Station will be used to validate deep space technologies and study the effects of long duration space missions on the human physiology. The second phase (Proving Ground) will focus on the research/scientific activities away from Earth and to be accomplished into cislunar space. Activities in this phase are to test deep space habitation facilities, and validate capabilities needed for human exploration of Mars. Finally, the third phase (Earth Independent) features the transition to independence from Earth resources. This last stage comprises long-term missions on the lunar surface, which leverage surface habitats that only require routine maintenance, and the harvesting of Martian resources for fuel, water, and building materials. Anyway, it is expected that Earth's independence could take several decades.

Crewed mission to Mars is extremely challenging both from the engineering and human point of views. A safe, reliable, and affordable mission design must include the shortest interplanetary journey, a safe transportation system with radiation shielding, centrifugal artificial gravity, in-transit consumable resupply, and an orbiter and a lander which can return.

As far as human factor is concerned, it is worth noting that a not negligible mission aspect is the psychological effort. A typical mission would last at least 18 months. Therefore, for a crew staying for this long time and very far from Earth (for the first time in the history) continuously subject to a hostile environment could be extremely challenging from a psychological point of view. Several experiments are planned or yet executed by Space Agencies in order to make sure that astronauts are prepared mentally and physically for the demands of long exploration missions. For example, ESA undertook a cooperative project with the Russian Institute for Biomedical Problems (IBMP) in Moscow, called Mars500. This test began in February 2010 and the end of the isolation period was November 4, 2011 [13]. Further, on August 28, 2015, NASA funds a year-long experiment, with six scientists, to investigate the effects of long Mars mission. The crew lived in a bio dome on Mauna Loa mountain, Hawaii, with partial connection to the outside world and were only allowed outside if they were wearing spacesuits [14].

For the time being, Mars still inspires next generations of scientists (physicists, engineers, mathematicians, and so on). It seems still far from human's exploration, but great efforts are made, ongoing and planned for the next future.

A day will arrive when a new small step will be moved forward for a giant leap for mankind.

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