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Erik Seedhouse

# Space Radiation and Astronaut Safety

INTERNATIONAL SPACE UNIVERSITY

Springer

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# About the Author

**Erik Seedhouse** is a highly published author. After completing his first degree, he joined the Second Battalion of the Parachute Regiment. During his time in the "Para's," Erik spent six months in Belize, where he was trained in the art of jungle warfare. Later, he spent several months learning the intricacies of desert warfare in Cyprus. He made 30+ jumps from a C130 aircraft, performed more than 200 helicopter abseils, and fired more light anti-tank weapons than he cares to remember!

Upon returning to academia, the author embarked upon a master's degree which he supported by winning prize money in 100-km running races. After placing third in the World 100-km Championships in 1992, Erik turned to ultra-distance triathlon, winning the World Endurance Triathlon Championships in 1995 and 1996. For good measure he won the World Double Ironman Championships in 1995 and the infamous Decatriathlon, an event requiring competitors to swim 38 km, cycle 1800 km, and run 422 km. Non-stop!

In 1996, Erik pursued his PhD at the German Space Agency's Institute for Space Medicine. While studying he found time to win Ultraman Hawai'i and the European Ultraman Championships as well as completing Race Across America. Due to his success as the world's leading ultra-distance triathlete Erik was featured in dozens of magazine and television interviews. In 1997 *GQ* magazine named him the "Fittest Man in the World."

Erik's PhD in space medicine and background in space life sciences provided him with a keen insight into and understanding of the medical problems faced by long duration astronauts. In 1999 Erik took a research job at Simon Fraser University. In 2005 the author worked as an astronaut training consultant for Bigelow Aerospace. Between 2008 and 2013 he served as director of Canada's manned centrifuge and hypobaric operations. In 2009 he was one of the final 30 candidates in the Canadian Space Agency's Astronaut Recruitment Campaign. Erik has a dream job as an assistant professor at Embry-Riddle Aeronautical University in Daytona Beach, Florida. In his spare time he works as an astronaut instructor for Project PoSSUM, occasional film consultant to Hollywood, a professional speaker, triathlon coach, and author. This is his 27th book. When not enjoying the sun and rocket launches on Florida's Space Coast with his fiancée, Alice, he divides his time between his second home in Sandefjord and Mauna Lani on the Big Island of Hawai'i.

# Abbreviations

| | |
|---|---|
| AHARS | As high as reasonably acceptable |
| ALARA | As low as reasonably achievable |
| ARS | Acute radiation syndrome |
| AST | Attentional set-shifting task |
| BEO | Beyond earth orbit |
| BFO | Blood forming organ |
| BMD | Bone mineral density |
| CME | Coronal mass ejection |
| CMO | Crew medical officer |
| CNS | Central nervous system |
| CPDS | Charged particle detector |
| ESA | European Space Agency |
| EVA | Extravehicular activity |
| EV-CPDS | Extravehicular charged particle directional spectrometer |
| GCR | Galactic cosmic radiation |
| GOES | Geostationary operational environmental satellite |
| Gy | Gray |
| HSC | Hematopoietic stem cells |
| ICRP | International Council on Radiation Protection |
| ISS | International Space Station |
| ITS | Interplanetary transport system |
| IV-CPDS | Intravehicular charged particle directional spectrometer |
| JSC | Johnson Space Center |
| LEO | Low earth orbit |
| LET | Linear energy transfer |
| LOC | Loss of crew |
| LOM | Loss of mission |
| LPA | Lysophosphatidic acid |
| LSAH | Longitudinal survey of astronaut health |
| MORD | Medical operations requirements document |
| MPCV | Multi-purpose crew vehicle |

| | |
|---|---|
| MSL | Mars Science Laboratory |
| NAD | Nicotinamide adenine dinucleotide |
| NAS | National Academy of Sciences |
| NCR | National Cancer Institute |
| NCRP | National Council on Radiation Protection |
| NHP | Non-human primate |
| NMN | Nicotinamide mononucleotide |
| NOAA | National Oceanic Atmospheric Administration |
| PEL | Permissible exposure limits |
| PSD | Positron sensitive detector |
| RAD | Radiation assessment detector |
| RAM | Radiation area monitor |
| RBE | Relative biological effectiveness |
| REID | Risk of exposure-induced death |
| SAA | South Atlantic anomaly |
| SEC | Space Environment Center |
| SPE | Solar particle event |
| SRAG | Space radiation assessment group |
| SRHO | Space radiation health officer |
| TBI | Total body irradiation |
| TEPC | Tissue equivalent proportional counter |
| TLD | Thermoluminescent detector |
| UNSCEAR | United Nations Scientific Committee on the Effects of Atomic Radiation |

# Chapter 1
# Radiation: A Primer

*One of the most challenging parts for the human journey to Mars is the risk of radiation exposure and the inflight and long-term health consequences of the exposure. This ionizing radiation travels through living tissues, depositing energy that causes structural damage to DNA and alters many cellular processes.*

—NASA Space Radiation Element Scientist Lisa Simonsen, Ph.D.

*Galactic cosmic ray exposure can devastate a cell's nucleus and cause mutations that can result in cancers. We learned the damaged cells send signals to the surrounding, unaffected cells and likely modify the tissues' microenvironments. Those signals seem to inspire the healthy cells to mutate, thereby causing additional tumors or cancers.*

—Dr. Francis Cucinotta, University of Nevada, Las Vegas

*Exposure to these particles can lead to a range of potential central nervous system complications that can occur during and persist long after actual space travel—such as various performance decrements, memory deficits, anxiety, depression, and impaired decision-making. Many of these adverse consequences to cognition may continue and progress throughout life.*

—Dr. Charles Limoli, radiation oncology professor at the University of California, Irvine

As long as there have been astronauts there has been talk of a manned mission to Mars. Hardly a week goes by without an announcement of another humans-to-Mars initiative. Over the years the public has been introduced to Inspiration Mars, Mars One, and SpaceX's Interplanetary Transport System. Most such announcements garner plenty of press before dying a slow and natural death, but each mission shares one common denominator: they are either oblivious to (such as in the case of Mars One) or choose to ignore (Mars One again) the dangers of space radiation (Figs. 1.1 and 1.2). So let's take a look at what radiation sources are out there. We'll begin with galactic cosmic rays (GCR)

 
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