JOURNEY TO MARS: HOW TO PROTECT ASTRONAUTS FROM SPACE RADIATION

VERONICA BINDI - UNIVERSITY OH HAWAII
THE HUMAN DESIRE FOR EXPLORATION LEADS TO DISCOVERY
C. Columbus, an Italian explorer, wanted to reach India by sea going west instead of east. Portugal, Italy, England thought it was a crazy idea and did not supported him. Spain and its Queen Isabella D’Aragona gave him 3 caravels with food and water to accomplish the travel. In 1492 Columbus arrived in the costs of America.
It is believed that the Hawaiian Islands were uninhabited until around 400 – 500 A.D., when the Polynesians arrived. Skilled mariners, Polynesians had a long history of exploration and settlement of other lands.
ANCIENT POLYNESIAN, COLUMBUS AND OTHER EXPLORERS WERE CONSIDERED LIKE TODAY WE CONSIDER ASTRONAUTS.

ASTRONAUTS ARE TRUE EXPLORERS
WHY DO WE WANT TO GO TO MARS AND NOT TO ANOTHER PLANET?
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https://solarsystem.nasa.gov
Venus

© ISAS/JAXA
**Surface Gravity**

Metric: 8.87 m/s²  
English: 29.1 ft/s²  
**By Comparison:** If you weigh 100 pounds on Earth, you would weigh 91 pounds on Venus.

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**Atmospheric Constituents**

Carbon Dioxide, Nitrogen  
**Scientific Notation:** CO₂, N₂  
**By Comparison:** Earth’s atmosphere consists mostly of N₂ and O₂. CO₂ is largely responsible for the Greenhouse Effect and is used for carbonation in beverages. N₂ is 80% of Earth’s air and is a crucial element in DNA.
Venus

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Quick Facts

- Day: 243 Earth days
- Year: 225 Earth days
- Radius: 3,760 miles | 6,052 kilometers
- Planet Type: Terrestrial
- Moons: None

Surface Temperature

Metric: 462 °C
English: 864 °F
Scientific Notation: 735 K

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### GRAVITY

On Mars, you'd experience 62.5% less gravity than you're used to on Earth.

### MARS FACTS / WEIGHT

If you weighed 100 lbs on Earth, you would weigh only 38 lbs on Mars!

**SOURCE:** NASA

<table>
<thead>
<tr>
<th></th>
<th>EARTH</th>
<th>MARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>7,927 miles (12,756 km)</td>
<td>4,222 miles (6,794 km)</td>
</tr>
<tr>
<td>Moons</td>
<td>One</td>
<td>Two (Phobos/Deimos)</td>
</tr>
<tr>
<td>Gravity</td>
<td>1.000</td>
<td>0.379</td>
</tr>
<tr>
<td>Average temperature</td>
<td>56.93°F (13.85°C)</td>
<td>-67.27°F (-55.15°C)</td>
</tr>
<tr>
<td>Average distance from the sun</td>
<td>92.6 million miles (149.6 million km)</td>
<td>141.6 million miles (227.9 million km)</td>
</tr>
</tbody>
</table>

DAY
[approximately]

24 HOURS
[23:56 SIDEREAL]

24 HOURS + 40 MINS
[24:37 SIDEREAL]

YEAR
[approximately]

365 Earth Days

687 Earth Days

ATMOSPHERE
[characteristics and approximate composition]

OVER 100 TIMES DENSER THAN MARS' ATMOSPHERE

78% NITROGEN

21% OXYGEN

1% OTHER

96% CARBON DIOXIDE

<2% ARGON

<2% NITROGEN

<1% OTHER
HOHMANN TRANSFER ORBIT

- The most efficient route to take from Earth’s orbit to that of Mars
- Mars oppositions happen about every 26 months (May 2016)
Mars Missions in This Decade

Operational 2001-2012
- Odyssey
- Mars Reconnaissance Orbiter
- ESA Mars Express
- ESA Aeronomy Orbiter

2013
- MAVEN

2016
- ESA Trace Gas Orbiter (Electra)

2018
- InSight

2020
- ESA ExoMars Rover (MOMA)
- 2020 Science Rover

Habitable Environments

Seeking Signs of Life

Future
WE ARE ABLE TO SEND ROBOTS TO MARS SO WHY DON’T WE SEND HUMANS?
IS IT SAFE TO GO TO MARS?

IS THE SPACE EMPTY?
INTERSTELLAR MEDIUM IS FILLED WITH SPACE RADIATION
WHAT ARE COSMIC RAYS?
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- CR are charged particles composed of the same subatomic particles that make up all matter on Earth (H, He, ions).

- About 79% of all CRs are nuclei of hydrogen atoms (protons), almost 14% are nuclei of Helium and 7% are heavier nuclei. The rest consist of electrons and extremely energetic light rays known as gamma rays.
WHAT ARE COSMIC RAYS?
WHERE DO COSMIC RAYS COME FROM?
WHERE DO GALACTIC COSMIC RAYS COME FROM?
COSMIC RAYS FROM THE SUN: SOLAR ENERGETIC PARTICLES
SOLAR FLARES AND CORONAL MASS EJECTIONS

- The Sun at its maximum of its activity, can experience many explosive events, such as flares and coronal mass ejections (CMEs).
- The largest and most energetic of these explosive events can accelerate charged particles that can reach Earth from a few minutes till a few days.
EARTH IS CONSTANTLY BOMBARDED BY COSMIC RAYS
COSMIC RAY AIR SHOWERS
DIRECT MEASUREMENT OF CR

- AMS experiment
ISS
Altitude: 400 km
Orbit: 90 minutes
Size: 70m x 110m x 20m
(240ft x 360ft x 70ft)

AMS-02
Size: 5m x 4m x 3m (16ft x 13ft x 10ft)
Weight: 7 ton (15000 lbs)
Power: 2.4 kW
May 16, 2011: AMS Flight, Space Shuttle Endeavor
May 19, 2011: AMS installation completed at 5:15 AM. Data taking started at 9:35 AM.
CR are not harmful at EARTH but... what about in space?
Cosmic rays and solar energetic particles represent a real problem for the safe leaving of astronauts in space. These particles easily penetrate shuttle and space station walls and astronauts suits, as well as human skin, cells, and DNA.
EFFECTS OF RADIATION

- Cataract formation
- Increased cancer risk
- Skin burns
- Neurobehavioral decrements (anxiety, fatigue, performance)
- Damage to quiescent neural stem cells in the hippocampus
- Degenerative damage to the circulatory system
- Procrômál effects such as nausea and vomiting
- Gonads susceptible to cancer and genetic germiné mutations
- Changes to bone, muscle and cartilage microarchitecture
CR are not harmful at EARTH but... in space without the protection of our atmosphere astronauts need some other type of shielding from the radiation (spacesuits and walls on spacecrafts).
The AMS group at UH works with NASA to improve radiation shielding for astronauts for the coming human mission to Mars.
WHAT WE HAVE LEARNED SO FAR

• We want to send astronauts to Mars. We have sent many robots and learn lots of things about Mars.

• Every two years is when Mars is closer to Earth.

• Space is not empty and is filled by Cosmic Rays. Most of cosmic rays are generated by Super Novae remnants, some others by the Sun and are called solar energetic particles.

• Atmosphere protects us from cosmic rays but astronauts in Space are not shielded and their body is exposed to this space radiation which is one of the main concerns for human exploration.

• NASA and UH are working together to study this radiation and find possible solutions to make Mars human exploration possible.
Let’s have a break!
IS AN EXTRA-TERRESTRIAL SETTLEMENT FEASIBLE FOR HUMANKIND?
Humans can live on the ISS for more than a year, monitored from Earth.
If it would be up to you to decide, where would you go? and why?
Moon Village
ESA

Near side

Far side

Topography (km)

-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
Working on the project

Sir Norman Foster (Foster and Partner)  Enrico Dini (Monolite)
MOON VILLAGE

INFLATABLE SCAFFOLD MEMBRANE
Biomimicry seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies.
honeycomb structure built by 3-D printing robots
Mars rovers: Spirit and Opportunity
Curiosity taking a Selfie on Mars!
Hawaiʻi Space Exploration Analog and Simulation is a Habitat on an isolated Mars-like site on the Mauna Loa on the Big Island of Hawaii at approximately 8200 feet above sea level.
Ice (water) absorbs infrareds and ultraviolet rays protecting from the radiation while being transparent to the light.
Allianz Arena, 2008, Herzog & de Meuron

Water Cube, 2008, PTW Architects
Igloo is sustainable and uses local material

Physalia physalis made up of different minute individual for mutual benefit in symbiosis
Hydroponic to grow plants using mineral nutrient solutions, in water, without soil.
Hydroponic plants consume CO$_2$ and produce Oxygen.
Hydroponic to grow plants using mineral nutrient solutions, in water, without soil.

Plants consume CO$_2$ and produce Oxygen.
Termites using a complex ventilation system keep nest temperature and humidity always constant to garden mushrooms in a symbiotic way.
Multiple subsystems cooperating to survive in a sustainable way.
CONCLUSIONS

• The Human Desire for Exploration Leads to Discovery.

• Discovery requires technical solutions that do not yet exist, embracing multidisciplinary aspects (engineering, architecture, agriculture, medicine) in a cooperative way.

• Nature has solved many problems and we can learn from those solutions.

• Science is nourished by creativity that is particularly necessary to overcome challenges. Often, solutions find application different from the original purpose resulting in human advancement.

• Today we have studied that cosmic radiation is still a barrier to go to Mars. People all over the world are working together and facing these challenges to make human manned mission to Mars possible. You might be the next explorers to Mars!
Pale Blue Dot is a photograph of planet Earth taken on February 14, 1990, by the Voyager 1 space probe from a record distance of about 6 billion kilometers.

“Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives.”

Carl Sagan, 1997
THANK YOU

Images Credit: NASA, ESA, AMS, Architect Sorito
Cosmic Ray flux is divided in three main regions.

Flux – number of arriving particles per (unit area x unit time)

- one volt times the charge of a single electron

\[1 \text{ eV} = 1.609 \times 10^{-19} \text{ joules}\]
THE UNIVERSE IS THE MOST POWERFUL ACCELERATOR