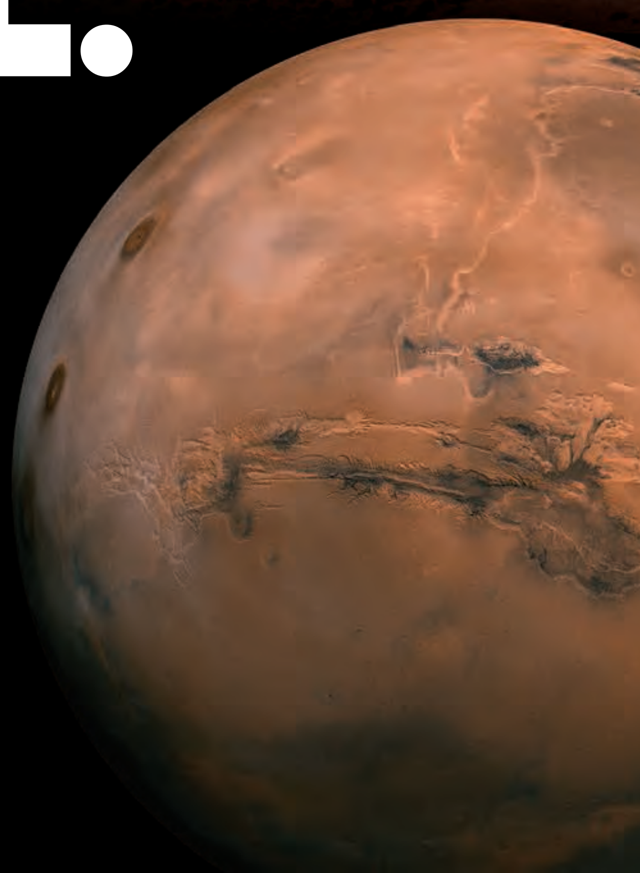
# CAREFUL:

## BABY ON BOARD!

## ROCKETING THE CRADLE TO MARS

BY JOHN F. KROSS

IMAGE CREDIT: © SHUTTERSTOCK(BABY, TOP LEFT); MARS SOCIETY(ASTRONAUTS, CENTER); MARS(NASA BOTTOM RIGHT)



## Mars ain't the kind of place to raise your kids. In fact, it's cold as hell. And there's no one there to raise them if you did...

**- Elton John**
**Rocket Man**

Popular song lyrics aside, Mars is undeniably cold (and dry and radiated), but children will be born and raised there whenever the Red Planet is colonized. Since the Dawn of Man, migration and colonization have been a part of human history. Whether driven by scarcity, overpopulation, or sheer wanderlust, waves of humans left Africa for greener pastures long ago. After 7,000 generations, homo sapiens have peopled the entire globe. So if past is prologue, missions to Mars will culminate in a permanent base—and finally, colonization.

To thrive and grow, a Mars colony will need to import people from Earth and/or reproduce them there. With 7.3 billion people on Earth and counting, human reproduction is hardly rare. But starting with conception and ending with the delivery of a newborn infant, it is complex and depends on an intricate choreography of events at the cellular, genetic, and biochemical levels.

The Martian environment poses special challenges to prospective Red Planet parents and their offspring. The effects of solar and cosmic ray radiation, reduced gravity, exposure to environmental toxins, even disrupted circadian rhythm can potentially impact parents and progeny alike.

### Relentless Rain of Radiation

Perhaps the most pervasive threat is not from Mars itself, but radiation from above. As on Earth, background radioactivity from local sources and secondary radiation will affect all living things, but the steady shower of cosmic rays and gusts of solar particles pose the biggest threat to inhabitants.

The Mars colony will be constantly basted in galactic cosmic rays composed of highly energetic protons and heavier nuclei of helium up to iron. These heavyweight particles zing through human tissue, causing damage in their wake. The Sun's bubble of solar wind—composed mainly of electrons and protons—does deflect some cosmic rays, especially when the Sun is active. On the other hand, Mars doesn't have a planet-wide magnetic field to repel incoming rays, and its thin atmosphere offers little defense.

Based on measurements by the Curiosity rover in Gale crater, the average dose-equivalent rate of cosmic rays is about 0.64 milliSieverts (mSv) per day on the surface. Day by day, that adds up. Over 500 days, or "sols," the cumulative dose-equivalent is several times greater than during a six-month stint on the International Space Station (ISS).


**Mars will join Earth as the cradle of new generations when the Red Planet is colonized.**

Sandbags full of Martian regolith will screen some of the cosmic intruders. However, high-energy cosmic rays are hard to stop. "They can typically go through several inches of solid matter shielding without being attenuated very much," explains Cary Zeitlin, a senior research scientist at Lockheed Martin who helped decipher the Curiosity findings. One estimate of the annual dose-equivalent of cosmic rays in a regolith-shielded habitat on Mars ranges from 70 mSv (at solar maximum) to 260 mSv (at solar minimum). More dirt overhead provides greater shielding up to a point. Curiosity rover scientists estimate that a three-meter deep layer provides the maximum shielding from galactic cosmic rays.

Radiation pulsing from the Sun is less penetrating than cosmic rays, but more unpredictable because of solar particle events (SPE) that hurl masses of protons. The Curiosity rover measured the dose equivalent of one SPE to be approximately 25 percent of that for cosmic rays over the one-day episode. Fortunately, while SPEs are intense, they can be almost fully blocked.

Nevertheless, Mars colonists will still face a steady rain of radiation even inside a protected habitat, and that poses a risk. "The concern is not so much any immediate effects on people, although those are possible, but long-term health effects like cancer or damage to the central nervous system," says Zeitlin.

It's difficult to pinpoint the precise amount of radiation that prompts reproductive complications in humans. And there's a difference between chronic versus acute doses. However, at some threshold, the reproductive organs of both genders are at risk—but especially men. The egg-producing organs in women are more resistant to radiation because of different anatomical location and the larger size of female reproductive cells—approximately 20-times larger than the male's. With less protection, chromosomes inside male reproductive cells are more susceptible to radiation damage, especially since the male Y chromosome seems to be more fragile than the female X chromosome. Injury to male reproductive cells could provoke infertility or even change the ratio of girl to boy babies.

Unborn children are at even greater risk than their parents since serious health problems can arise at substantially lower radiation doses. Prenatal radiation can spark structural malformations, growth retardation, sterility, and central nervous system abnormalities, to name a few. The threshold for developmental abnormalities during the period when major organs form is about 100mSv acute gamma rays, and may be even lower for highly energetic neutrons and heavy nuclei in cosmic rays.

The developing central nervous system in the fetus is particularly sensitive to radiation. Statistics from A-bomb survivors exposed in utero at 8 to 15 weeks after conception show decreases in IQ scores of about 21 to 29 points per 1000 mSv. The lifetime risk of cancer also rises following exposure in utero or early childhood—substantially greater than the increase risk in adults. Gender neutrality doesn't apply here as girls have a higher risk of cancer than boys.

Ironically, the most critical health effect for human colonization of Mars may turn out to be infertility in women exposed to radiation before birth. Studies in primates flash danger signals about the radiosensitivity of immature eggs in female fetuses—approximately half of developing eggs are killed by only 70 mSv of chronic beta (electron) rays. A female fetus exposed to this level could be born sterile or suffer premature menopause. Given these hazards, extensive shielding—a thick layer of Martian dirt—will be needed to protect mother and fetus.

## Planet-wide Powdery Poison

Almost as inescapable as radiation is the fine dust that carpets the Red Planet; suspended dust particles even give the atmosphere its distinctive salmon hue. Some of the dust is downright toxic—a poisonous blend of noxious chemicals. Among the offending compounds are perchlorates first detected in arctic Martian soil by NASA's Phoenix lander in 2008, and more recently spotted by the Curiosity rover roaming Gale crater.

"Anybody who is saying they want to go live on the surface of Mars better think about the interaction of perchlorate with the human body," says Peter Smith, the Phoenix principal investigator at the University of Arizona. "Perchlorate has become an important component of the soil…At one-half percent, that's a huge amount."

Perchlorates are a constituent of some solid rocket fuels and pyrotechnics and have a nasty reputation for extreme toxicity. "It's bad for astronauts because it is toxic for humans, as it interferes with the thyroid," explains Chris McKay, NASA's Ames Research Center. Thyroid hormones regulate metabolism in mammals.

Even tiny amounts of perchlorates could cause thyroid deficiency in women of childbearing age. An alarming study from the U.S. Centers for Disease Control and Prevention concluded that any perchlorate exposure could reduce thyroid hormones in women with low iodine intake. In about 10 percent of these women, the hormone disruption caused by miniscule amounts of perchlorate would require treatment during pregnancy for subclinical hypothyroidism (under-active thyroid). Major maternal thyroid dysfunction could potentially impact fetal neurodevelopment.


IMAGE CREDIT © NASA

**Dust devil: dust coating the surface contains a noxious blend of chemicals posing a potential threat to mother and fetus.**

Avoiding fine dust particles will be tough on a planet that gets its name from the ocher-colored powder on the surface; particularly since the highest concentrations might occur near the equator where humans are likely to colonize. "It'll get into everything…certainly into your habitat," says Smith. "You'd better have a plan to deal with the poisons on the surface."

Mitigation strategies, such as dust suppression and "docking" spacesuits to the habitat's exterior, could reduce exposure to tolerable levels. "I am confident we will be able to design around it," says Doug Archer, a scientist with the Astromaterials Research and Exploration Science Directorate of NASA's Johnson Space Center in Houston. "I have a lot of co-workers here at Johnson Space Center who work in the human exploration side of things, and none of them seems to think perchlorate is a showstopper." To avoid chemical curveballs, however, further characterization of the Martian regolith will be needed to identify other offending chemicals lurking in the environment.

## Weighty Implications of Reduced Gravity

Compensating for the lower gravity field of Mars is another matter. On a planetary surface, the grip of gravity tugs on everybody and everything. Because of its lower mass, the surface gravity on Mars is only 38 percent of Earth's. So a 7.5 lb (3.4 kg) infant born on Earth would weigh only 2.9 lb (kg 1.3) on Mars. More importantly, reproduction and fetal development evolved on Earth under the influence of 1 g and could be influenced by a lower gravity field.

Cell structure, shape, and genetic expression are all subject to the vagaries of gravity's pull. The internal architecture of cells is gravity sensitive, and animal studies in space and altered gravity experiments in the lab highlight the injurious effects of microgravity on cell structure and function. Of course, extrapolating to a reduced gravity setting like Mars is not straightforward. However, weaker bones and deconditioning of fetal muscular and cardiovascular systems are potential, if unconfirmed, hazards.

## First Breaths—Avoiding Oxygen Toxicity

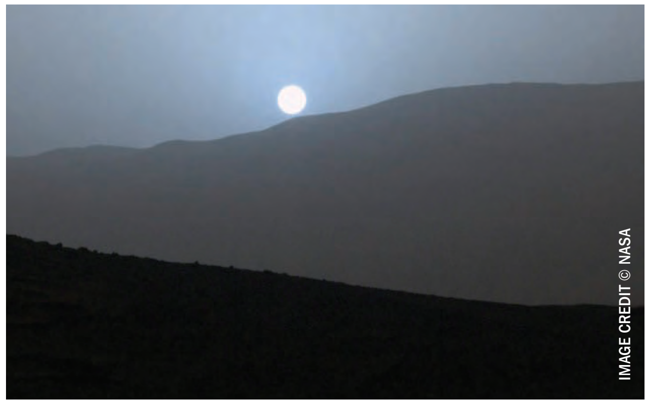
Unlike the pull of gravity, the colony will have moment-to-moment control of temperature, pressure, and oxygen concentration inside the habitat. Above all, the Environmental Control and Life Support Systems (ECLSS) must ensure a long-term and sustainable environment at all stages of life. That's its job. Over the past 40 years, U.S. spacecraft have used vastly different oxygen concentrations and cabin pressures reflecting different ECLSS frameworks. The international space station, for example, maintains 21 percent oxygen and 760 mmHg "sea-level" conditions. Forty years earlier, Apollo flew to the Moon with a pure oxygen atmosphere at 260 mmHg, about one-third the pressure of air we breathe at sea level.

A trio of rugged test pilots in their prime could tolerate most anything for a week or two. Not so a neonate. Major hemodynamic changes in the pulmonary vasculature occur at birth in response to oxygen level and other factors. Too little oxygen in body tissues (hypoxia) causes constriction of lung arteries, and too much (hyperoxia) makes matters worse. Hyperoxia can also trigger blindness and chronic lung disease in premature infants. This means that any ECLSS supporting a Mars colony will have to cater to the needs of its youngest inhabitants.

## The Perils of Being "Stressed Out" and "Out-of-Sync"

Atmospheric isn't the only kind of pressure that prospective parents will experience. Parenting—and just surviving in an alien land—will be stressful. Spaceflight itself is a taxing situation: The blood of space station occupants contains elevated levels of the stress hormone cortisol. Add to that the naturally heightened tension in a hostile environment and early Red Planet parents could be "stressed out." Unfortunately, chronically high maternal levels of cortisol could impact the development of some fetal organs and structures.

To reduce stress, many new and prospective parents may wish they had more time in the day to get things done. Mars obliges with a "sol" about 25 hours long; 24 hours, 39 minutes and 35 seconds to be precise. But while a little extra time may come in handy, it comes with a price. Just ask the mission teams for various Mars rovers. Synchronizing day-night cycles set during millions of years of Earth-bound evolution to Mars time wasn't always easy.



The most pervasive threat to parents and offspring is not from Mars itself, but from cosmic rays and solar particle events.

Steven Squyres, principal investigator for the Spirit and Opportunity Mars rovers, concedes that the longer days, at first, seemed attractive. "You get to sleep in 39 minutes later every day," but admits there are "very little hard data on the physiological impact of extended Mars-time living." NASA has sponsored studies that successfully cram an extra hour into a day using pulses of light, but the long-term impact during gestation is unknown. On Earth, disruption of circadian rhythms in female shift workers increases the risk of preterm delivery and high blood pressure during pregnancy. What would be the reproductive effects on a world perpetually out-of-sync with the body's master timepiece?

Despite the many hurdles, healthy human reproduction will be vital to the multigenerational colonization of Mars. Yet from the moment of conception, the developing embryo-fetus-neonate-child will face an environment unlike any previous generation. Environmental influences in utero and early in life will profoundly affect countless processes.

Rigorous steps to protect mother and child will be mandatory. Active monitoring and staying within safe distance of a radiation "storm shelter" will be daily precautions. Inside the colony, the Martian nursery will be particularly well-shielded to thoroughly filter any noxious chemicals. However, screening all facets of the Martian environment is impossible—it's a different world after all. As on Earth, humans will have adapt to the new conditions. If successful, the Martian offshoot of humanity will represent the latest link in the generational chain that stretches across time and, eventually, space.

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