How Safe Is Travel To Mars

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As NASA lays plans for travel to the moon and Mars, the agency is exploring propulsion systems, crew modules, and habitat structures. It has looked at the psychology of being cooped up with fellow astronauts for a years-long Mars mission, and studied how to maintain bone structure and muscle strength in microgravity.

But a new study should force renewed attention on one of the most intractable dangers of space travel: radiation. The review, published Sept. 29 in Mars, the *International Journal of Mars Science and Exploration*, identified major radiation hazards that must be solved before the safe completion of a human Mars mission.

Donald Rapp, an independent contractor in Pasadena, California, in study that was partly funded by NASA, pored over a number of previous NASA studies of radiation, in an effort to understand exposures to energetic protons from the sun, and the heavy ions in cosmic rays. These two forms of radiation will be the most hazardous to astronauts venturing beyond Earth.

"What the article does is pulls together all the data I could find, from the various investigators who tried to assess what the impacts would be for a human mission to Mars," said Rapp. "When you do that, you find that it is extremely challenging. Some of the NASA design reference missions have not paid a lot of attention to radiation."

Energetic protons are mainly produced during solar particle events, sporadic showers that usually coincide with maximum sunspot activity.

More dangerous is galactic cosmic radiation (GCR), atomic nuclei produced during supernova explosions that travel at almost the speed of light.

GCR arrives from all directions, and induces cancer as it hurtles through the body. On Earth, the planet's magnetic field and atmosphere combine to deter and block these particles. But shielding a spacecraft requires mass, and the mass of shielding that can practically be launched on a spaceship will only reduce GCR by 20% to 30%, says Frank Cucinotta, of NASA's Space Radiation Health Project at the Johnson Space Center.

Standards do not yet exist for limiting radiation exposure during travel to the moon or beyond, so Rapp used the standard now applied to astronauts in low earth orbit (onboard the International Space Station), which allows for no more than a 3 percent increase in the likelihood of fatal cancer.

A trip to the moon may not pose insurmountable radiation hazards, Rapp found, but Mars is a different story. Radiation during the transfer to and from the planet could far exceed annual limits now imposed on exposure in low earth orbit.

Rapp's key advance was to utilize the worst-case analysis developed by Cucinotta rather than the more conventional "point estimate" of radiation danger. A point estimate is a single number that estimates tolerable radiation exposure. The worst-case approach takes a broader view, which more accurately reflects the uncertainty of radiation health effects.

Because health and exposure data for space exposures are scarce, and some people are more susceptible than others, caution dictates protecting against a wider range of danger. The worst-case approach (also known as the confidence-interval approach) tries to avoid any exposure falling within what statisticians call the "95 percent confidence interval," a range that should include 95 percent of all possible dangerous exposures.

Cucinotta, who has advocated the confidence-interval approach, says NASA's Medical Policy Board adopted it two years ago as a basis for projecting radiation health effects. This decision reflects the many unknowns associated with space radiation, Rapp says. "We do not have actual experience with these kinds of radiation and their physiological effects and that leads to a great deal of uncertainty."

Much data on radiation health effects comes from atomic-bomb survivors, who were exposed to a brief shower of gamma rays. But it's not clear how applicable these data are to the effects of chronic exposure to the high-speed, heavy ions in galactic cosmic radiation, which long-term space travelers would face.

Experiments that started in 2003 at a NASA accelerator at Brookhaven National Laboratory are designed to sort out the health effects of heavy ions, but the research is complicated, and may take another decade to complete, Cucinotta adds. "We really need to get a good understanding of the biological effect of heavy ions."

The confidence-interval approach reflects the many factors linking a radiation exposure and its health effect: the source intensity and type, exposure duration, shielding material and thickness, the secondary particles produced when radiation strikes shielding, the actual relationship between dose and damage, and genetic differences among astronauts. Finally, while most radiation-health studies emphasize cancer, radiation is also known to cause cataracts, and gamma rays apparently caused strokes among Japanese bomb survivors.

When the worst-case approach was applied to human space travel, radiation quickly became a limiting factor. Setting the allowable radiation dose at the 95% confidence interval leads to an allowable radiation dose that is 3 or 3.5 times below a limit based on the point estimate.

The highest risk of a 6-month mission on the moon would arise from solar particle events. Although this exposure could be reduced by using regolith (lunar soil) for habitat shielding, Rapp questions whether regolith can literally be piled up for shielding on current habitat design concepts.

Mars would be much tougher, Rapp found, using data from NASA's proposed "reference mission" to Mars, which is used as a guideline for mission development. During a 560-day sojourn on the Martian surface, shielding by the planet and its atmosphere would reduce the GCR effects to marginally tolerable level, Rapp estimated. During each leg of a 400-day round trip to Mars in a crew capsule, astronauts would get about double the allowable annual dose of global cosmic radiation.

Hazards from solar protons on Mars were somewhat less extreme, but a strong solar particle event would also raise the lifetime risk of cancer above 3 percent, the current limit for low-earth orbit, Rapp found.

Overall, he concludes, the better-safe-than-sorry approach means we need to re-think the danger of heavy ions in space. "I don't know how to get more information, but I do know what answer is not: to go ahead with simple Mars mission plans, without radiation protection, on the vague grounds that because we don't know what it will be, we don't have to allow for it."

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