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Specific work guide about "Manned Mission to Mars"

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Introduction

46 years ago, or to be precise, on 20th July 1969, when Neil Armstrong stepped on the Moon and said that famous phrase: "one small step for man; one giant leap for mankind", it was the culmination of a technical effort of remarkable dimensions, that has never been repeated in the space industry and could only be brought about by the strong will of the American government of the time.

The decision to send a man to the moon was announced by American president John F. Kennedy on 25th May 1961. In a joint session between the senate and the chamber of representatives, he announced that the United States of America should lead the exploration of space and that the nation had to undertake the challenge of putting a man on the Moon before the end of the decade.

NASA, created only three years prior, had already taken the decision to begin a similar project, but soviet advances meant they had to rush. In April 1961, the USSR launched its first manned flight, making one complete orbit of the Earth. In May of the same year, the first American astronaut completed only one suborbital flight. The advantages the soviets were showing in the field suffered a series of political setbacks in the cold war. All this meant that president Kennedy could accelerate the initial plan to demonstrate the capability of American technology.

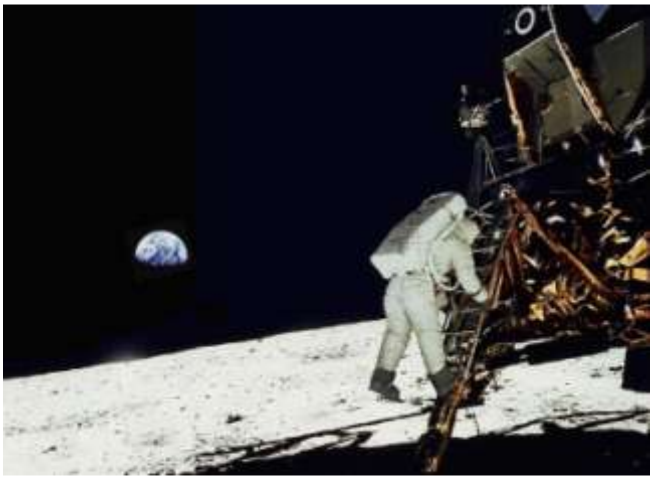
To give an idea of the efforts made, it is enough just to see the approximate cost of the project:: 121,000 million dollars (at 2015 value). Within this figure the projects Geminis, Mercury and Apollo, are included, but not Lunar Orbiter or Surveyor that also, as we will see later, contributed to the success of the Apollo program. For comparison's sake, the cost of the Mars Science Laboratory (Curiosity) was approximately 2,500 million dollars.

All of this adventure began with the Mercury project in 1959, whose objective was for an astronaut to orbit the Earth and study the effects of the lack of gravity on human beings. The program went on until 1963 and in that period they launched 5 missions. The first to were suborbital flights and the following four. The first and the second orbited the Earth three times, the third seven and the last twenty-two. They carried out communications and navigation tests for ships in orbit.

The continuation of the Mercury series was the Geminis. This program began in 1963 and continued until 1966. During their 12 missions they managed flights as long as those previously completed on the Moon missions. They also commenced activity outside the space vessel, trying out different space-suit designs. They carried out docking and separation manoeuvres between two vessels, equally necessary for the recovery of astronauts once their Moon mission was complete, and like on the Mercury voyages, they continued to study how microgravity affected the astronauts.

In parallel to Mercury and Geminis they accomplished two other programs, these ones robotic, focused on getting to know the Moon in more detail. They named them: Surveyor and Lunar Orbiter. The first ones were designed to understand the surface, landing on it and taking images and data about the types of materials existing on the surface and its physical characteristics, with the objective of finding out how a ship with large dimensions would behave whilst landing in this environment. There were six missions that were launched between 1966 and 1968. The four Lunar Orbiter missions photographed practically all the Moon's surface with special attention to the previously chosen landing spots.

The Apollo program was composed of 17 missions. It began in 1967 and continued until 1972, landing on the Moon from Apollo 11 onwards. The last three were fitted with a small rover allowing them to extend the astronauts' exploration area.

On the right is shown an image of Apollo 11 in which the Lunar Module can be seen. The left image corresponds to Apollo 17 and here the rover the astronauts used to move around can be seen.

None of the 6 missions (Apollo 11 had a problem on the flight to the moon that meant the mission was aborted) that arrived at the Moon's surface was there for more than three days. Activities of a scientific nature were carried out, collecting a large quantity of samples.

As it was seen that arrival on the Moon would not be easy, three previous programs were needed in which a large quantity of new technology was developed and tested. Either way they had to learn step by step about the behaviour of man outside Earth, in foreign surroundings.

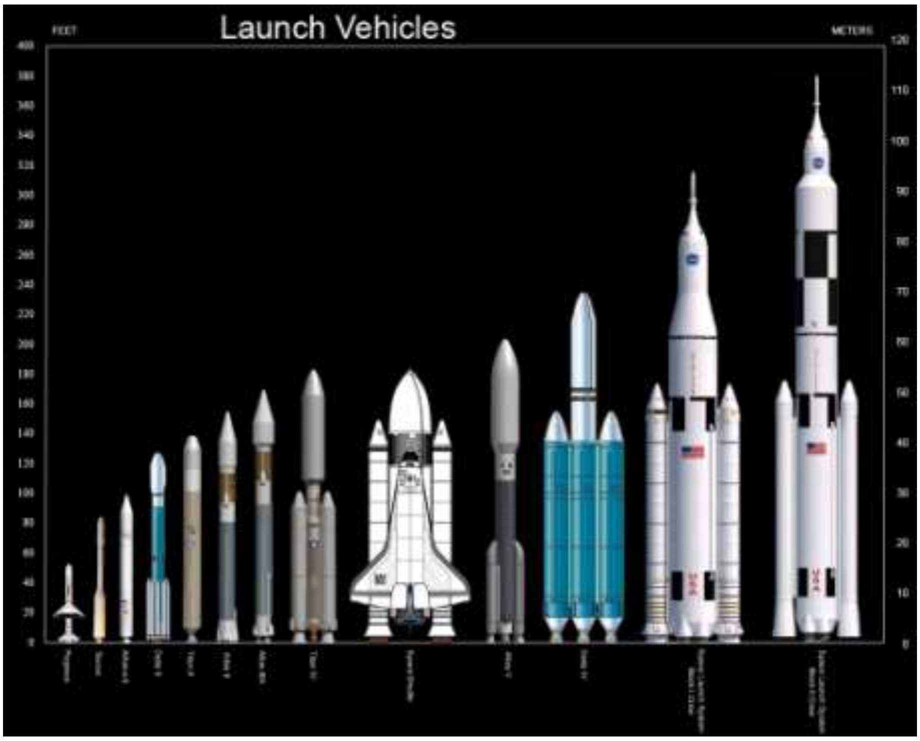
Since then the International Space Station (ISS), the robotic missions to Mars and other bodies in the solar system have been developed. The effects of weightlessness on human beings is better known. Much more is known about Mars, Venus, Europa, etc. All of this has been brought about by robotic exploration.

Currently the relaunch of the program abandoned in 1972 is being planned, and astronauts will again be sent further than the 400km journey to the ISS. Human missions to Mars have been proposed.

The same as the Moon, to go to Mars, new technological challenges arise. We will look at these briefly in the following section.

Planning manned missions to Mars

In 1989 president Bush ordered a study to evaluate the costs of maned missions to Mars and the Moon. Since then different estimates of costs to send man to Mars with varying credibility have been produced, but perhaps now is the moment in which we are closest to make study become reality, to having a program like Apollo, Mercury etc., that would permit us to arrive on Mars during the decade of the 30s, with adecuate financial sustainability.



Family of launch vehicles, in which we see on the right the dimensions of the new ones designed for human exploration of Mars.

More powerful boosters

Although not mentioned in the introduction, a very important part of the successful exploration of the Moon was the development of launch vehicles. In fact, they still use many of the designs produced at that time. In particular the most powerful of all, the legendary Saturn V, able to put 130 tons of cargo in low orbit, is still the only one who could take man to the moon once more.

But Mars exploration requires sending much heavier loads. It is estimated that all the equipment that would be the first astronauts on Mars could weigh between 700 and 1300 tons. What makes it absolutely necessary to develop a new generation of launch vehicles?

NASA began on this trajectory in 2005 when it launched the Constellation program, with the aim of developing a new launch vehicle able to return to the Moon and eventually reach Mars. This program was cancelled in 2010. Subsequently, President Obama signed a law which "required the immediate development of a launch vehicle for heavy loads and a vehicle for manned exploration missions that can withstand journeys beyond low earth orbit starting in 2016".

Since then, they have been working on what is called the Space Launch System.

The Space Launch System consists of a basic stage and different combinations of reconfigurable additional stages, depending on the mission. It will be able to launch loads up to 130 tons to Mars.

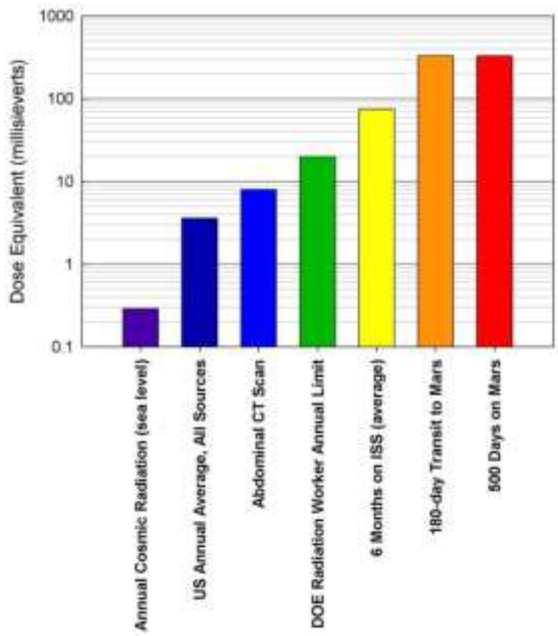
Currently the private sector is taking hold of space exploration. Proof of this is what the company SpaceX has developed: Falcon Heavy, with a capacity exceeding Saturn V. Its first flight is scheduled for 2016.

More efficient propulsion systems

Another challenge being faced is the duration of the trip: taking less time to travel the 55 million km that separate us from Mars. Currently it takes between 150 and 300 days, depending on the position of the planets and the initial speed that the launch vehicle can transfer to the cruise ship. To give some examples: Viking 1 took 304 days (it was launched in 1976), the Mars Reconnaissance Orbiter took 210 days (in 2006) and Curiosity 253 days (in 2012).

Space is a dangerous environment for man. The radiation received during a flight of this type can cause deadly diseases, so that the shorter the travel, the lower the risk to astronauts.

Various technologies are currently being tested, some based on nuclear propulsion and engines using plasma, with which the trip could eventually be reduced to 39 days.

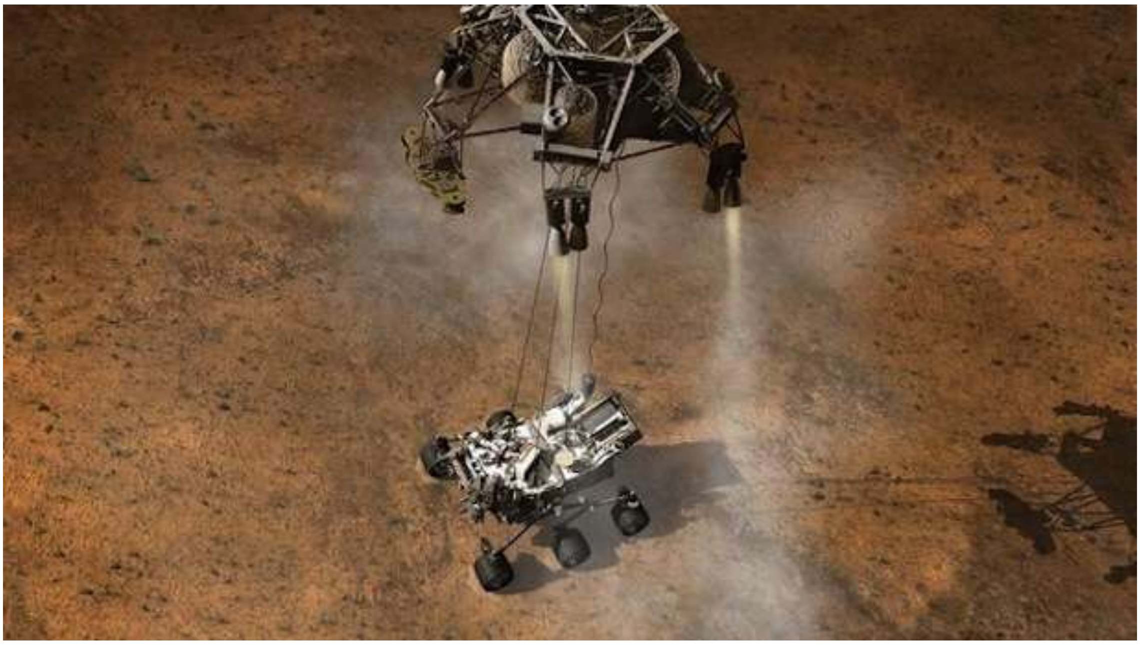


This figure compares different radiation levels during different activities. The green bar represents the maximum dose that a worker can receive over a year.

Entry to Mars and take off from its surface

One of the unresolved issues is the arrival and departure on Mars. So far three methods have been used to land: for small vehicles, a set of parachutes and thrusters to drop the craft on the Martian soil; the alternative to this system was a parachute and a set of air bags, like those in cars, used by Pathfinder and MER; and lastly, the combination parachute-thrusters and crane used for Curiosity. None of them would be usable in the future, mainly due to weight. It is estimated that vehicles having to land on Mars will weigh more than 40 tons, well above the previously tested weight, so a totally different system must be developed.

In addition to reaching Mars, the ship must also take off to return to Earth, and since the exploration of the Moon no manoeuver of this kind has been carried out. In this case the launch vehicle must be much more powerful, because Martian gravity is greater than that of the Moon. This vehicle should arrive there itself and would be used after many months of being inoperative. The fuel used should be transported from Earth. In short, practically we know almost zero in this field.



In this figure you can see the procedure followed when landing the Mars Science Laboratory (Curiosity). A flying crane lowered it gently onto the Martian soil.

Safe habitats

This is another of the major challenges to be faced: to develop capsules and safe astronauts' living quarters, both for their return trip and their stay on the surface.

We've all seen how small the ships are that carry astronauts to the ISS. Also we have seen pictures of how difficult life is in a weightless environment. Besides, the space environment it is extremely harsh: very low temperatures, cosmic radiation and radiation emitted by the Sun, both very dangerous for humans. So for long trips and longer stays new designs are required.

Habitats to complete the trip back and forth safely are needed, with adequate protection systems. Although it seems from a film, artificial gravity systems will be absolutely necessary, to avoid degradation of the health of astronauts.

On Mars it is equally necessary, although in this case gravity is a third that of the Earth. Extremely low temperatures, an unbreathable atmosphere, lethal ultraviolet radiation and equally lethal cosmic radiation are some of the problems to overcome. Also in this case there must be enough room for laboratories, waste processing areas, generating water, electricity, etc.

One of the problems of Mars exploration is derived from the need to be isolated in a small cabin for many months. Various experiments have been conducted on Earth to assess human behavior. In the image, we see the habitat designed by The Mars Society to carry out one of these trials.

Space suits

So far spacesuits are designed primarily for extravehicular activities (EVA, in English). These costumes generate adequate pressure and a breathable environment, maintain the ambient temperature within an acceptable range, protect the astronaut from ultraviolet radiation and partly from cosmic radiation, and also serves as a shield against the impacts of micrometeors. It should also allow an appropriate range of mobility such activities, as well as a communications system to keep the astronaut in continuous contact with its base of operations.

In the case of the exploration of the Moon, space suits fulfilled all these conditions and if we remember the images we have of them they did not seem to allow many movements, in fact some astronaut ended up falling to the ground.

For Mars exploration we are working on new designs that allow for greater mobility; greater work capacity. Some of these concepts are to be tested in southern Spain; more precisely in the area of Rio Tinto.

Use of natural resources

It seems obvious that it is very nearly impossible to take to Mars all the material and energy required for a group of astronauts working several weeks or even several months. To get an idea of numbers for the daily needs of a person: oxygen from 0.8 to 0.9 kg, drinking water from 2.3 to 4.6 kg water to wash 1.1 5.4 kg, food between 1.5 and 2.5 kg.

The waste must also be taken into account. In this case the numbers are: carbon dioxide from 0.8 to 1.1 kg, 2.5 kg to 1.8kg water, and solid waste from 0.13 to 0.2 kg.

From the atmosphere of Mars, at least theoretically, we can obtain: water and oxygen (from the reduction of CO_2) most importantly. Other derivative compounds can be achieved by different chemical reactions.

Surface water can also be obtained, and other materials that allow cement, glass, etc. And that might be used in building habitats.

Energy can be transported from Earth if we think of some methods based on radioactive material, otherwise the only possible alternatives are: solar energy, wind energy and geothermal energy. In the case of wind turbines, we could be use some similar to those used on earth but considering that the atmosphere there is much less dense than that of our planet.

Also, they are carrying out experiments to study plant growth in places similar to the Martian environments and analyze the possibilities for this type of in-situ resources.

Finally mention the need to process waste not generated by astronauts in all its activities.

Oxygen generator from water used on the ISS.

Astronaut health

Weightlessness, radiation and isolation are the main causes of physiological and psychological problems in astronauts on the ISS, which are the benchmark for future exploration missions. In addition to diseases not necessarily related to space but also possible such as infections, gastrointestinal problems, conjunctivitis, bumps, etc. diseases.

Bone demineralization, problems arising from exposure to radiation, such as those generating some type of carcinoma, are the two most important risks and, for this reason, we must develop methods that minimize the maximum risk.

The psychological risks are equally important. Mental health of astronauts suffers due to isolation, living with the same group of people for long periods of time. To learn how to deal with these situations, experiments in which a group of volunteers is held isolated for several months in places that simulate the base outside our planet and its daily behaviour are carried out.

Conclusion

As you will have seen, we still need to carry out major developments before the first humans to reach Mars, speaking of 2030-2040. To be more precise, those who are now in schools will star in this adventure for humanity.

Potential topics for discussion

- Why human exploration on Mars?
- Effects of weightlessness on humans
- How to obtain some of the resources needed to survive on Mars?
- How would a spacesuit for Mars look?

Information Sources

Apollo Program

https://es.wikipedia.org/wiki/Programa_Apolo
https://en.wikipedia.org/wiki/Apollo_program

Launch vehicles

https://es.wikipedia.org/wiki/Saturno_V
https://es.wikipedia.org/wiki/Proyecto_Constelación
http://www.upv.es/satelite/trabajos/pracGrupo15/Marte/Lanzador/LanzInd.html
https://en.wikipedia.org/wiki/Space_Launch_System
https://www.nasa.gov/exploration/systems/sls/index.html
https://en.wikipedia.org/wiki/Ares_V#Ares_IV

Propulsion

https://es.wikipedia.org/wiki/Propulsor_iónico
https://en.wikipedia.org/wiki/Plasma_propulsion_engine
https://en.wikipedia.org/wiki/Variable_Specific_Impulse_Magnetoplasma_Rocket

https://es.wikipedia.org/wiki/Motor_de_magnetoplasma_de_impulso_espec%C3%ADfico_variable
https://es.wikipedia.org/wiki/Propulsión_nuclear_de_pulso
http://danielmarin.naukas.com/2010/11/23/cohetes-nucleares-a-la-conquista-del-sistema-solar/

Mars entry and take-off

http://www.universetoday.com/96119/integrating-new-concepts-for-entry-descent-and-landing-for-future-human-missions-to-mars/
http://danielmarin.naukas.com/2012/08/03/asi-sera-el-descenso-de-curiosity-en-marte/
https://es.wikipedia.org/wiki/Curiosity

Habitats

https://es.wikipedia.org/wiki/Orión_(nave_espacial)
http://www.nasa.gov/exploration/systems/orion/index.html
https://en.wikipedia.org/wiki/Mars_Direct#Mars_Habitat_Unit
https://es.wikipedia.org/wiki/Gravedad_artificial
http://www.marssociety.org.es/paginas/especiales/ag.pdf

Space suits

http://www.nasa.gov/audience/forstudents/nasaandyou/home/spacesuits_sp-index.html
http://nationalgeographic.es/ciencia/espacio/evolucion-trajes-espaciales/imagen/traje-espacial-del-futuro
http://hi-seas.org

Using resources in situ

https://es.wikipedia.org/wiki/Utilización_de_recursos_in-situ
http://www.nasa.gov/centers/ames/research/technology-onepagers/in-situ_resource_Utiliza14.html
http://www.technologyreview.es/materiales/48444/como-hacerse-una-casa-para-vivir-en-marte/

Astronaut health

https://es.wikipedia.org/wiki/Efectos_del_viaje_espacial_en_el_cuerpo_humano
https://en.wikipedia.org/wiki/Health_threat_from_cosmic_rays
http://www.esa.int/Our_Activities/Human_Spaceflight/Astronauts/Living_in_space