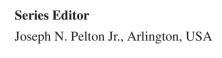
Erik Seedhouse

Space Radiation and Astronaut Safety





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Space Radiation and Astronaut Safety





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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!

xii About the Author

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

xiv Abbreviations

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



1

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)