

Mars Newsletter

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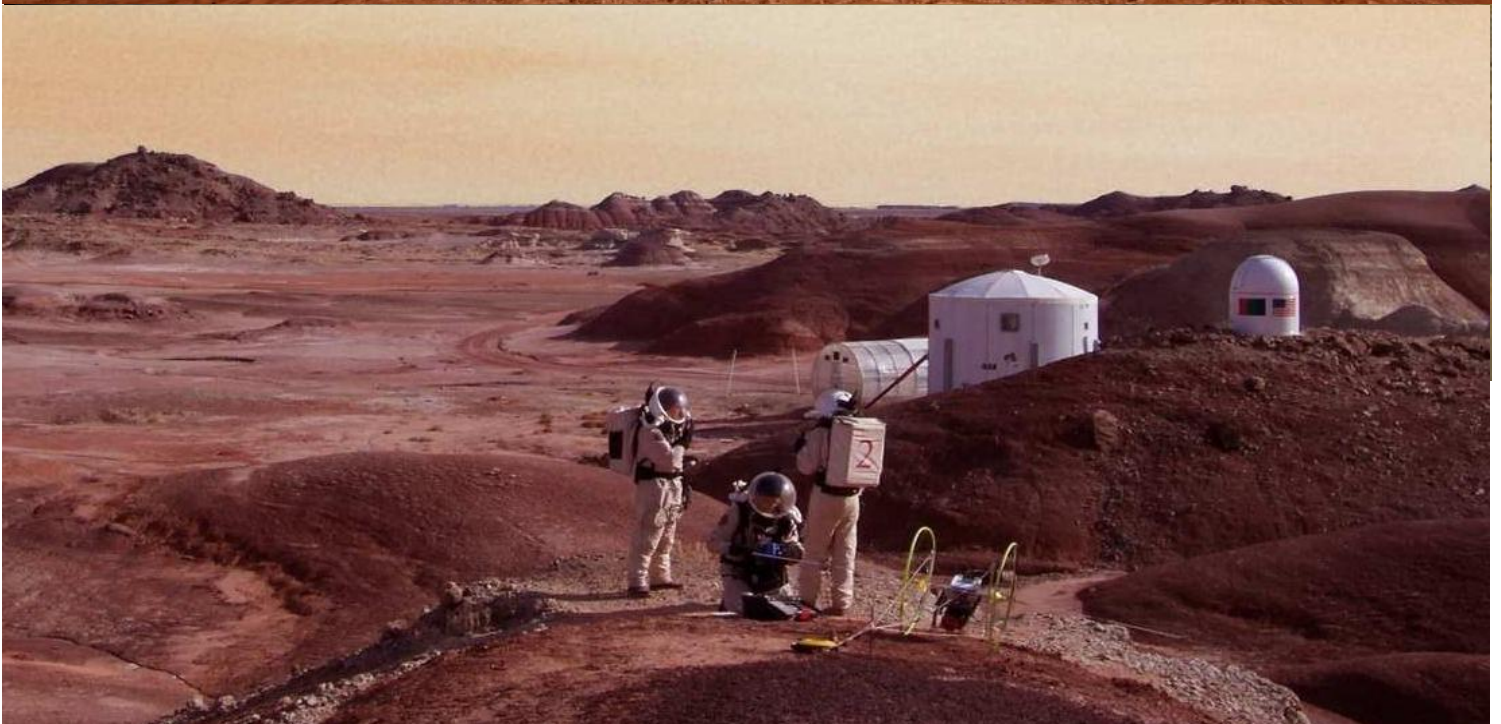
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Editor: Jean-Marc Salotti

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Editorial

By Jean-Marc Salotti

Dear members of the European Mars Societies

It is a pleasure to write the first editorial for the inaugural issue of the European Mars Newsletter.

A few months ago, in November 2025, a European Mars Conference was held in Paris. It provided a great opportunity to meet representatives from almost all European chapters. During the conference, it was decided to launch a series of webinars, and our Italian colleagues took the lead. The first webinar involved six chapters and attracted nearly 400 registrations, demonstrating that it responded to a strong interest within the Mars community.

Let us not lose momentum. It is time to strengthen collaboration among the chapters. Building on these first achievements, the launch of a quarterly newsletter is the next logical step. Its objectives are twofold:

- To provide the latest information and news about Mars exploration and the activities carried out by European Mars Societies.
- To address scientific and technical questions related to the exploration and settlement of Mars.

In this issue, you will find a commentary by Robert Zubrin, who argues that Elon Musk might be tempted by the lunar siren. We also feature a presentation of MarsCarto by Mikita Belikau, a website dedicated to the mapping of Martian terrain, as well as a technical article reviewing different methods of CO₂ removal in space habitats.

Most importantly, this newsletter is your newsletter. If you are aware of an event related to Mars exploration, please let us know so that we can include the relevant information in future issues.

Likewise, if you have expertise in a subject related to Mars exploration, you are welcome to submit a technical article for publication. There is no page limit, and the format is entirely flexible. Please send submissions and information to jean-marc.salotti@ensc.fr.

On to Mars

Jean-Marc Salotti



Musk Is Enticed by the Lunar Siren

By Robert Zubrin, President of Mars Society USA

Published 5th of March 2026 on quillette.com



On 8 February, SpaceX CEO Elon Musk tweeted:

<< For those unaware, SpaceX has already shifted focus to building a self-growing city on the Moon, as we can potentially achieve that in less than 10 years, whereas Mars would take 20+ years. The mission of SpaceX remains the same: extend consciousness and life as we know it to the stars ...

That said, SpaceX will also strive to build a Mars city and begin doing so in about 5 to 7 years, but the overriding priority is securing the future of civilization and the Moon is faster. >>

If Musk actually attempts to deliver on his words, he will be making the biggest mistake of his life. It is impossible to build a self-growing city on the Moon because many of the materials needed to support life—let alone technological civilisation—do not exist there. Those that do are present in forms that make their transformation into useful resources vastly more difficult than is the case on Earth or Mars.

Why the Moon is Unsuitable for Settlement

We ourselves are made of carbon compounds, as is everything we eat or wear and most of the things that we use. There is no carbon on the Moon. The other primary components of life are water and nitrogen. But with the exception of ice deposits in permanently shadowed, ultracold (-230° C) craters near the lunar south pole, water is only present in lunar soil in parts per million quantities. If there were concrete on the Moon, lunar colonists would mine it to extract its water content. Nitrogen is entirely absent.



By contrast, in addition to its polar ice caps, Mars possesses continent-sized regions of frozen mud that are sixty percent water by weight, as well as massive glacier formations of pure water ice in its northern hemisphere that extend as far south as 38° N—the latitude of Athens on Earth. Carbon and nitrogen are readily available everywhere, since Mars has an atmosphere that is 95 percent CO₂ and 3 percent nitrogen.

The Moon does possess some oxygen, but it is in the form of rock, and the complex processes needed to extract it require both a lot of energy and very high temperatures that limit the lifetime of the necessary equipment. It is hard but possible to extract lunar oxygen from regolith and developing the technology and facilities to do so would pay off for any lunar base program. But on Mars, water and CO₂ can readily be used to produce oxygen at room temperature via photosynthesis, water electrolysis, or other simple chemical engineering techniques that could be used on the very first human mission.

Unlike the Earth or Mars, the Moon has no history of hydrological activity. It therefore has no concentrated mineral ores, which are necessary for the practical extraction and production of useful metals and other chemicals. The average concentration of copper on Earth is only sixty parts per million. Yet people have made extensive uses of it since the Bronze Age because natural processes have concentrated it into useful ores. We also have vast amounts of nearly pure silica sand, highly enriched iron and aluminium oxides, and salt deposits. Mars was once a warm, wet planet, so it has enriched minerals, too. But no such substances exist on the Moon, which is just a vast pile of trash rock. This is a very important point, which we shall return to later.

To make matters worse, since the Moon has no atmosphere to shield it from solar flares, any plants grown there would have to be raised in underground greenhouses illuminated by electric lighting, generated at great expense by nuclear reactors or solar panels. By contrast, although the Martian atmosphere is thin, it is thick enough to protect against solar flares. This would allow plants to be grown on the Martian surface in thin-walled greenhouses, using natural sunlight to drive photosynthesis. This is very important, since plants need a lot of light. For example, to generate enough light to illuminate the entire state of Maryland (32,000 square km) you would need 32,000 gigawatts, roughly three times that currently generated by the entire human race.

Furthermore, while the Moon is closer to Earth and you can get there faster, the rocket propulsion requirement to travel one way from low-Earth orbit to the lunar surface is fifty percent greater than that needed to go to Mars. Rocket propulsion requirements are not determined by the distance travelled, but by the velocity change—the “delta-V”—that the mission requires. It takes 6 km/s of delta-V to travel from low-Earth orbit (LEO) to the surface of the Moon. But because Mars has an atmosphere, which can be used to decelerate an arriving spacecraft without the use of rocket propellant, it only takes 4 km/s of delta-V to go from LEO to the surface of Mars. The amount of propellant needed to accomplish a mission increases exponentially with the factor of delta-V divided by the rocket’s exhaust velocity,



which for the SpaceX Starship is 3.7 km/s. So this difference matters a lot.

But in fact, it's even worse than that, because it would be far more difficult to make the propellant for the return trip on the Moon than on Mars. The propulsion requirements for a lunar roundtrip would therefore be triple those for a Mars mission. If we accept SpaceX's numbers, the Starship will weigh 100 tonnes and be able to transport another 100 tonnes to orbit, therefore a Starship travelling to the Moon with 100 tonnes of cargo and returning empty would need to be refuelled in space using fourteen tanker Starship flights. Even if the Starship only travelled one-way, or lunar oxygen were available to support the return flight, it would still take eight Starship tanker launches. The same roundtrip to Mars would only need four tankers.

For the coming age of space settlement, the Moon compares to Mars as Greenland compared to North America during the age of European maritime expansion. Greenland was closer, and Europeans did visit it first. But it was too barren to support a vibrant new branch of human civilisation. If Musk actually wants to build a "self-growing city" to "secure the future of civilization" he is heading towards the wrong place. But why?

Robert Zubrin



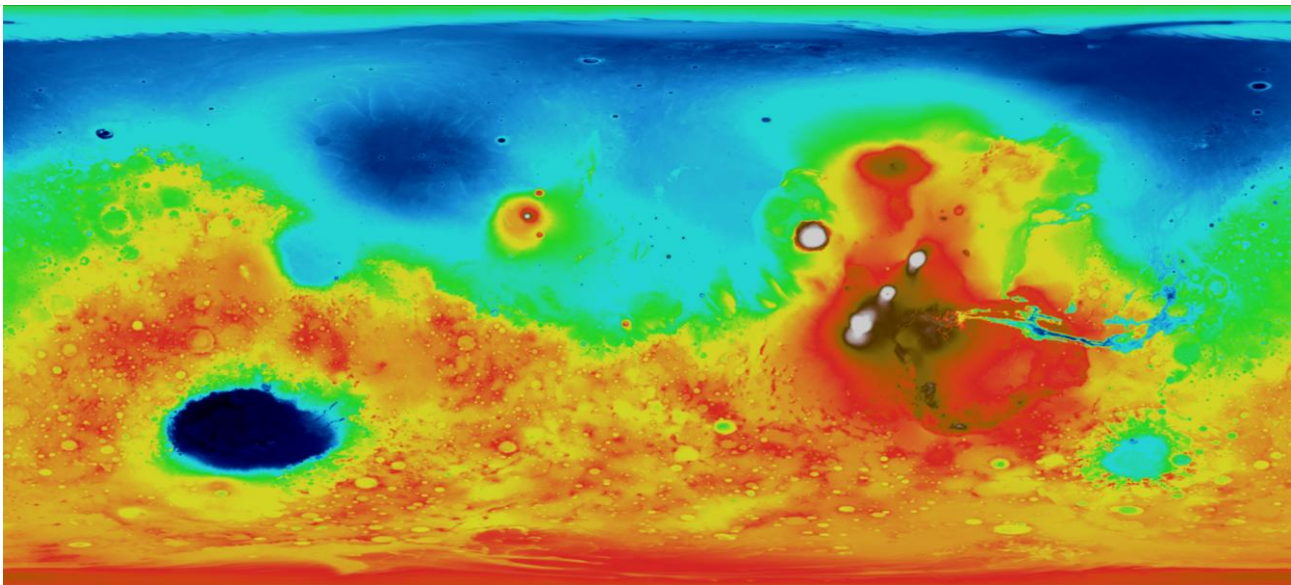
MarsCarto: Building a Next-Generation Interactive Planetary Map

By Mikita Belikau (mikita87@gmail.com)

1. Introduction

Decades of Mars exploration created huge amount of geospatial data. However, exploring this data interactively on the web has traditionally been a challenge. Legacy planetary Geographic Information Systems (GIS) often require specialized desktop software, or rely on heavy, expensive backend servers that struggle to render millions of data points smoothly.

This paper introduces MarsCarto (<https://marscarto.com>), a modern, high-performance web mapping application designed to democratize access to Martian geospatial data and add dynamic analytics. By leveraging cloud-native data formats and in-browser computing, MarsCarto provides an interactive experience that runs entirely in the user's web browser, without the need for a traditional backend server.



2. Objectives

Ultimately, the vision of this project is to serve as a bridge between pure science (academia) and practical engineering (e.g., SpaceX and aerospace companies). By making deep, complex scientific data fast and actionable, researchers (planetary scientists, physics, astrobiologists) and mission engineers can use a shared platform to explore, research, plan and analyze effectively. To achieve this, the map focuses on four core pillars:

1. **Global Scope with Local Precision:** The goal is to build a unified map for the entire planet, rather than just isolated sites. While it supports incredibly high-resolution "data patches" (like the Jezero crater), these are seamlessly integrated into a continuous global context.



Generating this global view draws inspiration from and builds alongside incredible community efforts like OpenPlanetaryMap (OPM) and Casey Handmer's global mapping work.

2. **Performance:** The ability to render massive global datasets, such as hundreds of thousands of impact craters, complex topographic contours, and high-resolution Murray Lab mosaic with performance on the level of Google Maps.
3. **Accessibility:** Removing the barrier to entry. Anyone with a modern web browser should be able to explore advanced Martian geology and topography without downloading gigabytes of raw data, installing GIS software and figuring out internals of the data.
4. **Interactive Analytics Without a Ph.D.:** Moving beyond a static viewer. The goal is to provide a dynamic analytics tool where users can click on features, filter data, and run spatial queries directly on the map using a simple, intuitive interface that doesn't require advanced scientific training.

3. How It Was Made: The Technical Architecture

To achieve these objectives, the map was built using a cutting-edge "serverless" geospatial stack:

- **Deck.gl & WebGL:** The visualization engine is powered by Deck.gl, a WebGL-accelerated framework that offloads rendering to the user's GPU. This allows the map to render millions of vector polygons (like craters and lakes) and massive raster layers seamlessly. Author considered several alternatives like OpenLayers, Leaflet, etc., but none of them was able to hold the massive vector/raster data smoothly.

- **PMTiles (Cloud-Optimized Archives):** Instead of hosting a traditional tile server, the map uses the PMTiles and GeoParquet formats. PMTiles are single-file, cloud-optimized archives hosted on plain cloud storage (Amazon S3 / Cloudflare R2). As the user pans and zooms, the browser issues HTTP Range Requests to fetch only the exact graphic tiles needed for their current view.

- **GeoParquet (Cloud-Optimized Analytics format):** For analytics GeoParquet format was used. It demonstrates incredible performance and very good data compression. This format is also used in a static (visual) representation (non-analytical) of the data.

- **DuckDB-WASM for In-Browser Analytics:** For interactive data querying, the Map utilizes modern DuckDB database engine, which is compiled to WebAssembly (WASM). This embeds a remarkably fast analytical SQL database directly into the web browser. When a user queries regional datasets such as analyzing the terrain of the Jezero Crater the calculations are performed instantly on the user's machine using Parquet files, without waiting for a remote server.

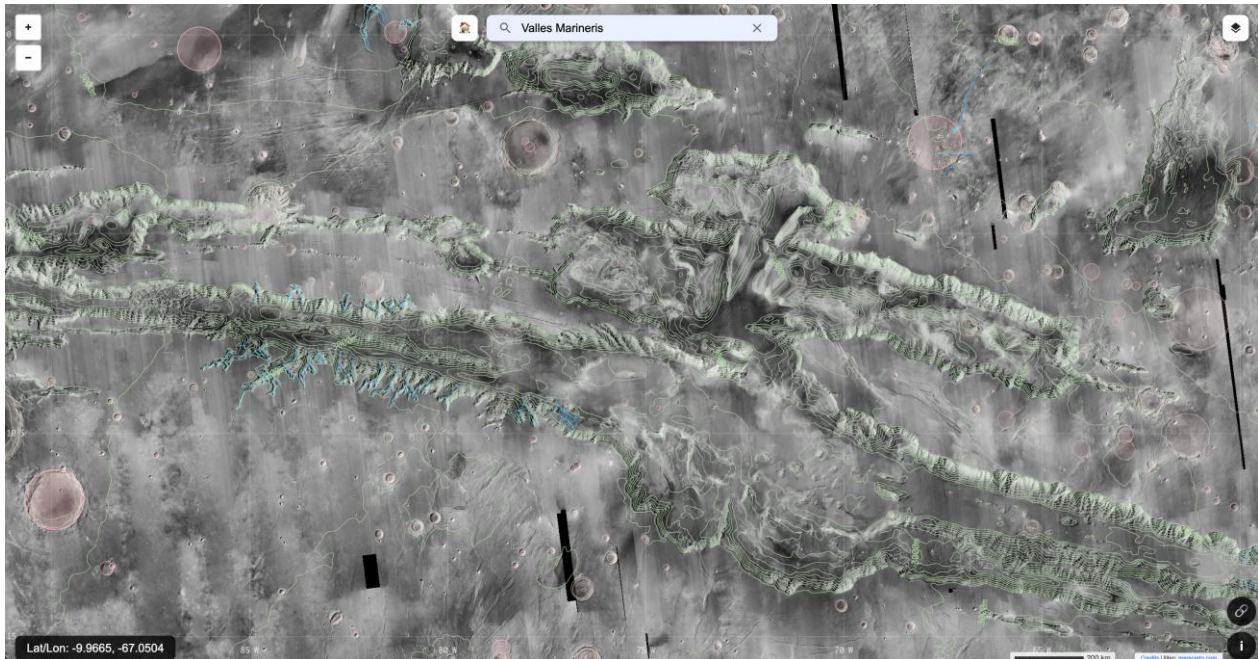
4. Key Features and Layers

The map currently integrates several foundational and specialized datasets, layered to provide a comprehensive view of the Martian surface:

- **Murray Lab CTX Mosaic & Multi-Layer Overlay:** The map incorporates the stunning, high-



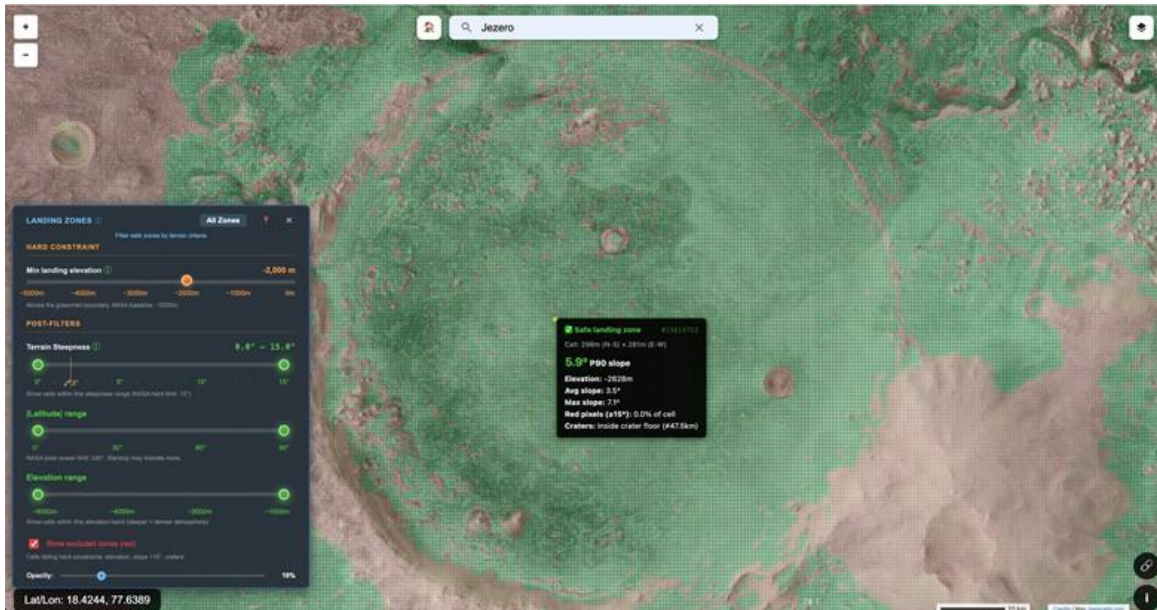
resolution global CTX mosaic created by the Bruce Murray Laboratory for Planetary Visualization. Users can easily overlay this detailed visual map with other scientific datasets at the same time, providing a rich, multi-layered view of the surface.



- **Search Functionality:** A built-in search tool allows users to instantly find and fly to named Martian features, craters, and regions, making navigation simple and intuitive.
- **Data Patches & Automatic Landing Zones:** The map includes powerful "data patches" for specific regions. By combining multiple datasets, the tool automatically calculates and highlights safe landing zones based on real (but simplified) NASA criteria (such as flat terrain and low slopes). These automatic zones are available at different levels of detail (LOD), with more regions being added soon.
- **Global MOLA Topography & Slopes:** Using data from the Mars Orbiter Laser Altimeter (MOLA), the map visualizes global elevation (provided by OpenPlanetaryMap). A dynamic Slope calculation layer highlights the steepness of terrain, critical for landing site selection and rover path planning.
- **Subsurface Water Ice Mapping (SWIM):** The map visualizes data from the SWIM project, displaying the density of subsurface water ice. This is crucial for planning future human habitation.
- **Hydrology & Ocean Simulation:** The map features a simulated Martian Ocean (originated somewhere in Acidalia Planitia) level, allowing users to dynamically flood the terrain to visualize hypothesized ancient shorelines based on topographic data. It also includes mapped networks of ancient river valleys and paleolakes.
- **Craters and Geology:** A comprehensive layer of Martian craters (including the Robbins database) is integrated. The map also features known Martian Caves.
- **Landing zones Analytics:** A specialized high-resolution analytics zone (with 59 m



rectangular side) is implemented around the Jezero crater (the landing site of the Perseverance rover), combining high-resolution visual imagery with deep interactive data analysis. Bigger size of analytics cells is available for all other areas where the data coverage is coarser.



5. Conclusion and Future Work

By combining modern cloud-native formats with sheer client-side rendering power, MarsCarto demonstrates that complex planetary GIS can be made fast, accessible, and highly interactive.

Looking forward, the project will go even further in making Mars data accessible by integrating Artificial Intelligence. Soon, users will be able to "talk" to the map in plain language instead of clicking through the user interface. For example, a user could ask: *"Show me the best landing zone on Mars which has the highest value of potential water ice and is closest to lava tubes."* The AI will automatically translate this natural language question into a complex database query and instantly display the results on the map. We also plan to develop 3D terrain rendering capabilities (Digital Elevation Models) and introduce collaborative tools for researchers.

The tools and datasets for Mars exploration are growing rapidly, and building map interfaces that keep pace with this data is essential for both public engagement and scientific discovery. I welcome feedback and collaboration from the planetary science community to further refine and expand this project.



CO₂ removal

By Jean-Marc Salotti, vice-president Planet Mars association

1. Introduction

Here we address the issue of carbon dioxide (CO₂) removal, as CO₂ is produced by astronauts through respiration. In Part 2, the principles of human respiration are reviewed, and the amount of CO₂ emitted per astronaut per day is calculated.

Before removing CO₂, it is necessary to determine how much is present and to assess the extent of the health risk it poses. Part 3 is therefore devoted to the hazards associated with excessive CO₂ concentrations in the air and to their monitoring using sensors.

There are five main methods for removing excess CO₂:

- The use of lithium hydroxide cartridges is described in Part 4.
- The use of molecular sieves is explained in Part 5.
- The use of amines is presented in Part 6.
- The implementation of the Sabatier reaction is described in Part 7.
- The use of green plants within a biological life-support system is discussed separately; see the corresponding section of the Human Mars Missions Wiki.

Note: Other methods exist (such as the Bosch reaction), but they are not presented here.

2. CO₂ produced by respiration

CO₂ is generated primarily through the oxidation of glucose by all cells in the human body. The simplified chemical equation for respiration is:



Let us estimate the amount of CO₂ produced by an average adult:

- Average daily oxygen consumption: 0.84 kg O₂/day
- Approximately one mole of CO₂ is produced for every mole of O₂ consumed.
- Molar mass of CO₂ = 44 g/mol, whereas the molar mass of O₂ = 32 g/mol.

Therefore:

$$\text{CO}_2 \text{ produced} = 0.84/32 \times 44 \approx 1.16 \text{ kg/day}$$

Notes:

- O₂ consumption if physical exercise is performed: 1.1 kg O₂/day
- 5th-percentile female (nominal activity): ≈ 0.52 kg O₂/day
- 95th-percentile male (nominal activity): ≈ 1.11 kg O₂/day
- For the same body mass, men generally consume more O₂ than women because of their higher lean body mass.



Summary: An adult at rest produces approximately 1.0 to 1.2 kg of CO₂ per day.

For an active astronaut, CO₂ production may reach 1.5 kg/day, or even more if a prolonged and intense exercise has been performed.

3. CO₂ control

3.1 CO₂ hazards

Although CO₂ is often criticized as a greenhouse gas, it represents less than 1% of the outdoor air, at approximately 0.042%, or 442 parts per million (ppm). In a poorly ventilated room, the concentration can rise to 0.2% (2,000 ppm), which marks the onset of discomfort. The critical hazard threshold is 4%. Discomfort and danger levels are defined in Table 1 below.

Table 1: CO₂ hazard levels

Threshold	Typical value	Effects / role
Pre-alert / monitoring	2000–2500 ppm	Concentration that triggers attention from ground control and the ventilation system. Mild discomfort may occur (headaches, reduced concentration).
Short-term limit (24 h)	5000 ppm	Maximum tolerated concentration for 24 hours according to NASA standards. Possible symptoms include headaches, fatigue, and drowsiness.
Long-term mission limit	2500–3000 ppm	Recommended concentration range for comfort and health over several days or weeks.
Critical limit / immediate danger	> 40 000 ppm	Severe hypoxia and poisoning; absolute emergency situation.

3.2 CO₂ detection

On the ISS, CO₂ sensors are primarily Non-Dispersive Infrared (NDIR) sensors. See Figure 1..

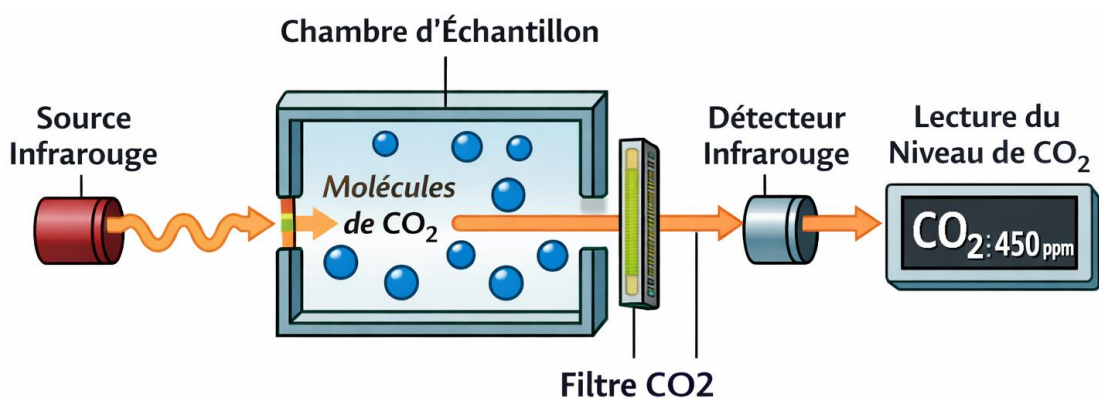


Image générée par IA

Figure 1: Operating principle of an NDIR CO₂ sensor. A small infrared lamp emits a beam of light. CO₂ absorbs infrared radiation at a specific wavelength (approximately 4.26 μm), unlike the other major components of air. A detector measures the light intensity after it passes through an optical filter that transmits only selected wavelengths.



Concentration Measurement:

$$C_{\text{CO}_2} = \alpha \ln \frac{I_0}{I}$$

- I = measured light intensity (the detector converts the incoming IR radiation into a small temperature change, which is then converted into an electrical voltage).
- I_0 = reference intensity (in the absence of CO_2).
- α = system calibration coefficient.

The higher the CO_2 concentration in the sample, the greater the absorption and the lower the infrared intensity reaching the detector. The sensor then converts the measured intensity into a concentration value expressed in ppm using the above equation.

Note: Numerous challenges are encountered when operating these sensors. In particular:

- a) Measurement drift may occur due to sensor aging, contamination, or thermal effects. This requires periodic recalibration or sensor replacement.
- b) Noise, i.e., physical phenomena that cause fluctuations in the measurement, may arise from internal electronics, air turbulence, or vibrations.
- c) Response time may be relatively long, meaning that a CO_2 peak can go undetected for several minutes.

For safety reasons, redundancy is mandatory. On the ISS, each module is therefore equipped with two to three CO_2 sensors. The ventilation system and an alarm are automatically activated if a predefined threshold is exceeded.

4. Removal Using Lithium Hydroxide (LiOH)

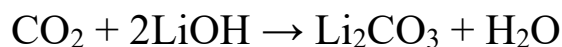
The first carbon dioxide (CO_2) removal system used in crewed spaceflight was the lithium hydroxide (LiOH) canister (see Figure 2 for illustration). Introduced during the Mercury program in the early 1960s, this canister chemically absorbs carbon dioxide through an irreversible reaction, thereby purifying the air inside crewed spacecraft [1].



Figure 2: LiOH-Based CO_2 Removal System



It later became famous during the Apollo 13 mission because of the challenge of adapting the lunar module's LiOH canisters to the command module's air purification system, which used canisters of a different shape and size. The corresponding chemical reaction is as follows:



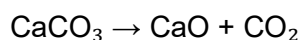
The advantages of this method are its simplicity, reliability, and low maintenance requirements. The energy demand is limited to the electrical power needed to operate the fan. Its main drawback is that the filter eventually becomes saturated, requiring periodic replacement of the canister and resulting in a significant mass penalty for long-duration missions. Approximately 22.2 kg of LiOH is required per person to remove 10 kg of CO₂, which corresponds to replacing the canister every three days for a crew of three astronauts. Furthermore, since oxygen is not recovered—the oxygen atoms remain bound in the Li₂CO₃ molecule—additional oxygen must be produced to support the astronauts' respiration.

Note: On a planetary surface such as Mars, it is possible to process the Li₂CO₃ and regenerate the LiOH-based filter according to the following principle:

1. Production of quicklime (CaO) using local resources (ISRU)

Two plausible pathways on Mars:

- 4a. Calcination of Martian calcium carbonates (to be identified)

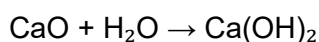


Conditions: 900–1000 °C; CO₂ is vented to the outside

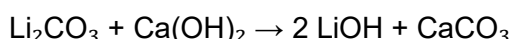
- 4b. Direct extraction of Ca from the regolith, for example from anorthite (CaAl₂Si₂O₈)

Electrolysis of molten regolith, or carbothermic reduction

2. Production of slaked lime, Ca(OH)₂, from quicklime:



3. Regeneration of LiOH from Li₂CO₃ using slaked lime (causticization):



5. Removal using molecular sieve

5.1 Zeolite

Principle: CO₂ is removed by physical adsorption using a molecular sieve [2]. A synthetic zeolite is a microporous material produced in the laboratory, featuring a highly regular crystalline structure with nanometer-scale cavities (cages) and channels. These cages can selectively trap certain molecules such as CO₂, ammonia, or water. For example, zeolite 13X is a silica (SiO₂) and alumina (Al₂O₃) framework forming cages and channels. Its approximate repeating empirical formula contains on the order of 1000 atoms: Na₈₆(AlO₂)₈₆(SiO₂)₁₀₆·xH₂O. Its structural geometry consists of 106 SiO₄ tetrahedra and 86 AlO₄ tetrahedra. Water molecules are already present in some cages, and their number varies.



Each tetrahedron is structured as follows: an oxygen atom is located at a vertex, while a silicon or aluminum atom is at the center. These tetrahedra assemble into spherical supercages (~13 Å in diameter) and hexagonal channels (~7 Å in diameter) connecting the supercages. This repeated framework forms a cubic unit cell. Each supercage and channel contains Na^+ cations and water molecules, which define the active sites for CO_2 adsorption. The continuous connectivity allows molecules to diffuse throughout the entire structure. For higher efficiency, particularly to prevent fouling, it is preferable to combine the zeolite-based molecular sieve with upstream air purification systems, as illustrated in Figure 3.

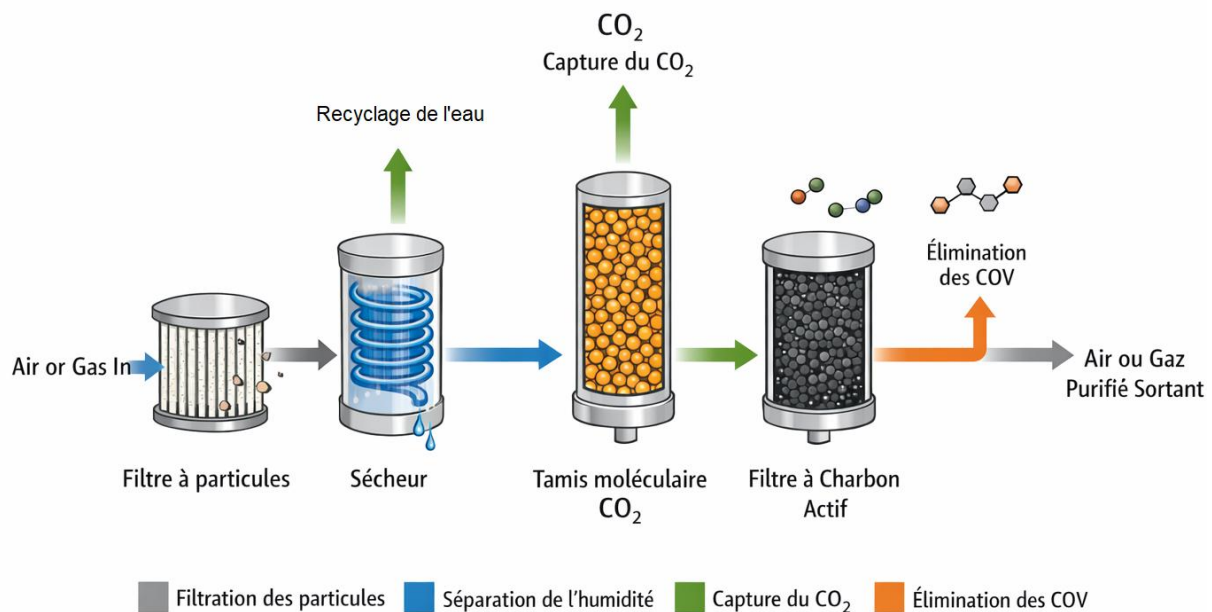


Figure 3: Combination with air purification systems.

The combined steps are typically as follows:

- Pre-filtration: Before reaching the zeolite column, dust, particles, microorganisms, and large molecules must be removed using mechanical filters (e.g., HEPA-type or particulate filters). Objective: prevent fouling of the zeolite or blockage of its pores.
- CO_2 molecules pass through the “channels” and are trapped in the “supercages” via:
 - Electrostatic interaction: CO_2 , due to its partial dipole character (oxygen atoms slightly negative), is attracted to cations (Na^+ , Ca^{2+}) within the cages.
 - Confinement effect: The cages have a size comparable to CO_2 molecules, allowing them to fit into the cavities like a mold.
 - Van der Waals forces: Polar surfaces of the framework attract CO_2 through dispersive interactions.

5.2 Regeneration

Adsorption is physical and reversible, meaning the material can be regenerated by heating or lowering the pressure. Regeneration is carried out before full saturation of the sorbent to maintain efficiency



(see Figure 4). Most systems have a defined capacity: for example, a solid sorbent cartridge can adsorb X kg of CO₂ before reaching 90–95% saturation.

To permanently remove CO₂, several options exist. The sorbent is placed in a reservoir, then heated to 100–200 °C, or the air pressure is significantly reduced, leading to CO₂ desorption. The released CO₂ can then be vented into space through a dedicated outlet.

It can also be compressed and stored for later use (e.g., the Sabatier reaction).



Figure 4: Regenerable solid sorbents.

6. Use of solid amines

6.1 Principles

“Solid amines” are porous materials bearing amine groups (-NH₂) capable of reversibly capturing CO₂ [3]. The cabin air passes through a sorbent bed; CO₂ molecules come into contact with the amine groups and are chemically bound to the material, according to the equation below:



R represents a generic organic group.

6.2 Regeneration

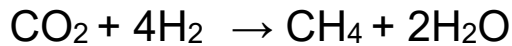
The amine sites gradually become occupied, and the CO₂ capture capacity progressively decreases. As saturation is approached, regeneration becomes essential. This process is called desorption: the reaction is reversed by changing the operating conditions, either by heating, by lowering the pressure (e.g., applying a vacuum in space), or both simultaneously. Weak chemical bonds, such as those associated with the COO group, are broken, and CO₂ is released or recovered in a concentrated form.



7. Sabatier reaction combined with water electrolysis

7.1 Basic principle

The Sabatier reactor, illustrated Figure 5, is a chemical device that carries out the Sabatier reaction, invented by the chemist Paul Sabatier [4]:



with:

- CO_2 : carbon dioxide.
- H_2 : hydrogen (produced by water electrolysis or another source).
- CH_4 : methane (a combustible gas, often stored or used as fuel).
- H_2O : water (which can be recovered and reused).

This is an exothermic catalytic reaction, meaning it releases heat.

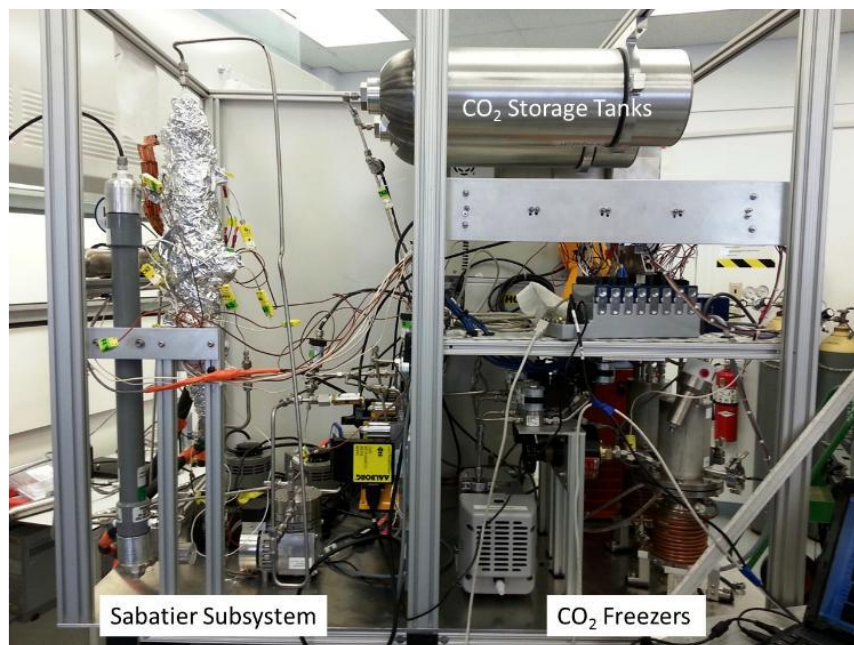


Figure 5: Sabatier reactor tested by NASA.

7.2 Operating conditions

Because the reaction is reversible, it is essential to use a catalyst so that it proceeds preferentially in the desired direction. The catalyst is metallic, often nickel or sometimes ruthenium, supported on a solid substrate. It enables the reaction to occur at moderate temperature ($\sim 300\text{--}400\text{ }^\circ\text{C}$) instead of requiring very high temperatures, and at pressures ranging from 1 to 10 bar. The ideal H_2/CO_2 ratio is 4:1 to complete the reaction.

The conversion rate depends on temperature, pressure, and the catalyst. Even under optimal conditions, CO_2 is never fully converted: typically, 80 to 95% conversion is achieved per pass through



the reactor.

7.3 Main components

A Sabatier reactor is generally a vertical metal cylinder (stainless steel or high-temperature alloy). It includes:

- A reactor vessel or body containing the solid catalyst (e.g., nickel beads or pellets on a support), designed to withstand temperatures of 300–400 °C and pressures of a few bar.
- Inlet tubes for CO₂ and H₂ gases, sometimes equipped with flow meters and control valves.
- Outlet tubes for CH₄ (methane gas) and H₂O, which is liquefied in a condenser.
- A heating system to reach and maintain the reaction temperature.
- Measurement instruments, including pressure sensors, temperature sensors, and gas composition analyzers to monitor and control the reaction.

7.4 Advantages and disadvantages

The main advantage of the Sabatier reaction is the recovery of oxygen atoms to reconstitute water molecules, and the production of methane, which can be used as fuel. Another positive aspect is the relatively low mass of a reactor system (6–8 kg per person for 100 days). The main drawback is the need for hydrogen, which is typically obtained by water electrolysis, a process that requires a large amount of energy.

Ultimately, the reactor is a complex system whose conversion efficiency is highly sensitive to energy and temperature control.

8. Applications

8.1 ISS systems

CDRA (Carbon Dioxide Removal Assembly) :

This is a standard rack installed in the American modules Destiny / Node 3. It has a mass of 90 kg and dimensions of 1.5 m × 0.8 m × 0.7 m. It contains two zeolite beds operating in parallel, in the form of cylindrical columns with complex piping and automated valves. The system is designed to remove 6 kg of CO₂ per day in nominal mode (6 crew members), with an air flow rate of 50 to 60 m³ per hour, supplied by the ventilation system. Regeneration can be performed continuously by alternating between the two columns.

Different zeolites are used on the ISS. Type 5A has pores of about 5 Å, selective for CO₂ molecules. Type 13X has pores of about 10 Å and is more versatile for various gases. It typically adsorbs between 0.1 and 0.25 kg of CO₂ per kg of zeolite depending on pressure, temperature, and CO₂ concentration. Therefore, to temporarily store 1 kg of CO₂ between two regeneration cycles, approximately 4 to 10 kg of zeolite is required.



Figure 6: CDRA maintenance onboard ISS.

Vozdukh :

Installed in the Russian Zvezda module, this system is more compact than the American CDRA. It consists of three solid amine beds:

- 1 adsorption bed (CO₂ capture)
- 1 regeneration bed (heating + vacuum)
- 1 transitional bed (preparation / balancing)

which enable near-continuous operation. Its design is simpler than CDRA, with fewer valves. It is sized to process 3 to 4 kg of CO₂ per day with an airflow of 35 to 40 m³ per hour, supplied by the ventilation system.

8.2 Long duration mission

For long-duration missions, reliability is essential and redundancy is necessary. Solid sorbents (zeolites or amines) are the safest options. Multiple beds can be arranged in parallel, each of them regenerable, to provide full redundancy. Solid amines, for example, are used in the Orion spacecraft, which is designed for a 3 weeks mission.

Electrolysis + Sabatier systems remain useful for oxygen and fuel production, but they are not the primary solution for habitat safety, as they are complex systems and therefore more difficult to control and maintain, and a failure can be critical.

Finally, for very long missions, as a contingency measure, it is recommended to carry LiOH cartridges as a backup, for example for 30 days.

9. Conclusion

For CO₂ removal, the simplest system is the lithium hydroxide cartridge, which is perfectly suited for short-duration missions such as Apollo. For longer missions, it is preferable to use molecular sieves



made of zeolites, which are regenerable and therefore help reduce the total mass of onboard systems.

Several other methods have not been presented here. In particular, CO₂ removal can also be achieved using liquid absorbents, such as strong alkaline solutions like NaOH (sodium hydroxide or caustic soda), KOH (potassium hydroxide or potash), LiOH (lithium hydroxide), or amine solutions such as MEA (monoethanolamine). These methods are of interest in industrial environments, but most of these chemicals are hazardous and must be handled with care, which is a major drawback for space applications. Another method, plasma CO₂ conversion, uses energetic electrons in a plasma to break carbon dioxide molecules into carbon monoxide and oxygen without heating the entire gas to high temperatures.

Still at the research stage, metal–organic frameworks (MOFs) are a class of crystalline porous materials forming three-dimensional networks. Their interest for CO₂ capture lies in the ability to precisely design pore size and surface chemistry to promote selective CO₂ adsorption. Although promising for advanced life-support systems and planetary exploration architectures, MOFs are still at a lower technology readiness level than currently operational solutions, particularly due to long-term stability issues and sensitivity to moisture.

As a reminder, plants can also be used to remove CO₂, but their use is not discussed here.

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News

Dear Members of European Mars Societies,

Here are the news:

- Webinars:

The first webinar of the European Mars Societies has been held the 16th of June. It was a great success with more than 400 subscribers. It was organized by the Italian chapter and headed by Antonio del Mastro. 6 speakers were allocated a 20 minutes talk:

- Gernot Grömer (Austria): Analog Mars Simulations as a Gateway to Mission Success
- Sarah Baatout (Belgium): Space Medicine and Cosmic Radiation: Understanding Risks and Enabling Human Space Exploration
- Jean-Marc Salotti, France: Comparison of Propulsion Systems for Mars Missions
- Antonio Del Mastro (Italy): Mars and the European Industry
- Krzysztof Zarsaka (Poland): Production of Oxygen and Hydrocarbons on Mars via Plasma Conversion of CO₂
- Pierre Brisson (Switzerland): Approach Methodology for a Permanent Human Presence on Mars

See: <https://europe2mars.space/>

- Astronaut training:

June 2026: The Austrian Space Forum (OeWF) presented its six new analog astronauts. See <https://oewf.org/en/2026/06/austrian-space-forum-trains-six-new-analog-astronauts/>

- Next European Mars Conference in Belgium

The next European Mars Conference (EMC 2027) will be held at the Eurospace Center in Belgium, probably in March 2027.

- 2026 Mars Societ International Convention, Los Angeles, October 22-24, 2026.

The [2026 International Mars Society Convention](#) is now accepting abstract submissions for presentations covering all aspects of Mars exploration and settlement.

On to Mars

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